Electronic Packaging and Manufacturing
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Lecture – 31
Shock and Vibration - 1

Dear friends welcome to the course on Electronic Packaging and Manufacturing. So, far you have learnt about many aspects of the packaging and then in last few lectures you have learnt about the thermal management which is a very important aspect of the electronic packaging. And in this and the coming few lectures you are going to learn about the importance of vibration analysis.

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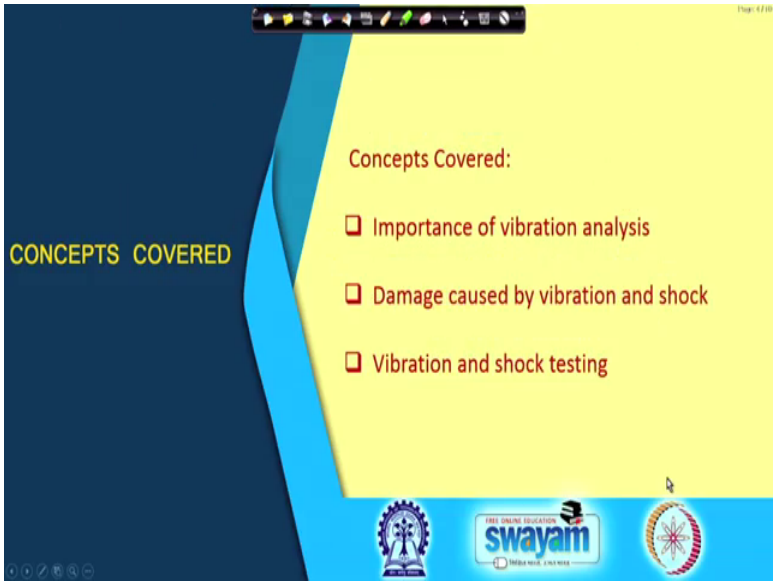

Now, in this lecture if these topics will be covered, first the importance of vibration analysis, second damage caused by vibration and shock and the third one is the vibration and shock testing.

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Now, let us first come down to the design aspects of electronic packaging which is just kind of a recapitulation. Now there are several aspects of design first one is the connection which is very important, then thermal management which is equally important. Manufacturing and maintenance I do not have to say anything because it is very important first part of the packaging. And then comes the shock and vibration and finally, ergonomics and environment.

Now, in these lectures we are going to learn about the Shock and Vibration aspects of the design.

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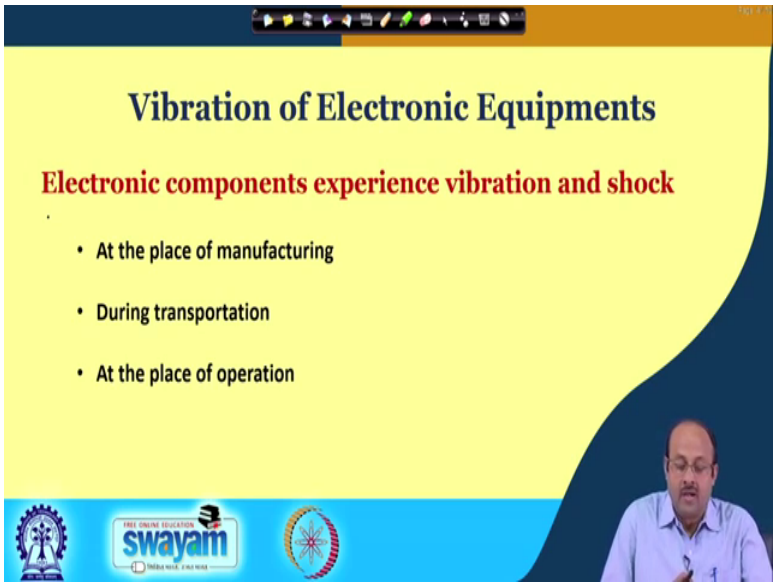

Now, let us first learn where the equipments or the electronic equipments experience shock and vibration. There are three places in which the a vibration is encountered. First is the at the place of manufacturing. Consider a product which is being manufactured and it is a complex product. So, therefore, it requires many places to be handled and from one place to another place there is a transportation and at times may be accidentally the equipment may get dropped by mistake or there are other in the during machining also it may be subjected to some vibration.

The second phase comes during transportation. From the manufacturing or from the manufacturing place to the final operating place it has to be transported; transported by road by ship or by air. So, during this transportation process there may be the vibration which will automatically come because of the because of many factors like during road transport, unevenness of the road profile; on the sea because of the undulation caused by the sea wave or in air transport because of the vibration of the aircraft and finally, at the place of operation.

Now, at the place of operation there may be a situations where the equipment has to operate in a very harsh environment. For example, during the military appliances the equipment is placed maybe at the missile or in the fighter craft which is moving at a very high speed and it is encountering vibrations. So, this is a very harsh environment sometimes the equipment may be placed in a less harsh or the benign environment. For

example, a very quiet place like a computer terminal which is in at the office place. So, therefore, the vibration level of vibration there which a is it is a facing is quite small. So, depending upon the place of operations the requirement of vibration will be different.

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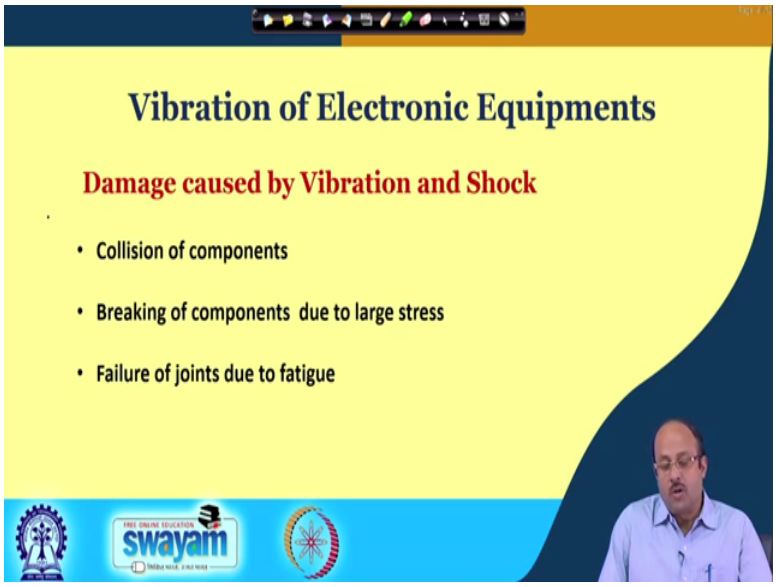

Now, then comes why do you study the shock and vibration in a electronic equipment. Now there are many things or many damages which could be caused by vibration and shock. One is the collision of the components, then the breaking of components due to large stress and the failure of joint due to fatigue. I will explain with a with an with a very simple example which all of you might be following.

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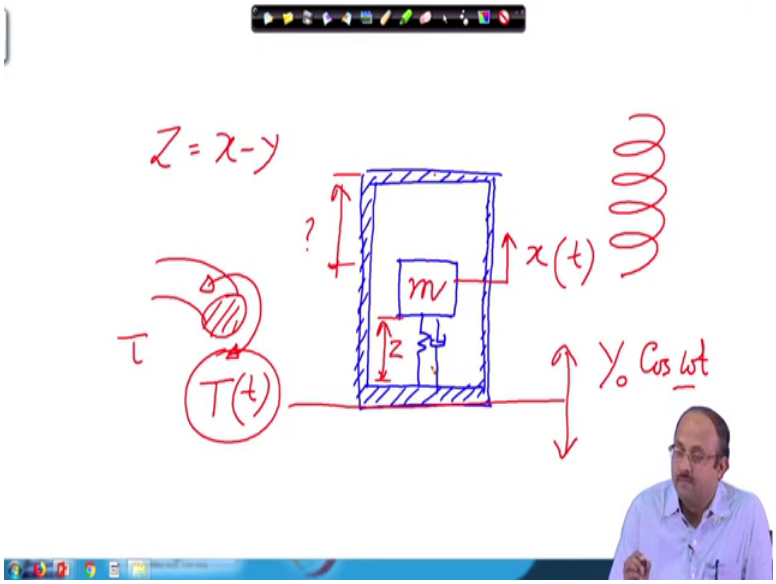

An equipment which is taken to be in the form of a box and there are other components I will explain in later classes that this could be modeled in a very simple situation as a spring and a mass although there may be some damper which may be always present damping element. And suppose that this is the box which is the.

Now, this box suppose it is vibrating now let us say that this is resting on a table and this table is vibrating with some excitations let us consider this excitation to be by simplest excitations that is harmonic excitation and as a result of that this mass which is m that will have some relative motion with respect to the box. So, this will have movement x which will be a function of time and it will move back and forth. So, there will be vibration in the mass.

Now, what may happen if this frequency, it actually take certain value then what may happen that this relative motion that is Z if I consider Z to be x minus y which is the relative movement; that means, if this is the Z. So, it may happen that the Z undergoes very large deformation, then what will happen? This mass actually this will start moving upward and this relative, this distance this distance will change.

Now, if the level of vibration is quite large then it may so happen that this distance becomes equal to 0 and at the extreme situation when this distance is it is trying to become less than 0, then the collision may take place. So, this component may get collided with the outer casing which may damage the component. Second part is that the

spring the spring is actually; let us consider this to be an helical spring. So, this spring now undergoes deformation and this deformation is cyclic in nature; that means, it can have both compression and expansion.

Now, all of if you know that this spring actually what happen; if you consider a part of the spring, then whenever there is a deformation, then actually the spring has experiences kind of a torque and this torque is fluctuating torque. So, in the when this torque is fluctuating and this torque will have the same fluctuation frequency omega which is the driving frequency.

Now, when you if you have a fluctuating torque, then what may happen? That there may be fatigue failure; that means, when there is distress the torque will develop shear stress into this into the spring. This shear stress will be fluctuating. Now if there is a fluctuating stress then it may so happen that the material can fail because of fatigue. Also it may so happen that the displacement of the spring or the deformation of the spring is so large that it can reach the ultimate breaking stress and the spring can also break. Although it rarely happens in a physical spring, but remember we are considering the electrical equipment electronic equipment where this spring is not like a helical spring, but it will have some other kind of structure.

Due to large stress large static stress, it may reach very high the breaking stress and then it may break. But the fatigue failure or the breaking is most prominent in the joint. I will explain this with the help of a simple example.

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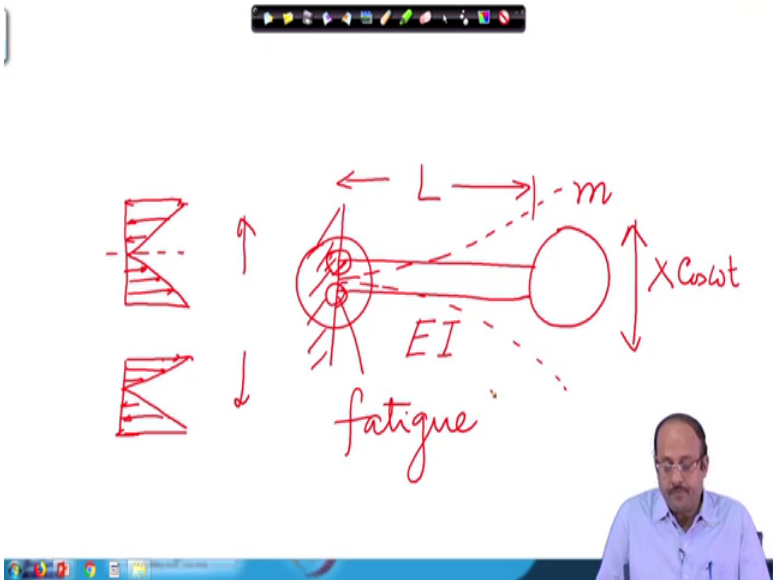

Now, if you consider a cantilever beam which is massless it has the Young's modulus E and the second moment of area I maybe we consider the length of this beam as L.

Now, as it vibrates suppose it is vibrating with certain amplitude, now as it vibrates this beam gets deformed. The beam will deform this way that way. And when the beam deforms, then what will happen? At this point; that means, near this joint the stress developed will be quite large. Here what will happen? When it when the beam is moving upward, then there will be compressive stress developed and compressive stress developed on the upper surface and the lower fiber will experience tensile stress and when it is going up when it is going down just the reverse is taking place; that means, compressive stress will develop in the bottom surface whereas, the tensile stress will develop in the upper surface.

Now, when this beam is moving back and forth, then what will happen? The top fiber and the bottom fiber will experience alternating stress with very high magnitude and there it can fail because of the fatigue ok. The stress reversal is quite large at the top most and the bottom most point and here these are the potential points where the fatigue failure may take place. So, this is so these are the mainly the damage caused by vibration and shock. And now by this time you understand pretty well that these are very important aspects the vibration and shock because it can easily break the components. So, we must

take proper care just to eliminate the vibration and shock which will be the subject matter of our study for the coming few lectures.

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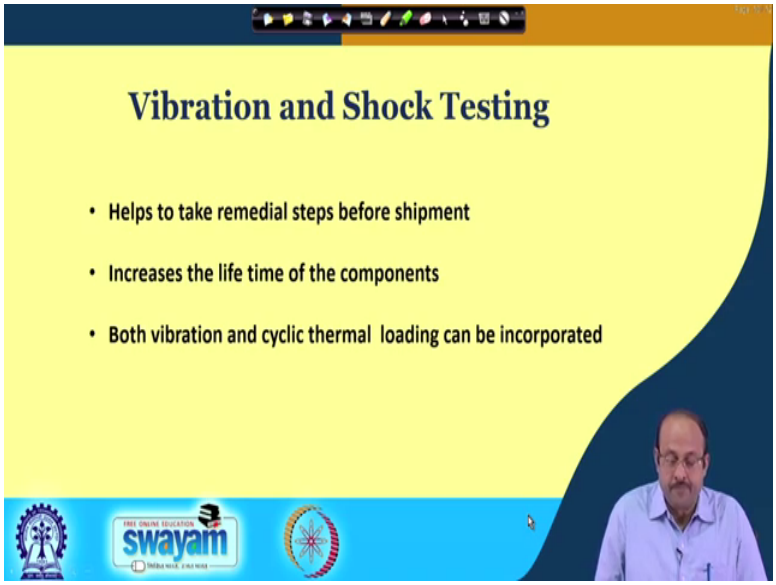

Now, vibration and shock testing. So, you see that the vibration and the shock testing is quite important because of the following reasons that is it can help that to take the remedial steps before shipment. Now what is that? Suppose that a an equipment is designed perfectly ok. So, they said no nothing wrong in the design, but during manufacturing process there may be some flaws which may be introduced. And these flaws they flaw these flaws appear in the form of micro cracks. When the equipment is in operation, then this from this micro crack the larger cracks may develop. So, these are known as the fatigue cracks. So, fatigue cracks can develop and it ultimately may lead to fatigue failure.

Now, vibration and shock testing if properly done, we can find out the defective component and eliminate this defective component. We can take proper measures to again to take the corrective actions so that these defective components can be made again better. So, before shipment the vibration and shock testing can help then it can increase the lifetime of the component. So, it is very much understood that as I said that the before shipment if the proper precaution is taken, then the lifetime of the component can be enhanced. Because the components which passes the test for of shock and vibration,

then its expected that this lifetime goes longer. Also in the vibration and shock testing we can take care of both vibration and cyclic thermal loading.

Now, in thermal management you have learnt how the thermal loading takes place. Now the thermal loading can be sometimes cyclic in nature that happens when the switching machine is switched on and switched off. So, therefore, suddenly the temperature increases and then after switching off a temperature goes down. So, there will be a thermal loading. At the same time there can be the vibration loading because when the machine operates, then there will be some certain atmosphere some environment where the vibration will be generated.

For example, when you are working in a computer there may be the fan is working and that fan may induce vibration into the components. So, these vibration both the vibrational load and the cyclic thermal load can be present in the in the equipment during operation. Now in the vibration and shock testing the both this can be taken care that is we can have a testing where either we can give only the vibrational load or we can give the thermal load or we can give both. Now when the both vibration and cyclic thermal load; they are incorporated, then it is found out that the lifetime of the component it increases ok. I will tell you how the thermal loading the cycle cyclic thermal loading is taken care.

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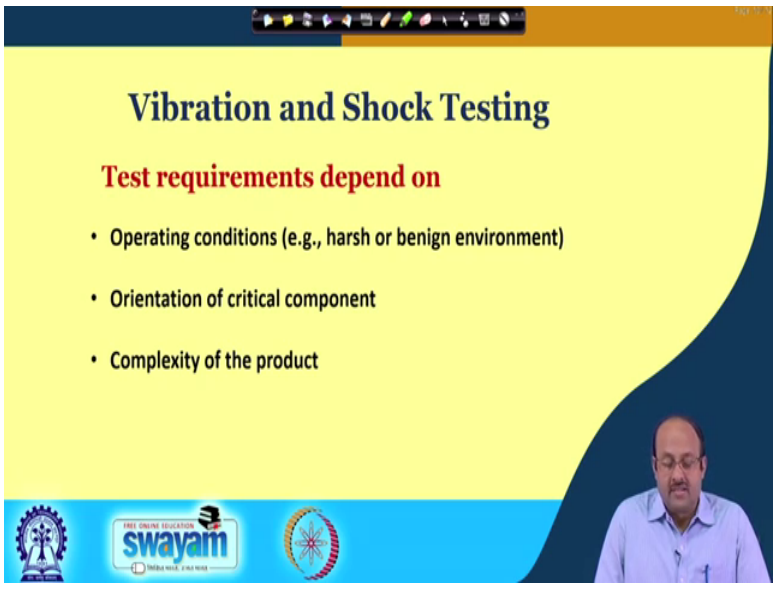

Now, the test requirements for a vibration and shock testing. Now operating condition is one of the most important part for the test requirement; that means, there are certain operating conditions which do not which do not which are not very harsh as I said the example is maybe the very home appliances electronic equipments where the vibration level is low. But on the other extremities there may be the equipments which will operate in a very harsh environment like in the military operations the electronic equipments have to work in the harshest environment and there the testing requirement is different.

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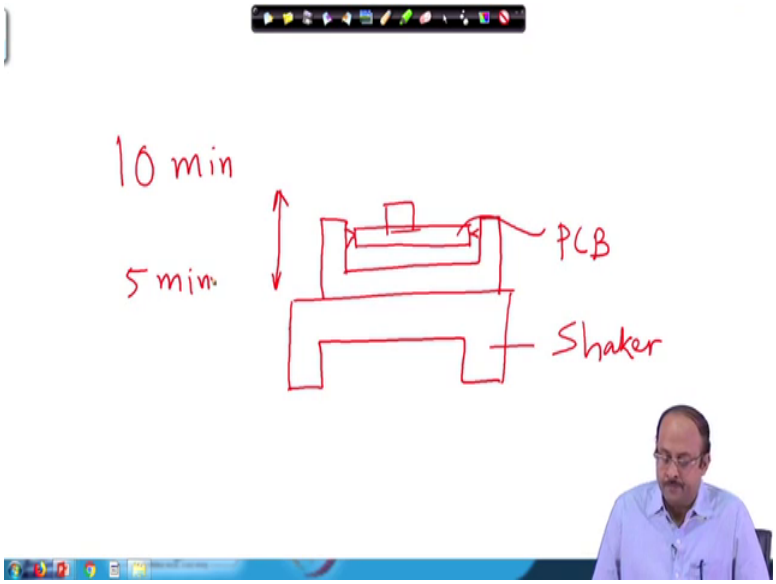

Then the orientation of the critical component; orientation of the critical component: so, normally an electronic component it is placed on a holder which is mounted on the shaker and this holder actually the electronic components are placed during testing. So, this is the board and the electronic components are there. Now usually the orientation of the vibration is actually a such that the equipments move perpendicular to the plane of the PCB, but it also depends upon the component. There may be some components which are prone to failure in certain preferred directions. In that case actually we can change the orientation of the of this holder and place it in such a way that particular orientation is given vibration.

So, depending upon how many axis of vibration is how many axis are to be vibrated, the vibration time actually changes. Normally, if there is only one axis which is to be vibrated, then normally the 10 minutes. It is vibrated for 10 minutes and then it is seen

whether the whether the failure is taking place or not. Now if the preferred axis is given then what will happen that we vibrate it in three all three axis and these three axis are given vibration for let us say 5 minutes. So, therefore, it is not vibrated for each axis 10 minutes, but 5 minutes given vibration for one axis and then other axis also for 5 minutes and so on. So, cumulatively, it is 15 minutes of vibration it is given. Now that is the aspects of orientation.

Now the third point comes the complexity of the product. Now depending upon the complexity of the product; that means, a product can be of a few chips or maybe a maybe hundreds or thousands of chips. So, depending upon that the requirement of testing is different

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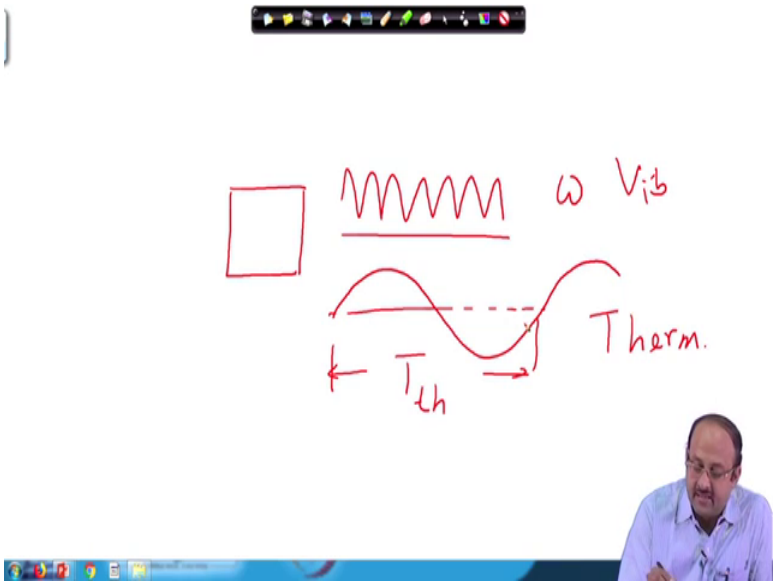

Now I was talking about the thermal cycling, here it is quite important that is if you have if you have let us say an equipment and equipment. It is given a vibration load let us say of certain frequency omega also the thermal cycling is given, but this thermal cycling is of less frequency. So, this is the thermal load and this is the vibrational load.

Now, if this is a simple equipment, then maybe one complete cycle is good enough, but if it is complex one then we can have let us say three or more cycles. So, this is one thermal cycle time period for the thermal cycle. So, we vibrate it and this is the vibrational this is the mechanical vibration and this is the thermal cycle given. Now if the complexity of

the equipment increases, then instead of one cycle we can give two, three or more cycles and it has been found out that with the with the complexity.

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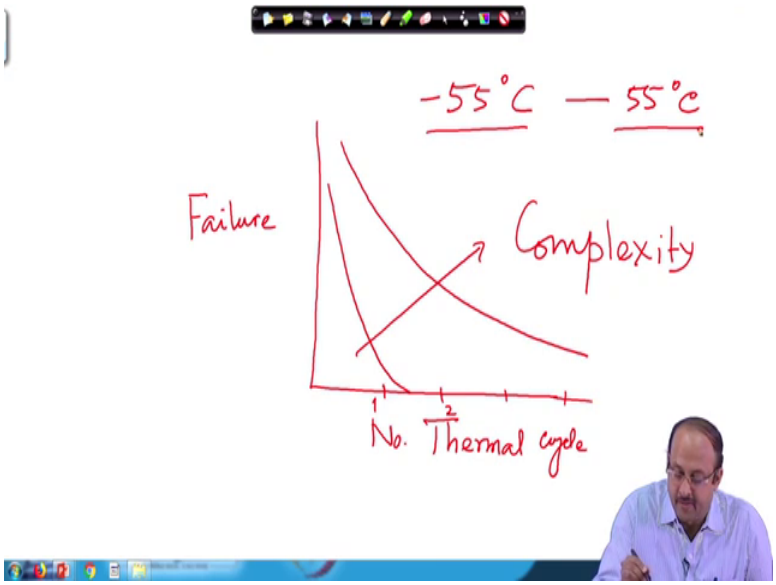

Suppose for a very a small equipment having a few number of chips or the components, then one thermal cycle; suppose this is the number of thermal cycle and this is the failure probability. So, if the component has if the equipment has less number of components maybe after one or two thermal cycles, the lifetime increases or the failure decreases. But if you have a large a very complex system maybe we have to go for a number of so, this is the complexity as complexity increases so we will have to go for number of thermal cycles. And here this thermal cycles this takes from minus 55 around minus 55 degree Celsius to 55 degree Celsius this is the limit the lower limit of the cycle and the upper limit of the cycle, the frequency is quite slow because you know the thermal process is actually diffusive process.

So, therefore, a it cannot be as fast as the mechanical vibration, but this is how the thermal cycle is taken care. Also during the shock it is the shock is actually it is slight vibration, but the shock has the loading which is kind of abrupt loading.

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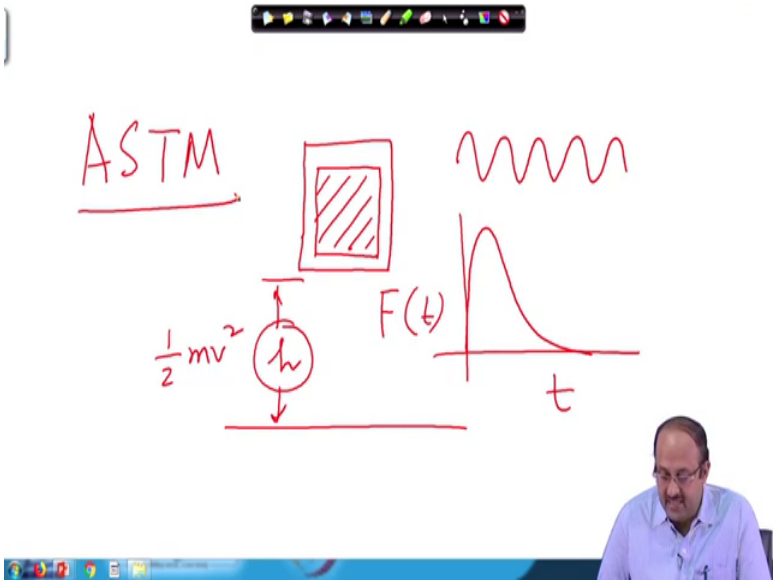

Like here we have the equipment; the vibrational loading is like this kind of steady state loading whereas, the shock loading is something like this.

So, the force depends on t in somewhat this kind of manner. Now when does it happen? For example, if the box which is containing the equipment it drops from a height h let us say, somehow it gets dropped then what will happen? The content material here it actually experiences kind of sudden force because it initiate this potential energy is transferred to the kinetic energy and this kinetic energy suddenly goes into the equipment in the form of the vibrational energy.

So, suddenly the a huge force is developed here and then this force gets transmitted. So, this is the shock. Now some you can very easily understand from this that is the during shock actually the fatigue more than fatigue it is the catastrophic failure or the breaking which is predominant. Because suddenly the stress component within this within the equipment component this builds up and it may lead to failure or the surface can be gets damaged and so on.

Now, the test criteria here for the shock testing can be different depending upon the weight of the equipment. If it is a very heavy weight equipment, then normally the height h is small whereas, for the lightweight equipment the testing is done with a large amount of height. So, that there are certain protocols which is standard in the ASTM protocol, you see ASTM or there are military standards which are followed during the testing

process is the testing is this protocol is set by the procurer. For example, a the military persons, they want to procure the component they setup the design put the testing protocols and depending upon the testing protocols the manufacturer has to comply with.

So, this is one aspect of shock and vibration which the manufacturer has to take care. Now remember in this you have learnt that the shock and vibration is a very important aspects because it can damage the system damage the components. These damaging can be due to the high stress or the high fluctuating stress or that may be because of the interaction between the thermal loading and the vibrational load. Now testing is very important by through testing, we can enhance the lifetime of the component many folds and that is why testing is to be thoroughly done for the electronic components. With this, I end the lecture here.

Thank you very much.