Mechanics of Material

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Constitutive relation, strain energy and potential
Lecture – 43
Thermal strain

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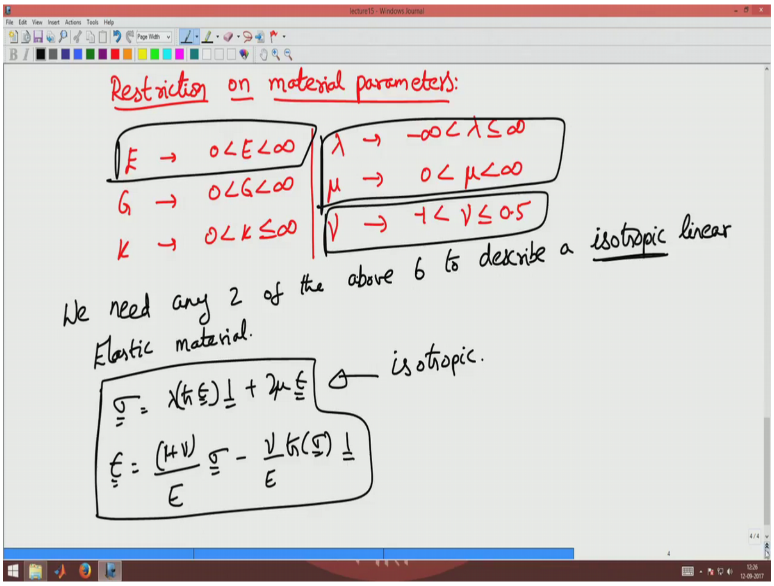

Now, all long we have been talking about the observed strain is what we have been talking about. There are various reasons why you observe the strain let us look at what are the causes.

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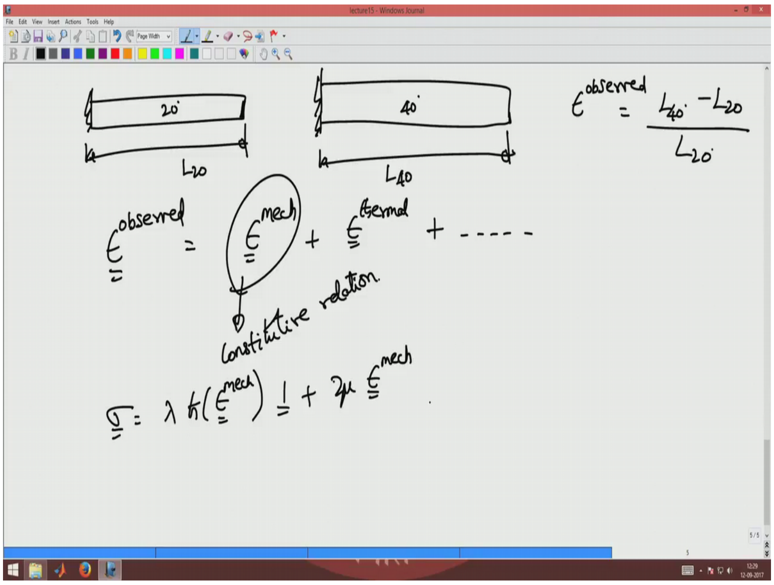

Say I have bar at 20 degrees the length was some L at 20. Now heat the bar and make it into 40 degrees, now the bar length as increase to L 40. So, what is the observed strain? Observed strain would be L at 40 degrees minus L at 20 degrees divided by L at 20 degrees. There is some strain in this bar because it has expanded due to our thermal change in temperature.

So, does this mean that be mechanical stress induced this bar? Does it mean there will be any stresses in this bar at 40 degrees? The answer is no; because the observe strain it is a sum of the mechanical strain plus the thermal strain plus there can be multitude of other reasons why a strain arises. For example, a humidity change in a gel can produce strains; so that is called as a hydroscopic strain.

So, such strains are also can be added up to get the observed strain. For example, in a piezoceramic material; the applied electrical field produce a strain which is the observed strain due to a electrical field. Such electrical strains also can be added up here so, but in this course we will be interested only in the mechanical strain and the thermal strains.

So, the observe strain is sum of mechanical strain and thermal strain; now what enters the constitutive relation? Is only this mechanical strain should enter the constitutive relation. So, when I write sigma as lambda stress epsilon; I should write it as the mechanical strain and not the observed strain; mechanical strain because when I have other strains coming up to the other affects, I have to be specific on what is the strain that

I missing the constitutive relation? It will be mechanical strain that I have to use; now having understood that the observe strain is some of mechanical and thermal strains, let us look at different scenario first; let us look at what is the representation for thermal strain.

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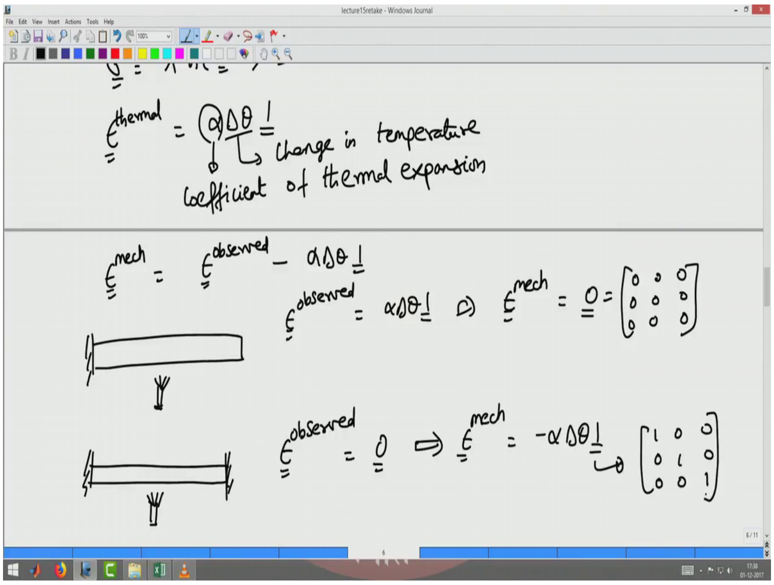

Thermal strain is alpha delta theta into identity our alpha is coefficient of thermal expansion and delta theta is change in temperature.

Let us put this in the observe strain and you will get the mechanical strain as epsilon observed minus alpha delta theta identity. Now let us considered two cases; one case where in I have bar, which is free to expand where I heat this bar up; what will happen? What will be the observed strain here? The observed strain would be alpha delta theta identity; if I assume that the expansion is isotropic and its equal in all directions. So, the observed strain will be alpha delta theta identity.

Now, what will be the mechanical strain then? Epsilon mechanical would be 0 from this expression here which means there is no mechanical stresses develop because of this heating of this bar, On other hand, I take another bar and which is clamped at both the ends and I heat this bar. What will be the observed strain? Observed strain would be 0 in this case, but mechanical strain is minus alpha delta; theta identity. Remember this identity tensor means is 1, 0, 0, 0, 1, 0, 0, 0, 1; this minus alpha delta theta identity.

So, what happens now? If I heat the bar, there is compressive stresses that are develop.

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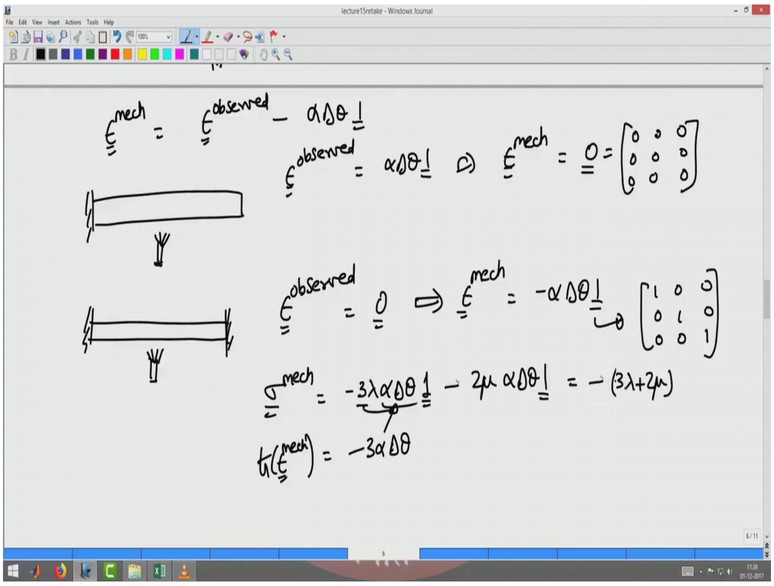

So the corresponding from this sigma mechanical stress would be 3 lambda alpha delta theta minus identity to mu; minus alpha delta theta identity where I substitute for this is epsilon mechanical. And stress of epsilon mechanical would be minus 3 alpha delta theta which I use in here for the expression lambda stress epsilon identity.

So, summing these two up I will have minus 3 lambda plus 2 mu alpha; delta theta identity would be the mechanical stress that is developed; that is I am assuming is not only clam along the actual direction, but I assuming clam along the X and Z direction also. On the other hand, if they are free to contract or expand the X and Z directions; what will happen is; I will have epsilon observed will not be 0.

If I allowed strain if it were free to expand the Y and Z direction; epsilon observed will not be 0. In that case, I will have a different expression for a mechanical stress and mechanical strain. So, you have to understand that the observed strain is not what gets into the constitutive relation, it is the mechanical strain that gets into constitutive relation which is to get the mechanical strain; you have to subtract from the observed strain, the thermal strains, hydrographic strains, the electrical strains and so on.