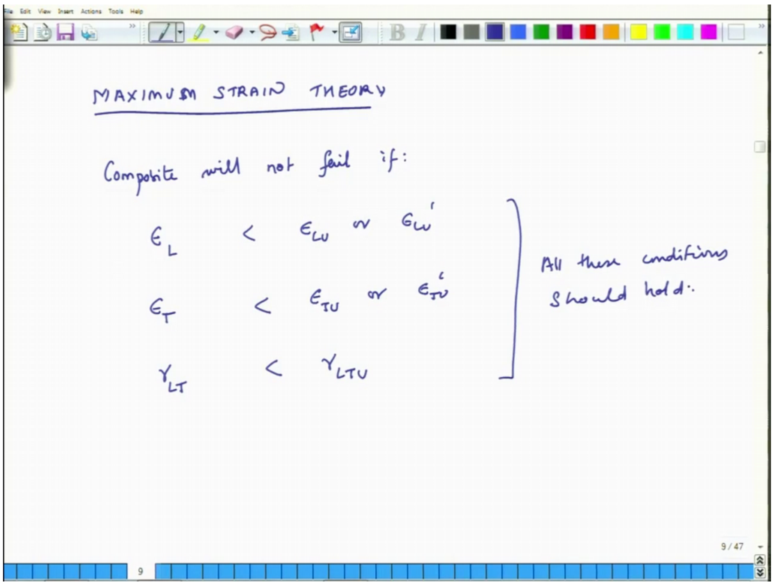
Advanced Composites
Prof. Nachiketa Tiwari
Department of Mechanical Engineering
Indian Institute of Technology, Kanpur

Lecture - 21
Maximum Strain Theory

Hello, welcome to Advanced Composites. Today is the third day of this ongoing week which is the fourth week of this course. And what we plan to do is today is discuss another theory relay, which helps us to understand failure in composites and this is the this is known as Maximum Strain Theory.

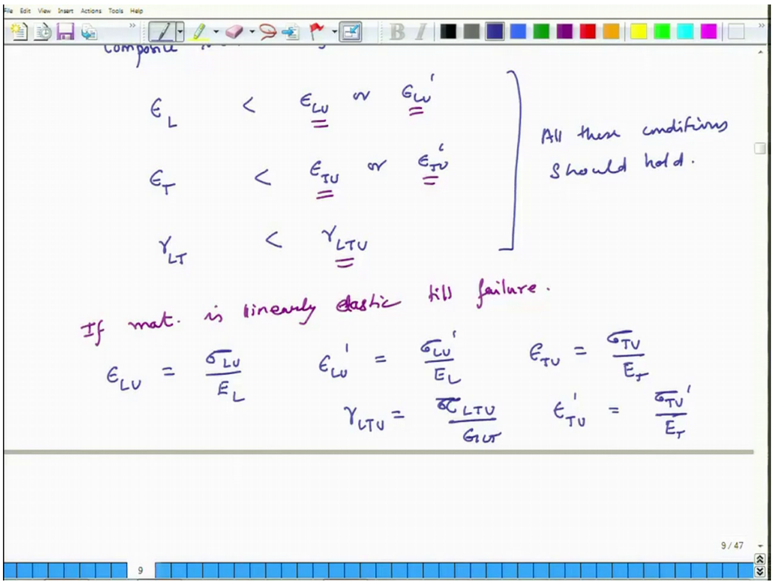
(Refer Slide Time: 00:39)



So, this theory in principle is pretty similar to maximum stress theory and maximum strain theory. And here the composite will not fail, if so, here we consider strains epsilon L is less than epsilon LU or epsilon LU prime. Then we have epsilon T should be less than epsilon TU or epsilon TU prime. And shear strain gamma LT and gamma LT should be less than gamma LTU.

So, all these conditions all these conditions, should hold if there is no failure. If any one of these condition gets violated, then the composite is going to fail.

(Refer Slide Time: 02:15)

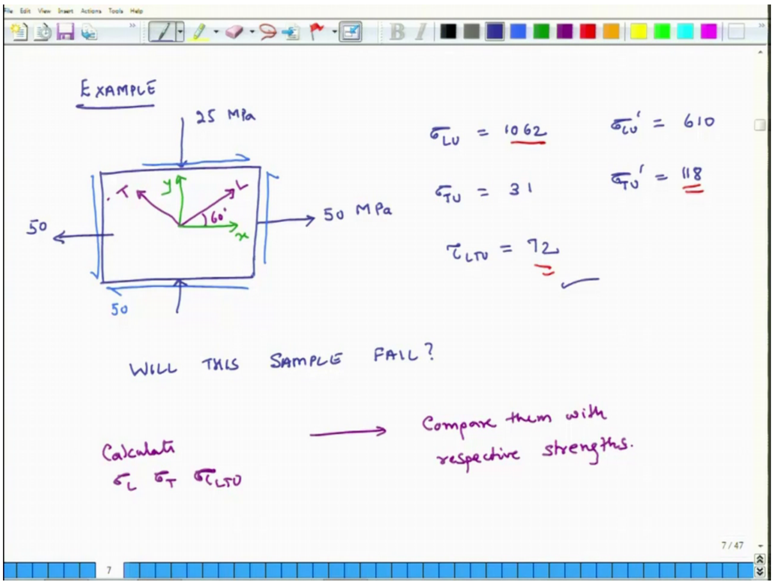


Now, we can either experimentally determine these numbers, epsilon LU, epsilon TU gamma LTU and so on and so forth or if the material, if the material is linearly elastic, if it is material is linearly elastic till failure, if it is not linearly elastic then we cannot use the relations which I am going to just write down.

Then, we have to experimentally determine these parameters, otherwise if the material is linearly elastic. Then what we can say is that epsilon LU is what? It is nothing but, tensile strength in terms of a stress in the longitudinal direction by EL, epsilon LU prime is sigma LU prime divided by EL, epsilon TU equals sigma TU divided by ET and gamma LTU is maximum shear stress or failure shear stress tau LTU divided by GLT.

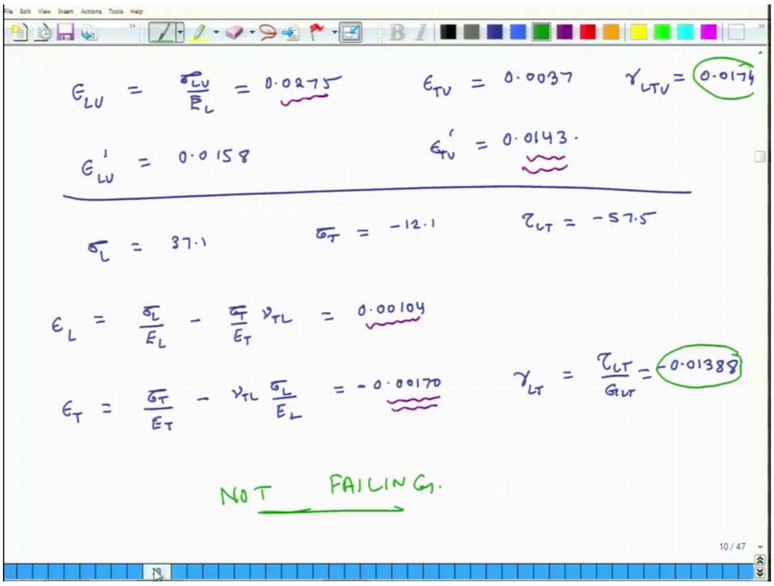
And then I omitted one more which is epsilon TU prime equals sigma TU prime divided by ET. So, we can actually calculate these failure strains for the material, but we can do that only in the material is linearly elastic till it fails. If it starts becoming non; you know if it starts becoming non-linear or starts exhibiting plasticity, then we cannot use these relations.

(Refer Slide Time: 04:19)



So, with this background, we will redo the same problem which is this problem and the only difference here will be that what we will say is that instead of using the maximum stress criteria. We will use the maximum strain criteria so, that is what we will do. So, let us say what it tells us so, first we will calculate, we will assume that, material is linearly elastic and we will compute the different strengths of the material.

(Refer Slide Time: 04:45)



So, epsilon LU equals sigma LU over EL and this works out to be 0.0275 ok, similarly, epsilon TU we compute through the relation which we have discussed and this is 0.0037 and then gamma LTU is 0.0174 and epsilon LU prime equals 0.0158 and finally, epsilon TU prime equals 0.0143 ok.

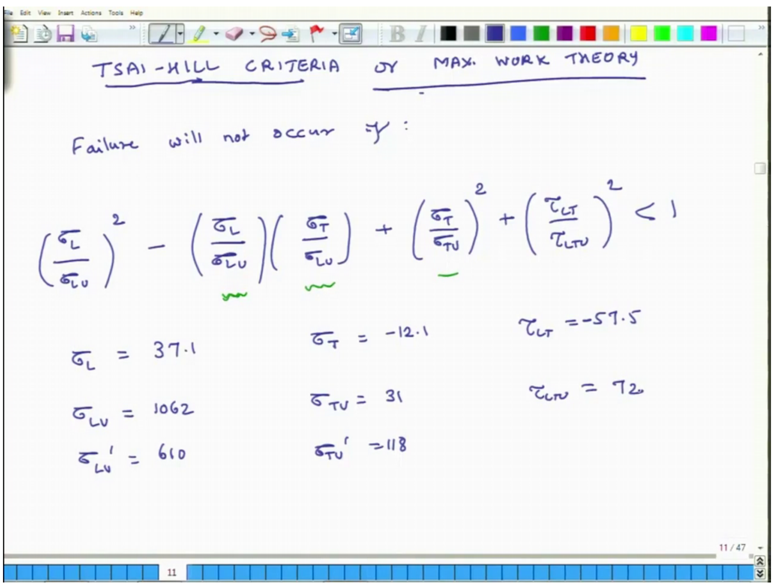
So, now, with this understanding we have to compute strains in the composite for the stress state which we have discussed and we know that sigma L we actually already calculated in the last example and it is value as 37.1. Sigma T we calculated it as minus 12.1 and tau LT we found it as minus 57.5.

So, now, we will compute strains so, what is the what are the strains epsilon L is equal to sigma L by EL, but there is also a Poisson effect due to sigma T. So, that is equal to sigma T divided by ET nu TL and this works out to be 0.00104. Similarly, epsilon in the transverse direction, strains in the transverse direction is sigma T divided by ET minus nu TL sigma L divided by EL and this comes out as 0.00170 and it is a negative number. And finally, gamma LT is equal to tau LT divided by GLT and this is found to be minus 0.01388 zero.

So, now we start comparing so, this is epsilon L it should be less than epsilon Lu, it is tensile. So, we are what is the about the how about the stress in transverse direction it is negative and it is value is 0.0017 and it is smaller than epsilon TU prime these things.

And finally, the shear strain is less than the failure shear strain so, we are. So, material does not fail not failing. Now these two theories maximum stress and maximum strain they do not involve interaction of stresses. And they do a fairly good job in if the strains are limited, but if there is interaction of stresses then these two theories do not do a such a great job.

(Refer Slide Time: 08:40)



So, then, there is another theory and it was developed by Tsai and hill. So, it is the theory is also named after this so, it is called Tsai in criteria or it is also called maximum work theory ok. And what does this says? So, I am just going to write down the statement that failure will not happen, if the following condition is satisfied.

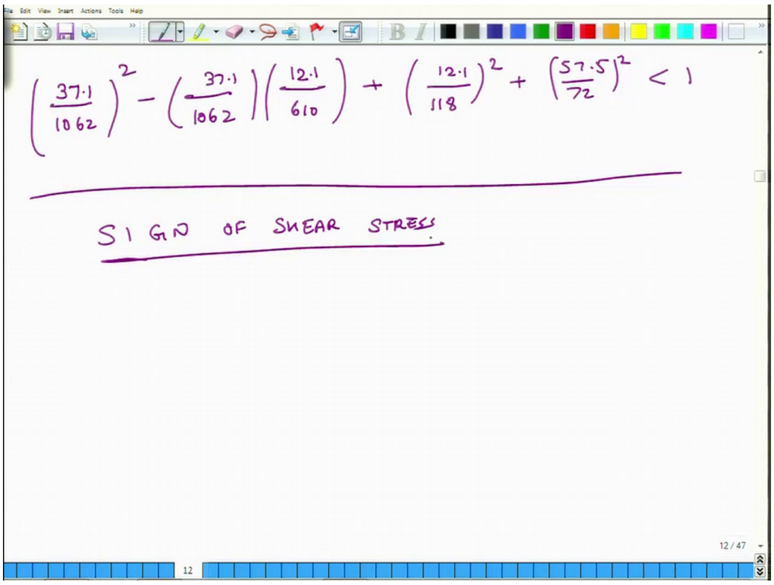
So, what is that condition? Sigma L over sigma LU whole square minus sigma L over sigma LU times sigma T divided by sigma LU plus sigma T over sigma TU whole square plus tau LT divided by tau LT U whole square it should be less than 1. So, if this entire expression is less than 1, then the material will not fail.

Now, as we are computing this function on the left side, we have to make sure that if sigma L is compressive, then instead of sigma L U we consider sigma L U prime and this same thing in other terms also. So, if in this term whereas, in this term sigma T is compressive then we use sigma L U prime, ok. And same thing in the third term also so, that is there so, now, we will again consider the same example.

And we will say so, what we did was we had calculated sigma L to be for the example which we have been discussing sigma L was found as 37.1, sigma T was found as minus 12.1 and tau LTU tau LT was found as 57.5 and it is negative.

So, these things were computed and what are the stress strain not strains, strains sigma LU is 1062, sigma LU prime is 610, sigma TU is 31, sigma TU prime is 118 and tau LTU is 72. So, using these two numbers, these sets of numbers, we will see whether the material fails under this criteria.

(Refer Slide Time: 12:00)



So, we will first do this so, this is 37.1 and sigma LU this is tensile. So, I use this number 1062 whole square minus sigma L is again 37.1 divided by 1062. And then, next look at the next term sigma T, sigma T is minus 12.1, so, it is compressive so, 12.1 divided by sigma LU.

So, I have to choose pic between this and this and because the numerator is compressive so, I pic 37.1, I am sorry, I pic 610. And then I have sigma T 12.1 and corresponding course compressive strength is 118, whole thing square plus 57.5 by 72 square and if you add this up it indeed turns out to be less than 1.

So, this material will not fail, even according to maximum work theory. So, this is the discussion on these work theories and what you see from this discussion is that this third theory it actually, involves interaction of all the so, in one single criteria all other stresses are involved sigma L sigma T and tau LT.

So, it somehow integrates all the effects and it accounts for their interactions in the failure criteria. The next thing we will discuss is the sign of shear stress so, what do I mean by that? So, in our system, whenever an orthotropic lamina is subjected to stresses and strains, it experiences stresses in L direction T direction and also it experiences shear stresses with reference to the LT access system.

And whether the shear stress star is these shear stresses are positive or negative it makes a very significant influence on the failure of the composite. So, this is something very important to understand and if we do not account for the sign of shear stress correctly, we know how to handle the sign of tensile stresses in L and T direction.

But, if we do not account for the sign of shear stress correctly our results could be significantly off from the actual situation. So, this is what I want to discuss in the next step and that is something we will start discussing tomorrow. So, with that we conclude for today and I look forward to seeing you tomorrow.

Thank you.