Introduction to Materials Science and Engineering
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Lecture – 106
Tensile test

Let us now discuss the mechanical behavior of materials. One of the quick way and easy way to find mechanical behavior and the starting point is usually the tensile test. It is a simple test, which gives us various mechanical behavior parameters or mechanical properties of material. So, let us look at this simple test.

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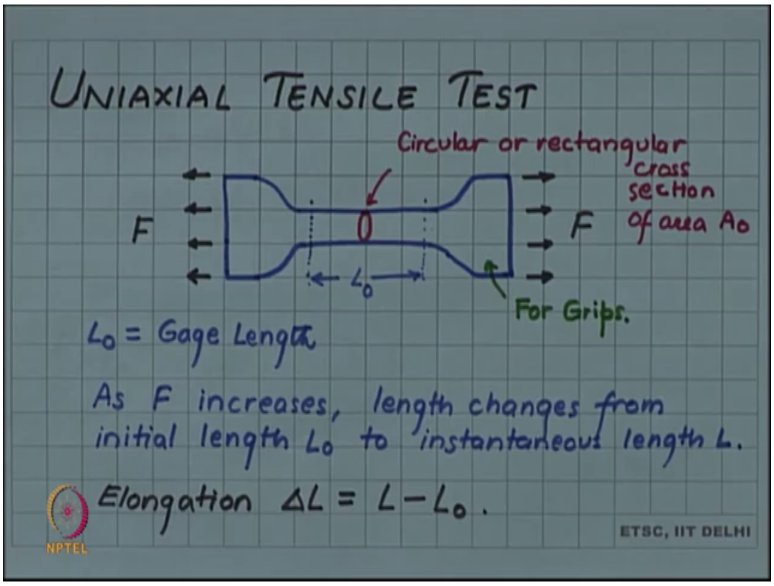

The uniaxial tensile test is usually done on a sample of this kind of shape where, the center portion is of uniform cross section and the length of that portion is called the gage length. So, this is this is the gage length. And gage length has a uniform circular or rectangular cross section circular or rectangular cross section of area A O. The larger portion here we at the ends is for gripping the sample this is for grips.

Now, such a sample is held in a tensile machine is gripped at the 2 ends and is then pulled under a force. So, you apply a force F and pull the specimen, as you pull the specimen the specimen will elongate and as the force will increase the sample will elongate. So, as F increases length changes from initial length L O to instantaneous length L.

So, the change in length is called the elongation of the specimen. The elongation symbol delta L is given by L minus L O.

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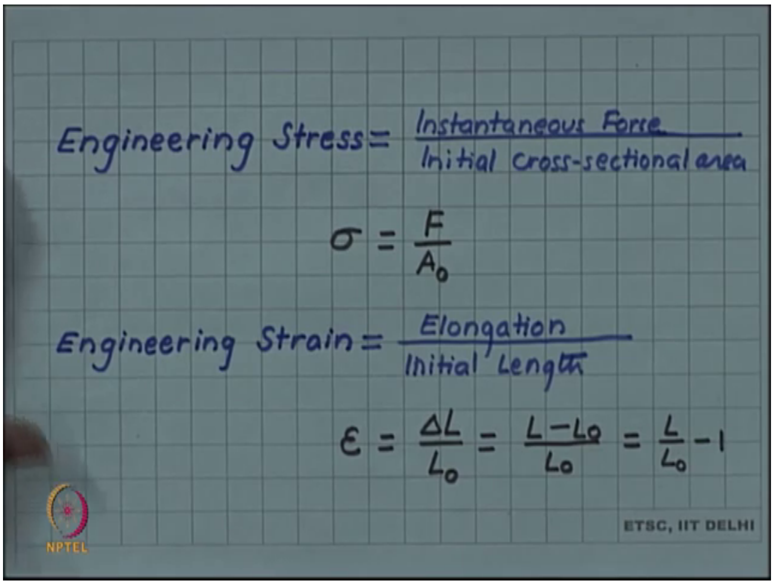

So, this is the simple uniaxial tensile test. The uniaxial tensile test the variables instead of force and elongation are taken to be engineering a stress and engineering a strain. We define the engineering stress as instantaneous force by initial cross sectional area. A common symbol for engineering stress is sigma for force we use F, and for initial cross-sectional area A O. So, we have sigma is equal to F by A O. For engineering strain, we define elongation divided by initial length for the gage length.

So, we have the symbol for engineering stress is epsilon which is change in length divided by the initial gage length, or you can write L minus L O by L O. L by L O minus 1. So, the results of the uniaxial tensile test is presented in terms of a plot of engineering stress versus engineering strain.

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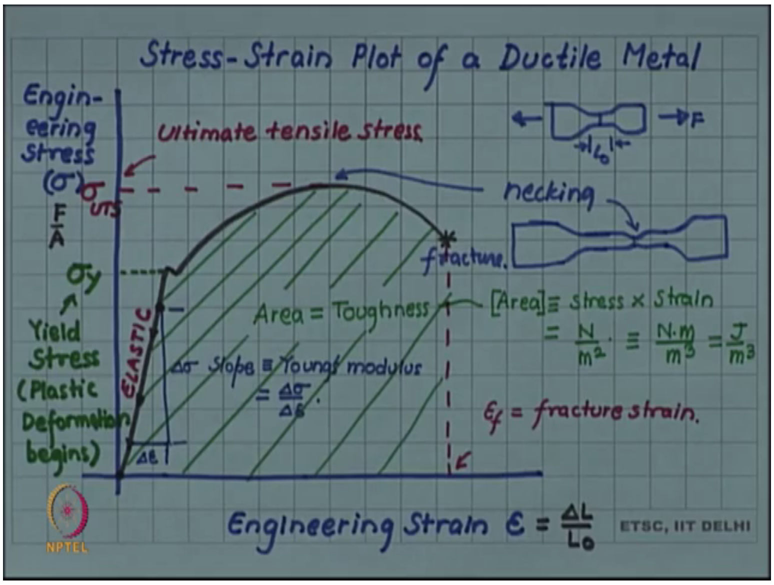

So, the y-axis is taken to be the engineering stress the x-axis the engineering strain. You have seen the engineering stress is F by a an engineering strain is delta L by L O.

So, what the result looks like. Of course, the result depends upon material to material and it can vary a lot if the material type is very, very different. For example, metal will show a very different kind of stress strain curve than a polymer or a rubber or a ceramic. So, let us look at to begin with the stress strain plot for a ductile metal. So, it initially as the material is being deformed remember you have a you have a test specimen, which is being deformed under load and you are plotting the force divided by the initial cross-sectional area and change in length by the initial gage length.

So, when we do that we find that for many metals we have an initial straight-line portion, then there is a non-linearity develops in the material goes through a maximum load and finally, it breaks at some point. This is a typical stress strain plot of a ductile material through this plot through the analysis of such a plot many parameters of mechanical interest can be derived. First of all, we see that in the initial portion is linear this is an elastic portion.

This is elastic portion mean that is if we unloaded the material, if we did not go all the way up to further deformation. Suppose we stopped the test here and we unloaded then, the material would have followed this same line back to the origin and there would have been at 0 load, there would have been 0 deformation at 0 stress 0 strain.

So, material would have come back. So, this is a reversible deformation and is an elastic deformation, but if we keep deforming the material the elastic deformation keeps increasing and at some point. The material stops being linear and a stops being elastic and it starts undergoing what is called a plastic deformation. This point the stress corresponding to this point is called the yield stress, and that is the point where the plastic deformation begins, then the material reaches a sort of maximum load corresponding to the maximum point on the curve.

And the stress corresponding to that is called sigma UTS that is ultimate ultimate tensile a stress. And finally, after UTS actually what happens that material develops a neck in it is gage length suppose this was the uniform gage length, but then suddenly at some point it will develop a neck this is called necking. That is the cross-sectional area is reduced at one given point, and this happens at this UTS point the neck develops as soon as the neck developed, the further deformation is concentrated at that point because the cross-sectional area reduces.

So, the stress at that point starts increasing and so, more and more deformation is now concentrated there. And further increase in the engineering stress is not required because the cross-sectional area is decreasing. So, even at a lower load you still have quite high stress for deformation and the deformation progresses and finally, you have the fracture point.

Now, if we look at the elastic portion and if we look at the slope of the elastic portion so, this slope is known as the young's modulus slope. This is a measure of stiffness of the material that higher will be the young's modulus more stress is required to create the same amount of a strain.

So, this is called stiffness and we also have a measure of ductility, which is if we drop a perpendicular from here and get what is the strain at this point? That strain is the fracture strain, e f is fracture strain. And finally, one can find the total area under the curve this area and this is called toughness. Notice that since our axes are stress and strain the area will be stress times strain in terms of the units or dimensions, you have to actually integrate the area under this curve.

So, the dimensions will be stress times strain the, if stress is in you can think of it as Newton's per meter square and a strain is a dimensionless quantity. So, the dimension of this area is Newton per meter square, this can be thought of as Newton meter by meter cube or joules per meter cube.

So, this area is energy per unit volume which has to be provided to the material up to the point of fracture. So, this much energy per unit volume is required to fracture the material this is called the toughness of the material.

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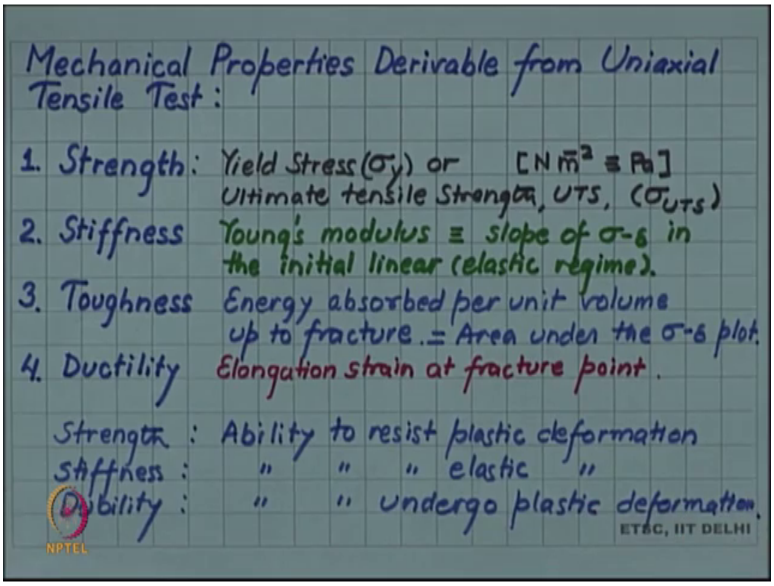

So, let us look at all these properties and summarize the mechanical properties which are derivable from the uniaxial tensile test is the strength property. The strength is the stress value either the yield stress or the ultimate tensile stress is considered to be the strength of the material. So, yield stress sigma Y or ultimate tensile strength also known as UTS or written as sigma UTS the. These 2 parameters are the strength parameters and they will of course, be measured in Newton per meter square or pascals.

A stiffness your stiffness is given by the young's modulus and that is the slope of the stress strain curve in it is linear part slope of stress the strain linear or elastic regime. Toughness is property of material that area under the curve. So, energy absorbed per unit volume up to fracture, there is the area under strain stress strain plot. And finally, ductility is how much the material elongates. So, the ductility in elongation up to fracture elongation strain at fracture point.

So, notice that these different material parameter which are easily derivable from a uniaxial tensile test, have different technical meanings and should be used in this particular sense. Because in common uses strength stiffness and toughness can sometimes be used interchangeably, but in the technical engineering sense these are the definitions which we give, also note that strength is actually strength is ability to resist plastic deformation.

And stiffness and it is ability to resist plastic deformation and is measured by yield strength or UTS. It is stiffness is ability to resist elastic deformation and this is measured by young modulus. And ductility is ability to undergo plastic deformation and this is measured by elongation in strain at fracture point.