Indian Institute of Technology Kanpur

National Programme on Technology Enhanced Learning (NPTEL)

Course Title
Manufacturing Process Technology –part-1

Module 08

by
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Hello and welcome to this manufacturing process technology part 1 module 8 we were talking about how dislocations help in changing the overall ultimate yield stresses of material and what was deciphered was that because of the presence of the dislocation the modulation the shear modulus of rigidity gets changed by almost a hundred folds meaning thereby that the ultimate read strength goes down in shear by about 100 folds.

So how do you actually do these testing or how you actually get this data of elongating a specimen is also known as tensile testing so typically in the tensile testing the standard specimen is prepared.
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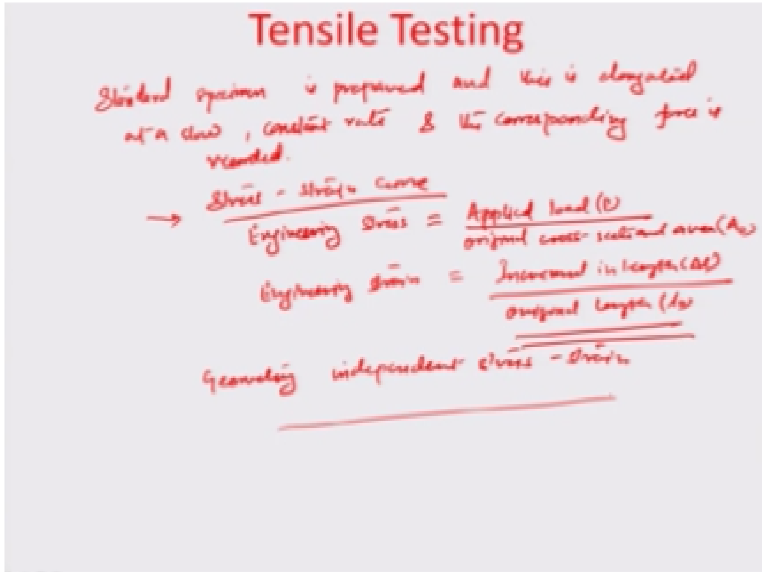

And this is elongated at a slow constant rate and the corresponding force is recorded so the stress-strain curve is plotted which I am going to explain just in the next figure so next slide so stress strain curve is plotted and that is basically showing the engineering stress which is actually the applied load P by the original cross-sectional area is A0 and similarly the engineering strain.

Which is equal to the increment in length of the change in length Δl per unit original length l_0 or so this is a geometry independent stress strain that we are talking about a geometry independent stress strain. so the stress-strain relationship in case of mild steel has been very well recorded and well used.

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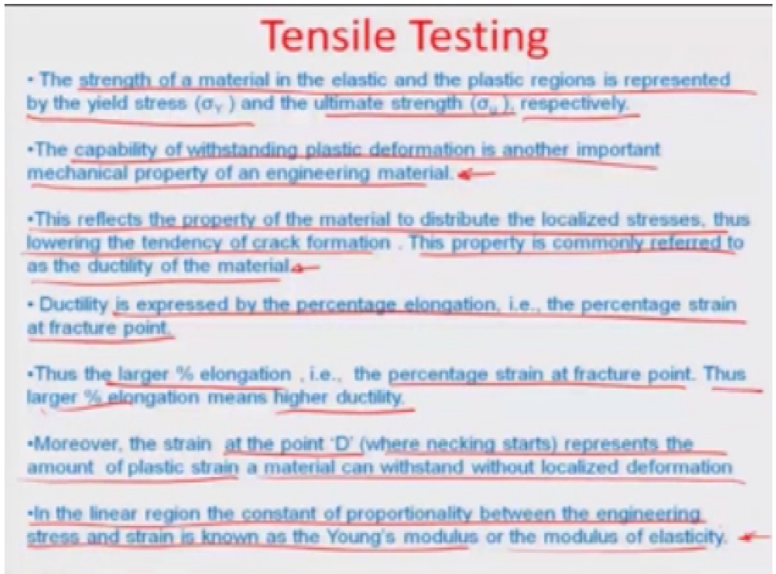

And known so basically this is how the you know plots are being made with the strain or percentage elongation as I defined earlier on the x-axis and the stress in Newton per millimeter square on they-axis so you can see here that the stress-strain relationship is linear up to a point a here for example if you look at this particular section of the curve, it is a linear increase so you know you can say that the stress per unit strain probably is constant or the slope is constant.

So also this A because of this phenomena proportionality between the stress and strain is known as the proportionality limit on the stress-strain curve .the point B as you can see here just above the point A is called the elastic limit so up to the point B the idea is if the specimen is extended up to the point B it will return back to the same path and it will just return back to this original dimensions.

So that is why this is called the elastic limit so elastic limit and it is really if we look at definition what elastic limit means the elastic limit is defined as the greatest stress up to which the material would deform elastically which the material would deform elastically meaning thereby that supposing you know the material you know goes beyond the elastic range so it will not be able to come back to the normal shape and size right.
That is how we define elasticity so beyond this AB the strain that is there let us say is recorded as e_b here so beyond AB the stress value drops suddenly as you can see so any further strain increase beyond be registers a drop in the stress value that is why the curve actually is dropping down here as you can see so for any further deformation the material does not resist as much as it was resisting up till the elastic limit.

So this is supposed to be the yield of the material so beyond e_b the stress value drops suddenly and the material is said to yield so this is actually a very strange situation that you know if you are applying more stress to it or if you are applying let us say the same constant stress to it the strain value keeps on increasing because of that so in other words it does not resist as much the external force as it was resisting before.

So the point Y above the point B so this is not visible really here but then if you look at the B and the way B goes beyond be there is a point here Y Which is also known as the upper yield point where the actual flow behavior of the material start to take place so beyond B and threshold Y and you know you see that the stress comes all the way down to this point C here from the upper yield point.

So if I shall two more external force obviously the material is going to be strain hardened as I told you earlier that there is going to be a lot of dislocation movement within the material creating a traffic jam which will not allow the material to extend further or it resists the process of dislocation movement within the crystal lattice so here in this case also similar kind of a hardening behavior is observed and the stress again rises as you can see all the way to the point D.

So it goes to this particular point right here so C is basically recorded as the lower yield point just as Y was the upper yield point because obviously this is the point beyond which again the stress pattern would change and hardening would start to take place so this material is really the strain hardened part strain hardened material so the stress value finally reaches a maximum at the point D as you can see the point right here and this value is known as really the ultimate limit often stress beyond which the material can hold no longer the additional forces.
And it would get deformed or it will start you know necking or fracturing beyond the point D so we call this D the ultimate tensile stress so the point D is really the point up to which the material is integrated but beyond that there is going to be some kind of a fracture or necking which will start take place so having said that the corresponding stress at Point D is known as the ultimate tensile stress of the material also that is how the mild steel stress-strain characteristics are described a few points which need to be just the take homes the strength of material in the elastic and the plastic regions are represented by the yield stress sigma Y ultimate strength sigma u the capability of withstanding plastic deformation is another important mechanical property of an

engineering material as you saw in this particular curve that you know beyond the point C that is a beyond the point Y there is a flow state of the material which would really be the plastic state so this reflects the property of the material to distribute the localized stresses thus lowering the tendency of crack formation properties commonly referred as ductility of the material.

And ductility is expressed by percentage elongation that is the percentage strain at the fracture point does the larger the percentage elongation that is percentage strain at fracture point the larger elongation means higher ductility so inability of the material to sort of distribute all the localized stresses more uniformly moreover the strain at the point D were making starts represents.

The amount of plastic strain a material can withstand without such localized deformation beyond which there would be a localized deformation and fracture and further in the linear region the constant of proportionality between the engineering stress and strain is known as Young's modulus or modulus of elasticity so therefore this slope that is stress per unit strain is known as the modulus of elasticity of the material.

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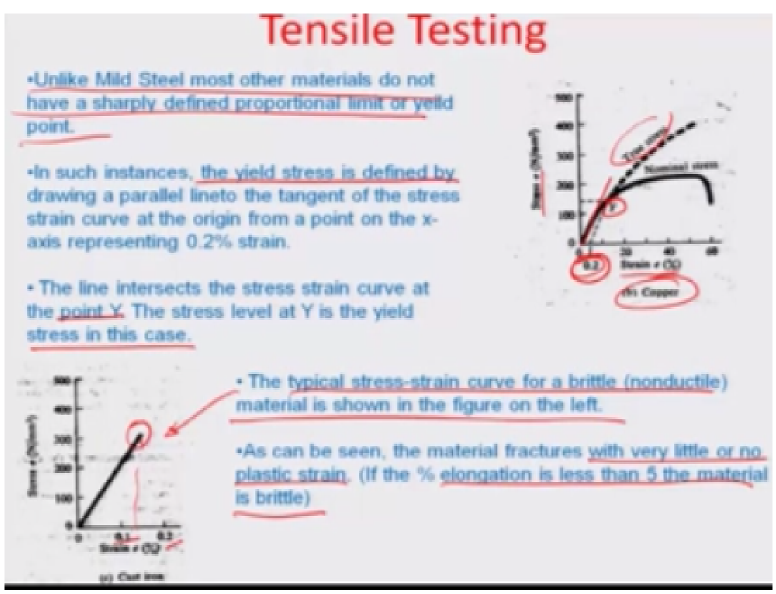

So unlike mild steel most other materials do not have a sharply defined proportional limit or yield point for example look at copper here the stress-strain engineering stress graph of copper there looks somewhat like you know what you can see here so this is the true stress and this is the nominal stress also known as engineering stress so you can see that it is not that sharp or it does not have that many features like the well-defined yield point or the well-defined portion where the necking or breaking would take place as the mild steel case.

In such instances yield stress is really because there is no it is one continuity there is no point where there would be a sharply defined upper real point as the case of mild steel so the way that you define it basically is by drawing a line parallel to the tangent of the stress curve so the tangent of the stress curve If you look at here in this case is somewhat in this particular region okay so you are drawing a line parallel to it at point two percent strain and wherever it intersects with the particular stress strain curve is basically the point what we are calculating.

So the typical stress strain curve for a brittle non ductile material is shown in the figure here where there is going to be a breakage after a certain stress as crossed over and as can be seen the material fractures with very little or no plastic strain so if percentage elongation is less than 5% the material is quite brittle you can see the percentage train here is 0.1% or near about let us say Oh 0.5% beyond which the material breaks down so such materials are known as brittle materials.

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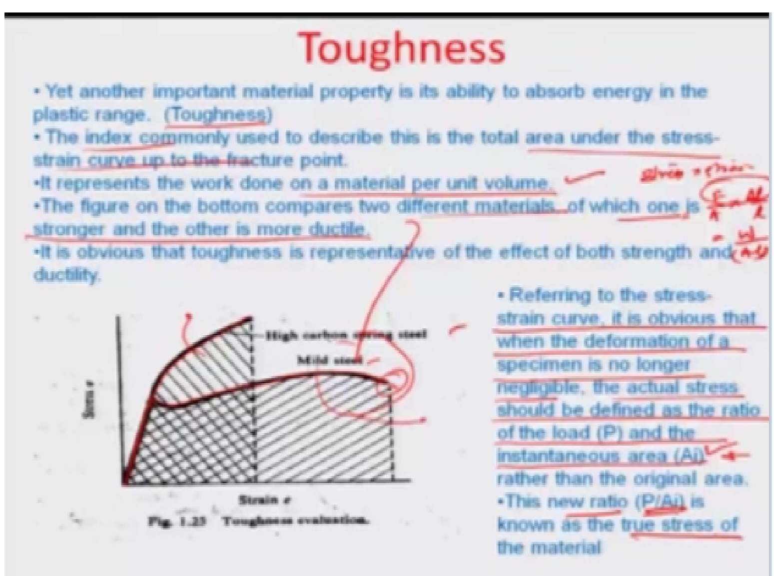

And the other property which is important is toughness and toughness can be really described as the area under the stress-strain curve as you can see herewith these hashes so both these materials for example the mild steel and high carbon steel may have similar area under the curve although their behavior are quite different you know but so they are considered to be equal toughness material so the index commonly used to describe the toughness as I told this area under stress strain curve.

So it represents that the work done on a material per unit volume and because obviously if you look at the stress strain product its force per unit area times of length, change in length per unit original length and I have dot L is basically the work done so it is work done per unit volume okay dimensionally and it represents the so the figure on the bottom compares two different materials one of which is stronger the other is more ductile as you can see here.
Which is more ductile is probably the one which has more strain percentage so in this case the mild steel is much more ductile in comparison to the high carbon steel although the ultimate yield strength of the high carbon steel may be higher in comparison to the mild steel so referring to the stress-strain curve it is obvious that when the deformation of a specimen is no longer negligible the actual stress should be defined as a ratio of the load the instantaneous area A_i .

And this is typically known as the true stress of the material just as we did the engineering of the nominal stress or the material as the applied load per unit the actual area which is actual cross-sectional area without any changes to that area but in this particular range when there is a change in the area obviously the instantaneous area is going to be much different than the real area and so P/A_i is a new ratio it is known as the true stress of the material.

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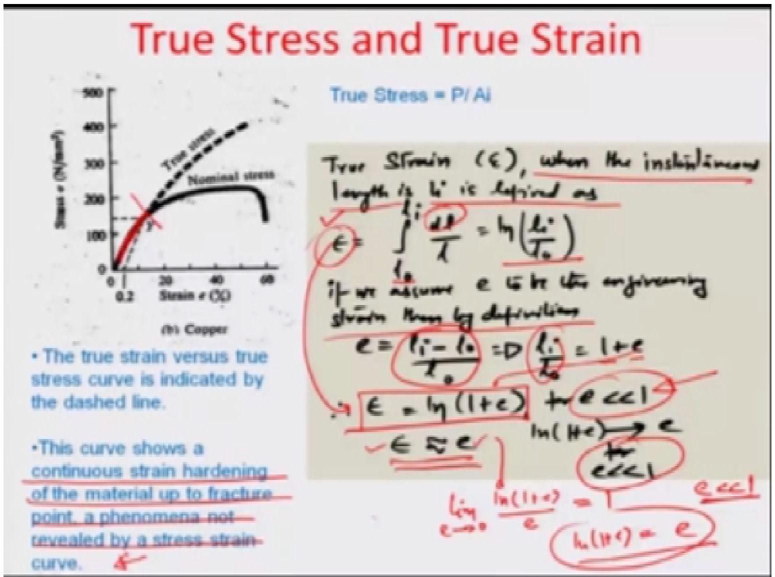

So similarly you can actually have true strain when the instantaneous length is Li from an original length Lo you can define the strain as the change in length *dl* per unit *l* and integrating that makes this come out to be $\int_{l_0}^{l_i} dl/l = \ln\left(\frac{l_i}{l_o}\right)$ if we assume e to be the engineering strain by definition e should be equal to $e = \frac{l_i - l_0}{l_0}$ and which means that the $\frac{l_i}{l_o}$ which we are seeing here as the e to the power of the true strain ∈ should be equal to the 1 plus the engineering strain e and so the relationship that exists finally between the true strain ∈ and the engineering strain is that true strain is equal to the natural log of 1 plus the engineering strain.

So for typically the cases where the engineering strain is much less in comparison to 1 you can assume the you know ∈ to be equal to a very small number *e* and so we already know here that the limit of $\ln(1+e)/e$, limit e tends to very small let us say *e* becomes equal to 1 so therefore the $\ln(1+e)$ can become equal to e at certain you know cases where e is very small smaller in comparison to one okay.

So that is how you can record this engineering strain to be equal to the true strain at small values of strains which is true if you look at the curve up to here where the true strain and the nominal stresses are following a similar pattern but beyond which you can see the true stress strain curve to be quite different in comparison to the nominal stress strain curve so that is how you will basically arrive at all this theory.

So this curve shows a continuous strain hardening of the material up to fracture point a phenomena not revealed by the stress-strain curve so that is how we define the true stress and true strain idealize the stress-strain curves.

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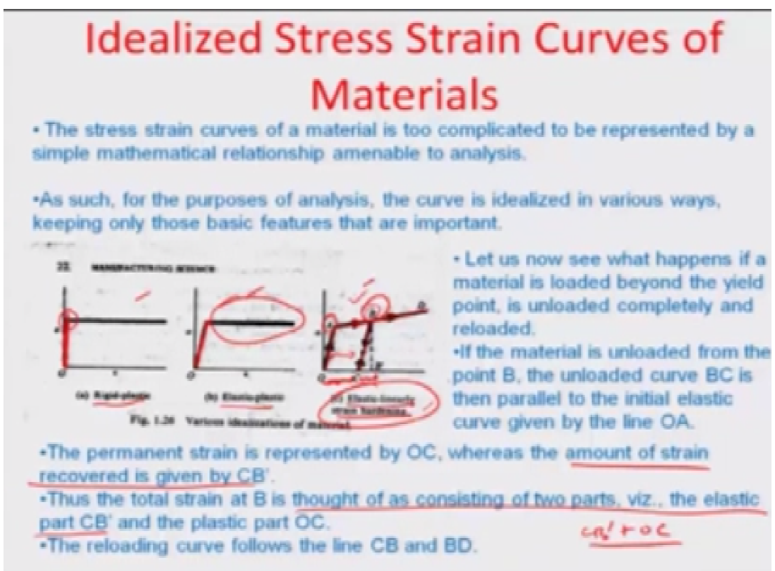

There are many materials which can be idealized in terms of their stresses and strains. For example, let us say if there is a rigid plastic or an elastic plastic or elastic linearly strain hardening material these are the strain curves stress-strain curves you know which represents the various ideal situations so for example in a rigid plastic gate there is a there is a ultimate stress value beyond which the material comes into the plastic flow region there is no coming back as you know post deformation coming back of such material to the original shape and size.

If it is a elastic plastic then you have a region where the material can still come back if the four are released linearly in a certain region beyond which the material comes into the plastic flow strain and if it is a elastically elastic linearly strain hardened kind of material so beyond this you can see that because of the hardening strain hardening there is an increase in the overall applied stress as a strain proceeds.

So that is how you define these three idealizations of the material and so particularly in this elastically elastic linearly strain hardening kind of a material if the material is unloaded from the point B for example the end you know the unloaded curve BC is represented in this particular region this is kind of parallel to the elastic region OA of the curve and you know if you always have something called a permanent strain recorded when there is a linearly hardening material.

Obviously mild steel is not a linearly hardening material but still you have a something called a permanent set which comes up this is the permanent set when the material has crossed its upper yield point and is still there is a possibility of returning which is up to the point B remember in the case of mild steel it was a point C up to which the lower yield point would be reached beyond which the material will not be able to recover and it would have a permanent stress permanent set induced.

If you release the load at the Point C in the same manner here also if you release the load at point B the material would come down so the amount of strain which is recovered is given by CB' okay so this is the amount of strain which is recovered and thus the total strain at B is thought of consisting of two parts except the elastic part CB' which is recovered on the plastic part or C which has been set in the reloading curve will follow the line CB and BD as you know obvious.

So it will not go back anymore because it is starting from a new deformed size OC so that is how you should visualize the elastic linear strain hardening material so having said that I think I will come to the end of this module in the next module we are going to start looking at some of the other properties like for example friction and wear and material and how the material gets into different phases as it gets already fired from the liquid form thank you so much you.

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