Principles of Metal Forming Technology
Dr. Pradeep K. Jha
Department of Mechanical & Industrial Engineering
Indian Institute of Technology, Roorkee

Lecture-16
Measures of yielding and ductility in tensile testing

Welcome to the lecture on Measures of yielding and ductility in tensile testing. So, in this lecture in this week mainly we will discuss about the different types of terminologies related to tensile testing, the failure of the material mostly related to the effect of the different parameters on the flow properties and all other associated you know topics.

So, in this lecture we are have going to discuss about the terminology related to yielding and also ductility in the case of tensile testing. Now, when we earlier talked about the stress and strained, now as we know that we have the two types of stress and strain curve. And normally when talk about stress and strain curve it refers to the engineering stress, engineering strain curve and in that normally the engineering the stress is defined as the load divided by the original area.

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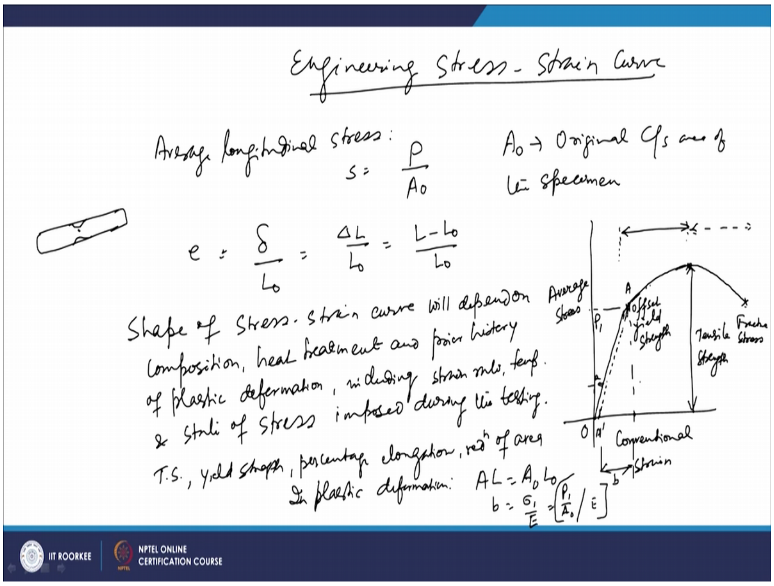

So, basically when we to talk about the engineering stress strains curve. Now, in this case we defined the engineering stress have for that we have the load and the load is divided by the original cross-sectional area. So, we find the average longitudinal stress and for that so, what (Refer Time: 02:12) we get in the case of these engineering stress strain curve. Now, in this basically as you know that we try to subject the specimen to continuously increasing you know stress and then ultimately material fails. So, in this case what we do is we find the engineering stress and that basically is found by the load divided by the original cross-sectional area of the specimen.

So, this is basically original cross-sectional area of the specimen. Now, in this case the strain which we get that is basically the average linear strain and it is again divided by it is found by dividing the elongation of the gauge length of the specimen to the original length. So, we get e as delta by L naught. So, that is this is the elongation in the gauge length that is your delta L upon L naught and that is nothing, but L minus L naught by L naught.

So, this is how you get the engineering stress and engineering strain and you have a curve which talks about the this engineering stress strain curve, which initially increases and you have certain up to certain portion you have the linear region and then it deviates from linearity and then it goes on increasing to certain point. And at that point there is a point where you know it has the maximum value of the these stress and then after that the stress value you goes on decreasing.

So, from there it will come and then finally, at some point of time it will be the fracture of the specimen. Now, the thing is that the stress and strain in this case the shape and magnitude of this stress strain curve. Now that depends upon many things like the composition of the material or the heat treatment of the material or the state of stress, which is imposed on the material; the shape of shape of the stress strain curve will depend on composition, heat treatment and prior history of plastic deformation, including strain rate temperature and state of stress imposed during the testing.

So, what it means that the stress strain curve typically look at these stress strain curve. Now, what we see? We have already seen that it will go linearly up to certain point and from there it will we changing from the linearities vanishing and then it will come at one final point and then at this point; this is the point after that this average stress value is going on decreasing. So, this is your average stress and this is your conventional strain. So, what we see that now what we see that now this is the point what we call if you live it here.

Now, the actually add this point if you live there will be some amount of the plastic strain left and this point is so, normally this is known as the offset you were defining this value some percentage of some percentage or some value of the strain we defined. And that is why this point is the strength is an offset yield strength. Now, this point which is the maximum offset this value goes on decreasing, this point is known as the tensile strength of the material. And the stress which we get here that is known as the fracture stress. The thing is that what we see this is the case normally in this region you have the elastic deformation and then you go from here the plastic deformation starts and finally, the material is going under the fracture.

Now, the thing is that these terminology which are required for analyzing the stress strain behavior of the material. So, they are like so, as we see you have the tensile strength, then you have yield strength and then you have the percentage elongation. Similarly, you have the reduction of area. Now, what happens that since you if you are straining in the direction so, in the longitudinal direction. So, there will be certainly there will be increase in length. So, you will have percentage elongation again will be defined as the change in length divided by original length into 100. So, that will giving you the percentage elongation and as there is elongation as we know that we have the transfers direction, the transfer direction you have the compression area will go on decreasing. So, basically you have the reduction of area.

So, so, this way your engineering typical engineering stress strain curve looks like. Now, the thing is that as we discussed that in this elastic region the stress is proportional to the strain. Now, when this you know load will be exceeding a value corresponding to the yield strength, in that case the from here from this point where from the where the this loads increasing the yield, you know the stress value. Now, from here onwards you have the that is the plastic range of deformation and this is known as the plastic deformation. It means that if the material is unloaded even then also you know you will have some actually the deformation which is still there in the you know, permanent deformation will there of the material.

Now, if after these the stress required which is there in the plastic deformation range is basically increasing; that is what we see in this curve that stress requirement is going on increasing in this zone. Now, this is the zone where this you see that this is there is stress increasing, basically this is the zone of the where the material is getting hardened. So, as there is increase in the plastic strain the material is getting hardened and that is why this zone is known as the strain hardening zone. So, this is what the strain hardening topic is known as.

Now, the thing is that when we talk about the plastic deformation. So, as we already discussed that in the case of plastic deformation the volume constancy has hold good. So, volume constancy if it is there in that case you will have A into L. So, in plastic deformation you have volume constancy will tell that A naught L naught will equal to AL.

So, it means that if the L is increasing, if L naught is the actual gage length, if the L is larger than L naught in that case A has to be smaller than A naught. It means that there will be change in the reduction of the cross sectional area. So, you will have the compensation to the change in length or increase in length by the reduction of the cross-sectional area. Now, what happens into these zones? In one zone what you see if you look at these zone there is a one zone where you see that is going on increasing and then in the second zone what you see is that it is decreasing. Now, what is the reason for increase or decrease?

So, what we see that in this zone there is basically the strain hardening being taking place and initially this strain hardening which is taking place. Now, this is more than compensate for the decrease in the area and that is why your stress value is continuing to raise with the strain. Whereas, after one point of time what happens that there will be the decrease in the cross sectional area, that basically is greater than the you know increase in the deformation load and that is why this basically in this zone it starts decreasing. So, so in this zone the load which there that dominates and in this zone basically the reduction, basically reduction becomes quite less load has lesser value

So, that is why what happens that in this zone this goes on decreasing and ultimately it will come at a point where it will fracture. So, as you know that once it comes here then the specimen starts basically necking. So, this is a point once you come to this state a point is reached and this point is in the specimen you will get a place which is weaker than the rest of the material or rest of the part of the specimen and from there basically the localized necking starts.

So, in this case the because during the plastic deformation the specimen starts thinning down or necking locally at that particular point; you may have any specimen and in that during the at any point it may start you know necking downs. So, it locally it starts thinning down and this area of cross sectional basically is decreasing locally quite, you know at a you know very rapid rate. So, with rapid rate it is decreasing the this is cross-sectional area and that is basically that is how these actual load requirement; basically if you look at the load which is because you are here it is the average stress which is nothing, but the load divided by the original area.

So, actually you have required lower load. So, the load becoming lesser and divided by original area actually that gives you the smaller value of these average stress values. But in actual case if you look at the load and since the area is decreasing a lot. So, if you find the actual stress value then that does not decrease

So, that can be seen from the graph of or the curve of the true stress true strain curve. In the true stress true strain curve it does not basically decrease in fact, the in that case although there is a decrease in the load you know which is required for further deformation, but at the same time there is rapid decrease in the cross sectional area. So, the stress value which is there generated that is still you know in the in the increasing side.

So, what happens after this also in the case of true stress true strain curve it does not go in the bottom side, but it will go in the upper side and then at one point of time it will fracture. So, that is there in the case of the true stress true strain. Now, if you look at these curve what you see if you can analyze this curve? If you look at this curve you see that this is suppose a point and suppose you are getting this point as a and it has come to a prime. So, this is total and then it has gone to this side.

So, we have recoverable strain elastic part; now this is the plastic strain. Now, the thing is that if you look in this zone which is which has a linear zone and we know that you have this is in the slope of this line this is nothing, but we find the models of elasticity of the material. And you have the recoverable elastic strain and that will be basically the sigma 1 by E. So, that is what we get the recoverable elastic strain and if you define this recoverable elastic strength. So, if this recoverable elastic strain in defined as b so, this be will basically sigma 1 by E.

So, that is basically P 1 by A naught and then. So, if suppose this is P 1 in that case P 1 by A naught and divided by E so, that is known as the b part. And you have then you have the permanent deformation that is there and it is the offset that is that is A. So, this A part which is sound this is the offset value which is taken and that is why this is known as the offset yield strength because that will be the permanent you know deformation which is retained in the material.

So, this material which is if suppose you are coming to the another point then from there it will; again if you go to any point it will come in this same fashion. You will have some of some as the elastic recoverable strain that will again divided by so, that stress value divided by the models of elasticity E and then other part will be your plastic strain. So, that way you find it so, and your path goes in that fashion. So, it will be parallel to this line you know up to which it was the linear one so, it will go and come in a in this direction. Now, we will deal with the different other terminologies which we come across in the case of plastic deformation.

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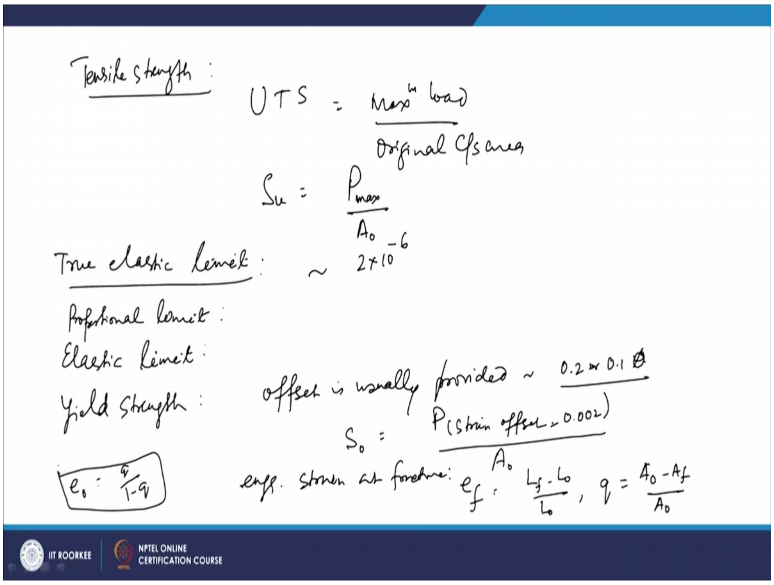

One of the term is tensile strength. Now, this tensile strength it is the so, if you we also call it as ultimate tensile strength or we also call it as tensile strength TS and this is basically the maximum load and divided by original cross-sectional area.

So, as we see that engineering stress strain curve now, this is where you have the maximum load and this divided by the original cross-sectional area that gives you the ultimate tensile strength. So, we define it has Su and this is P max and divided by A naught. So, that is known as the ultimate tensile strength and it is very much important whenever we talk about the property of the materials.

So, for a tensile test we give a lot of significance to this parameter. And for the ductile materials it is measured as the maximum load basically which the material can with stand under the restrictive conditions of uniaxial loading. So, that is how we define these ultimate tensile strength. Now, we will discuss about the measures of yielding, what are you know what are the other you know terminologies which we discuss when there is yielding in those cases.

So, if you talk about the different you know criteria for the insistence of yielding. So, it will be depending upon many parameters and we will discuss one by one. Now, if you see if you we refer to the this graph; now in this graph we have seen that this point up to which the elastic there is linear region. Then we have some region where there is no linear, but still it is elastic it will come to back to its on position. But then after that you have the presence of the plastic zone.

Now, so, it means that the material gradually it is changing from the elastic to the plastic behavior and it is very sometimes very difficult where actually the plastic deformation in fact, starts. So there are various criteria, various parameters which basically define also that where how much sensitive that point will be. How you can say the different point I mean on this stress strain curve. So, if you try to see the different terminologies what we discuss one is true elastic limit.

So, true elastic limit is basically it is based on the macro strain measurement and it will be of the order of so, if you look at this strain value it will be order of 2 into 10 raised to the power minus 6. So, it is basically because the movement of the few hundred dislocations only and elastic limit has very very low value in this zone. Then we come to the proportional limit. Now, the proportional limit it is the highest stress which is directly proportionally to the strains where we see that we are going to the zone at the end of this line where we reach.

And this point where this the maximum point which we reach where the stress is linearly proportional to strain and that point is known as the proportional limit. And this point can be understood by locating that place where the stress strain curve is basically deviating from the linearity. So, straight line proportion from where it is deviating from straight line proportion that point is the proportional limit; then you have the elastic limit. Now, the elastic limit it is the greatest stress which the material can which stand without any measurable permanent strain remaining in the material once you release the load. So, as you know that you had gone in a straight line and after that also you have a zone which is not following in the same path, which as some deviation from linearity.

But still if you are trying to unload the material you come to 0 stress 0 load, in that case the material will not have any you know plastic deformation. So, that is known as the the elastic limit of the material. And if the sensitivity of the strain measurement is increased; in those cases these elastic limit value is a decreased until this until this until you know at the limit where it will be equal in the true elastic limit determined from the micro strain measurement. So, truly a that that will be basically decreasing to as the sensitivity of the instrument will be increasing, you can come back come back to down to down values and ideally it should be the true elastic limit of the material.

Now, further you have to see that the other point is the yield strength value. Now, this is basically the stress which is required to produce the specified amount of plastic deformation. As we have seen that the yield strength yielding starts basically and we are specifying certain value of the plastic deformation and that basically normally is the offset yield strength.

So, you know we are basically deriving a line which is parallel to this straight part and where it is cutting. So, this part is the offset and this way we are reaching at a point so, if you leave the material at this point then you will reach at this point. So, if you take offset you know from this point and from here you draw parallel to this time then you will reach the point which is the offset yield strength point and normally we specify certain strain value.

So, for the offset yield strength the offset usually provide, offset is usually provided and this is normally of the order of 0.2 or 0.1 percent. So, this is how you are getting the yield strength. So, yield strength you can define as we define S naught and that will be P that is load when the strain is basically strain offset is coming as suppose 0.002. So, strain is 0.002 or and then so, this is not percentage and then this by A naught. So, this way get the yield strength value and be define that.

So, we also call it as the proof stress value in many terminologies. Now, we will come to the measures of ductility as we know that in the case of metal forming your requirement is the material has to form, it has undergo the plastic deformation. So, it must have a adequate ductility and you know there is another appropriate term that is malleability, but they have the equal you know capability certainly in an difference sense. But now, you must know that the you must have the understanding of proper understanding of the ductility..

You know because it is very qualitative when we talk about the you know ductility term and for that what we do is that when we do the material undergoing these a operational like rolling or extrusion. Now, in this case the it will be quantified in terms of the degree up which you can either roll them or extrude them till it fractures. So, that is how you basically indicate the extent to which this the material can be deformed or you also define in a very general way, you can plastically deform the material up to fracture. So, that indicates its ability to be ductile or ability to be worked upon..

Now,. so this is about the you know the measures of the ductility of the material. We have discussed about the terminologies like you have engineering strain or you have also the so, you have change in length that is increase in length or reduce reduction in the area and that also is basically expressed as a percentage. So, if you look at these elongation so, if you look at the engineering strain at fracture.

So, when we do the tension test in those case engineering strain up fracture e f that will be a denoted by so, L f minus L naught by L naught. Similarly, you have reduction in area so, that will A naught minus A f divided by A naught. So, because the area is decreasing and length is increasing. So, that is how you find e f and q. So, we find it and if you try to find the relationship between e naught and basically q so, basically e naught you can get as q by 1 minus q.

So, this can be found from the this expressions; you have other terms like modulus of elasticity which talks about the rigidity of the material, because that will be the that is found by finding the slope of these engineering stress strain curve where you see that it goes straight.

So, these are the terminologies then you have other terminologies like you have toughness, resilience. So, resilience will be there during that zone when the stress deformation is less and when we talk about the zone plastic deformation zone; they are the energy of absorbed or the energy inside these stress strain curve. The area under the stress strain curve that is indicative of the toughness of the material, when we talk about the plastic deformation.

And as we discuss that when we talk about the true stress true strain curve in those cases normally your graph is not basically decreasing but it will go and then it will be going and doing fracture like this. So, these are the different terminologies, which we come across in the case of these yielding of the materials.

Thank you.