Fundamentals of Materials Processing (Part- II)

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Lecture – 14
Wire Drawing continued

In the previous lecture we saw what is the maximum drawing reduction that is allowed, if you go beyond that remember the material will fracture outside the drawing or the die zone which is something you do not want. Now we will understand the same concepts and through this stress strain plot what exactly or where exactly do we see this maximum strain. So, let us draw the stress strain plot.

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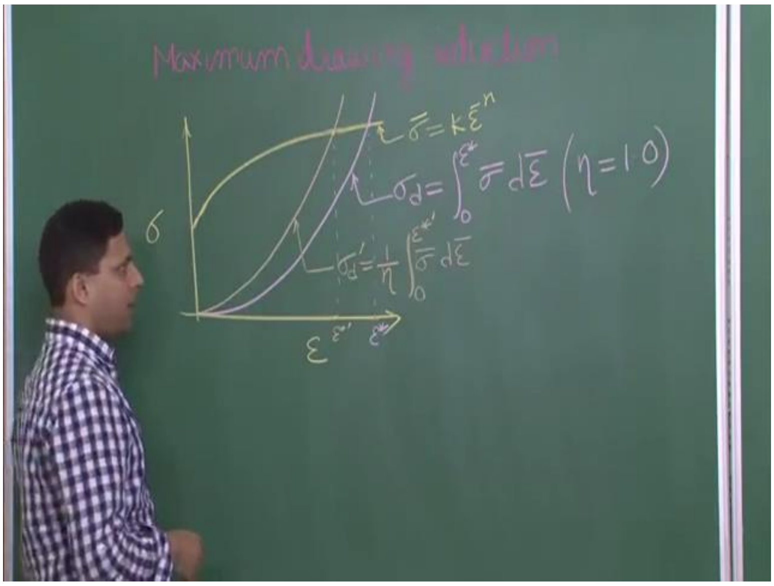

So, we are looking at maximum drawing reduction. So, this is our true stress strain plot. So, this is stress this is strain. Now if we draw just the flow behavior which is the plastic component the plastic deformation behavior it will come out like this. So, this is what this is sigma equal to effective stress is equal to k epsilon to the power n. Now if we plot our drawing stress on to this sigma d how would it look like, it will look like this; so this plot is. And what is the assumption here if you see we have not put 1 over eta at this point which means we are said that eta is equal to 1.0. And this epsilon star is the critical strain up to which we can go and what is this it is this strain. What if we have the efficiency of the system little lower than this? Then it will; the plot will look something like this. So, this is our sigma d to differentiate it let me put a prime over here and we have 1 over eta. So, you can see it is 1 divided by a factor less than 1, so sigma d is always higher for a given strain. So, this sigma d prime is always higher than this sigma d.

And again to differentiate from this epsilon star which is the critical I will put up prime over here. So, this is our epsilon star prime. So, all those things that we discussed using equation can now be also seen through this plot. This is our stress strain plot, this is the actual sigma d and our sigma d; sorry this is the flow behavior sigma which is given by the power law behavior and one of these plots are our drawing stress behavior. So, you see that our strain should always be such that sigma d is below this value. So, if we had efficiency of one in the system then all the way up to this point the sigma d value is lower than the flow stress sigma or even if we have efficiency is less than 1 then we have another plot and up to this strain value the sigma d prime remains below sigma bar.

So that is what we want. The point at which cross it is the critical strain we should never cross. And therefore these define your critical strain the maximum pass or the maximum drawing that is possible in one pass. And we also said that if you need more reduction than that what is the way out you will have to have multiple passes. So, that makes the picture clear about per how we get to this critical stress or and the critical strain value for drawing operation. Now that we have to seen it let us try to solve a simple problem based on this.

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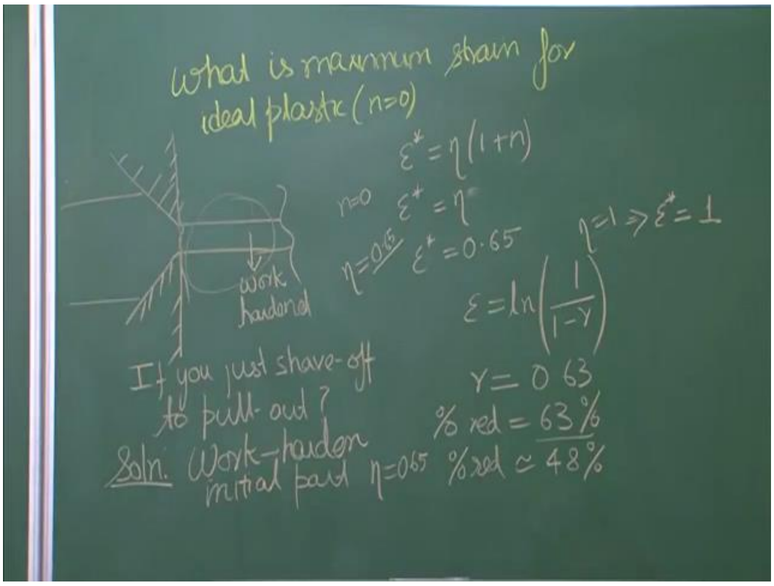

What is maximum strain for ideal plastic (n=0)

$\varepsilon^* = \eta(1+n)$

$n=0 \quad \varepsilon^* = \eta$

$\eta=0.65 \quad \varepsilon^* = 0.65$

$\eta=1 \Rightarrow \varepsilon^* = 1$

$\varepsilon = \ln\left(\frac{1}{1-r}\right)$

$r = 0.63$

% red = 63%

If you just shave-off to pull-out?

Soln. Work-harden initial part $\eta=0.65$ % red ≃ 48%

And the problem is what is maximum strain for a material which shows ideal plastic behavior; what is ideal plastic? Ideal plastic is when n is equal to 0. That is if you were to draw the stress strain plot to stress strain plot for the flow behavior part it will remain constant. So, this is sigma bar and epsilon bar. So, the material flow stress value remains constant no matter what is the strain and that is called Ideal Plastic.

The question is what will be the maximum strain for this kind of ideal plastic when you are doing a wire drawing operation. So, all we need to do is putting the values in our equation; we know that epsilon star is equal to eta 1 plus n, but n is equal to 0 therefore epsilon star is equal to eta times or just eta because n is equal to 0 so it is just eta. And that means, that if you have efficiency of 65 percent which is more or less that you will get in industry then epsilon star could also be equal to 0.65. So, this is the maximum strain that you can get.

And for a system where eta is equal to 1 you will get epsilon star is equal to 1. Now you remember that epsilon is also equal to or in terms of area deduction we can put it like this l n 1 over 1 minus r, we went through the individual state to show that epsilon is actually equal to l n 1 over 1 minus r. So, if we know that epsilon star is equal to 1 we can inversely calculate what is the area reduction and you would get area reduction of 0.63 which means in percentage 63 percent area reduction. So, this is the maximum that you can get for ideal plastic and assuming a very efficient system. If your system was not efficient let us say if the system efficiency was 65 percent and then this value would also reduced. So, you will get something like 50 or 48 percent depending on.

So, for example, eta 0.65 you can see the calculation or try it your own for eta equal to 0.65 and assuming that your strain would come out to be 0.65 and in that case and I just assuming a ideal plastic you would get percentage deduction approximately equal to 48. So, this is the maximum area reduction that you will get for material which is ideal plastic and for which the efficiency is equal to 65 percent. So, this is example for this and here also you can see that if you want more than 48 percent area reduction you will have to do more than 1 pass.

Now let us get to another still interesting aspect of wire drawing. Again let me just draw rough sketch of the wire drawing operation. So, this is how your; this is the die, this is where your wire comes in and this is your wire goes out. Now remember we said that you are able to put a stress in a cleaner region and still able to do it deformation on a thicker region because this is work hardened. Now what if you like we said at some point your wire has broken for whatever reason it could be because there was some defect, not particularly because of your fault it has broken. So, now, what we need to do is; let us say it has broken somewhere over here.

Now what you need to do is to begin the process you will have to shave off some material so that you can start pulling it from the other end. I if just start or if you just shave off the material to pull out what will be the problem, can you do this? What will happen is that this part will not really be work hardened anymore? And so you are trying to pull a by applying stress on a thinner region same yield stress and your expecting or hoping that a material with the same yield stress, but with thicker diameter will start to deform which is not possible.

The solution is, that you need to work harden this part of the region some other way around, you cannot do the wire drawing because you need to insert through this die at some point. And since the wire is broken from somewhere over here you cannot insert it or pull it out from here. So, you need to work harden this initial portion by some method. And that is the solution but how do we achieve that? We cannot apply like I said wire drawing operation. What can you do? This operation is called Swaging. So, basically every time your wire breaks down you will have to add an additional step which is of swaging which is another way to look at why if you are running an industry you will not want to your wire break down because then this involves delaying the process and less productivity.

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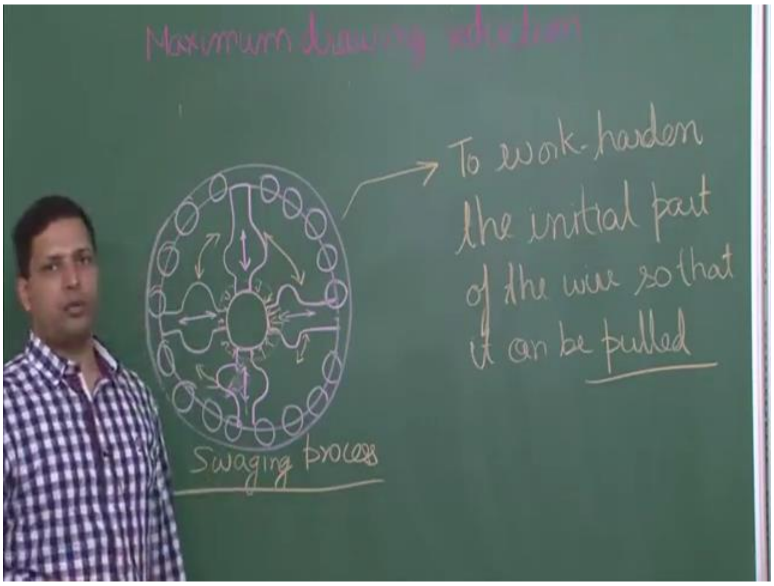

But anyhow at some point it may break and in that case you will have to have to do this work hardening, how it is done? So it is a swaging is a process like this let us see this is the final diameter that you want it will have a hammer kind of structure. So, these are four hammers which can move in and out like this and there is a fourth one over here. So, what next one goes in and out? There are spherical balls all around, so these spherical balls are still inside another cylindrical structure.

Now, what is done is that this whole part is rotated, which means these spherical balls will at some point come and press this hammer on to this wire or you can put a wire over here or you can put a rod over here. So, let us say that initially your rod was of this diameter. Now when it is starts to rotate every time a ball comes over here it will push this hammer inside and it will kind of hammer this wire at this point and keep rotating. So, this whole thing is also rotating at the same time and also the spheres are rotating which ensure that this hammer operation is carried out.

So, this hammer operation gets carried out and this part gets hammered and eventually it will get beaten in to this thinner diameter. In the end you will get a wire of this diameter and you can keep pulling or pushing through this so that you get sufficient length of wire with this kind of diameter. So, this is called the Swaging. So, the purpose of swaging is to work harden the initial part of the wire so that it can be drowned or pulled. So that is all we have about this uniform energy method or the lower bond method were we discussed in some amount of detail extrusion method and the wire drawing processes, we also looked at the maximum reduction that you can get in wire drawing.

We also saw that you can relate the extrusion pressure or the drawing stresses to the actual work and if you are assuming that the actual work is equal to the ideal work which is when no friction is present or no reduction is being or no redundant reduction has been carried out in that case this extrusion pressure would also be equal to the ideal work and so we get a very nice relation or nice way to calculate extrusion pressure or the drawing stresses. And we also saw that under this condition of ideal stresses or ideal work your drawing stress required to reduce the diameter is less than the same deformation or the same reduction that you can get in tensile stresses.

So, that covers most of the important or fundamental aspects using the uniform energy method or the lower bond method. You can extent this to any other kind of operation you just need to calculate the integral sigma bar d epsilon which is ideally what is the real work that is going on so that is the ideal work and then you can related to some of the external parameters assuming no friction.

Now, we will go to another method as we promised earlier which is upper bound. Now, we have seen at the lower bound which is the minimum amount or force operation that is required now we will go and try to calculate pressure or forces calculated which will form the upper limit; that is in reality you cannot or you need not go beyond that pressure or force. So, our next step is upper bound analysis.

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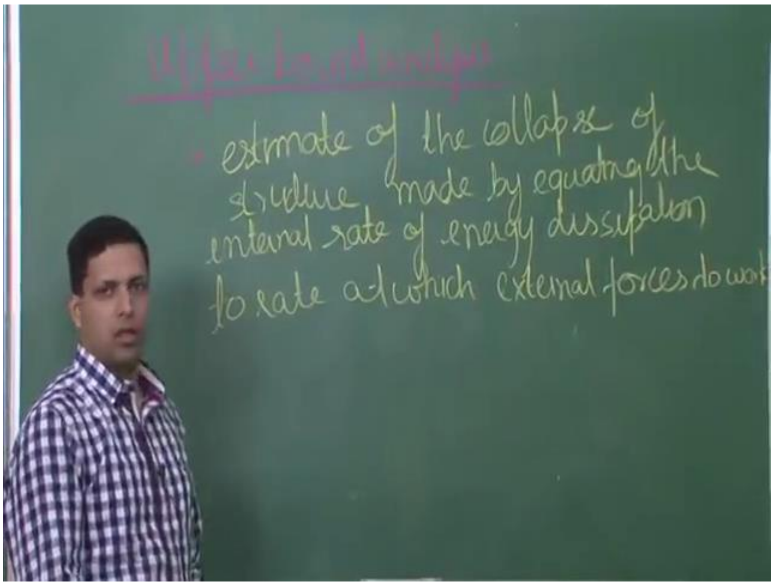

Upper bound analysis

- estimate of the collapse of structure made by equating the internal rate of energy dissipation to rate at which external forces do wo

What is upper bound or how do we obtain upper bound analysis? In upper bound analysis what we do is we assume a particular deformation field which is as long as it is self consistent and follow some assumptions we will look at that. And then we calculate what will be the internal work rate in that deformation field and calculate what will be the external force a power or stress requirement for that. And now we equate these two; the internal deformation rate and external work rate, we equate these two and from this we are able to obtain pressure or some stress value which we can calculate or which we can relate to or which we basically form the give us the upper value for this kind of operation.

So, this is the estimate of the collapse; collapse meaning deformation we do not mean failure we mean just when you are doing the deformation at some region some were shear is taking place we are calling that just as the collapse. So, estimate of the collapse of structure made by equating the internal rate of energy dissipation to external rate of work to rate at which external forces do the work.

When we are using this analysis we are taking certain assumptions so it is important to first look at some of those assumptions before we can proceed and start to formulate the equations. So, what are those assumptions some of those assumptions are straight forward for example, we are assuming isotropic behavior; meaning we are saying that the material must behave similar in all directions.

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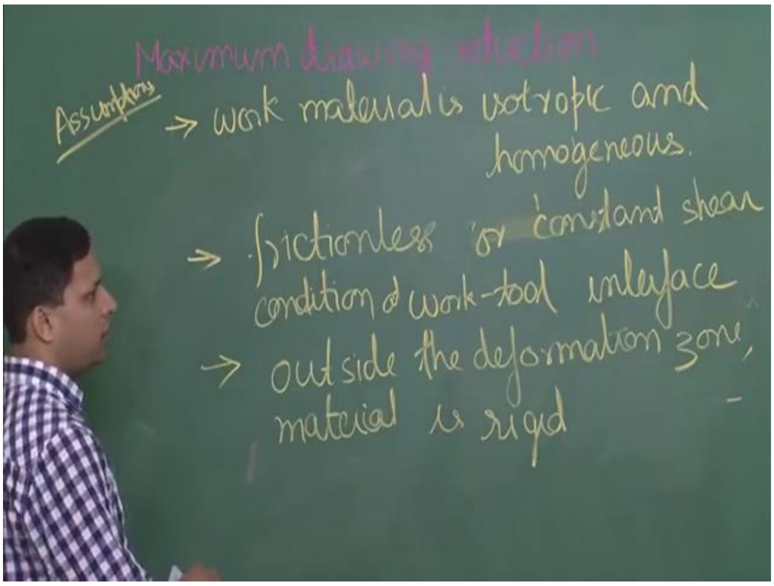

Maximum drawing reduction

Assumptions

→ work material is isotropic and homogeneous.

→ frictionless 'or' constant shear condition at work-tool interface

→ outside the deformation zone, material is rigid

So, these are the assumptions work material is isotropic, and you would see why we will be able to justify the use of this assumption when we start formulating or trying to get formal equations for this; isotropic and homogeneous. So, not only isotropic, but also homogeneous; meaning, one part of the material does not behave differently from the other part. So, this is assumption number one. Another important assumption is that that of frictionless, frictionless may not be the real situation, but we also have frictionless and constant not and, but or constant shear condition at interface basically work tool interface. So, for example if you are doing the wire drawing operation the tool would be die and the work piece would be the material which is deformed. So, this is the assumption number 2.

And another very important assumption is that outside the deformation zone we assume that the material is hard or basically it does not deform or that is it is rigid material, behaves material is rigid. So, there is no scope to assume that there will be graded behavior of the material, that is less deformation from very sharp or high deformation to small deformation to even a smaller deformation and to the region that there is no deformation which you may say is the true behavior in most of the deformation processes, but you would see that we are still able to get a good upper bound estimate for most of the processes.

In this we are saying that all the deformation is limited to that particular deformation zone or that particular shear plane that we will say is the deformation zone, but beyond that it is not deforming. So, these are the assumptions that we have, and based on this assumption we can now come to what is the actual step involved. I am going step by step here to make sure that you can come back and see those things to see what are the different step in formulating the equation over here.

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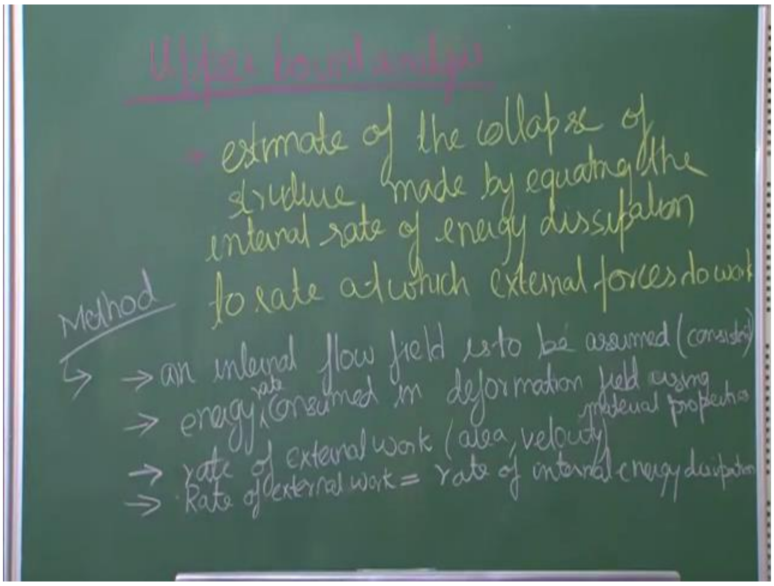

Upper bound analysis

- estimate of the collapse of structure made by equating the internal rate of energy dissipation to rate at which external forces do work

Method

→ an internal flow field is to be assumed (consistent)
→ energy rate consumed in deformation field using material properties
→ rate of external work (area, velocity)
→ Rate of external work = rate of internal energy dissipation

Now, next is what is the method or a steps, these will become very clear once we start solving some of the problems. The method involves that we have to have an internal flow field is to be assumed. So, it is giving you a lot of levier you can define your own internal flow field or the deformation what kind of deformation which particular way the deformation is taking place. And internal flow field is to be assumed and of course it has to be consistent. And with example when we come to example I will show what exactly do we mean by consistent, we just to put it in words to say consistent it means that you cannot assume that after deformation material is remaining inside the deformation zone.

At some point the material if it keeps moving after deformation it must come out and so on.

Some of these things when you put together you can these make consistent behavior. Second is that, we have to calculate energy consumed in this deformation field. We have made a deformation field which is consistent then you have to calculate the energy consumed in deformation field, using material behavior, material properties. So for example, material property is would be like the shear strength or the yield strength. So, this part when you are calculating the energy consumed or actually the energy rate consumed you are putting or utilizing only the material properties or all the properties that exist of for the material and based on that you are saying this is the energy consume for the deformation.

Then you calculate rate of external work. And for that you will utilize the area on which these forces are working the velocity at which parts are moving. So, here you utilize external information. For the internal rate of work you utilize internal or inherent properties like the material properties. For the rate of external work you utilize external parameters like area and which the force is the shear stresses are acting the velocity which parts are moving and so on.

And the last part is to equate rate. So, in these four steps you would be able to get a equation and from that equation you will be able to obtain a relation for pressure or stresses in terms of property parameters and mostly the velocities. And to leave you with something to think about I will draw a simple condition or a simple deformation field and give you some hint on how to approach it.

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So let us say, we have this is something which true for operation like machining in machining also you are doing although shaving off the material you are taking of the material, but there is also some deformation taking place particularly that chips that come out. So, let us say this is part that is been shaved off and this is the chip that is coming out. So, this is s s prime. Let us say this part moves on and from over here it gets on to a deformed zone like this, so if a b c d has converted to a prime b prime c prime and d prime. The velocity here was to v 1, velocity here is v 2. And what we will need is to relate this velocity and you will get another additional velocity.

To begin with I would ask you to draw a vector diagram and how these velocities are changing, and what will be the third velocity vector that you get here, how can you relate it with the deformation field. The deformation field is as you can see is related somewhere contained over here. So, you give a thought on to this and we will come back to this point in the next class.

Thank you.