Principles of Metal Forming Technology
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Lecture - 23
Determination of flow stresses in metal working

Welcome to the lecture on Determination of flow stresses in metal working. So, as we know that in the case of plastic deformation you need to know the load with which you are going to apply on the specimen so, that the, you know because every material will have some flow resistance. So, you required to have the stress value reached in all these circumstances so that there is plastic deformation. So, you are basically this is what is required then whenever you have any specimen any billet or slab or so and that will again depend upon its state. So, underwater state you are going to do the deformation. So, the deformation may be done at the temperature.

Deformation now, you know the amount of load which will be required may depend upon these value of stress, strain or you know I mean strain or strain rate or temperature or even sometimes it also depends upon the geometry of the work piece. So, if you try to see that what will be the, you know normally ah what will be the forming stress or pressure.

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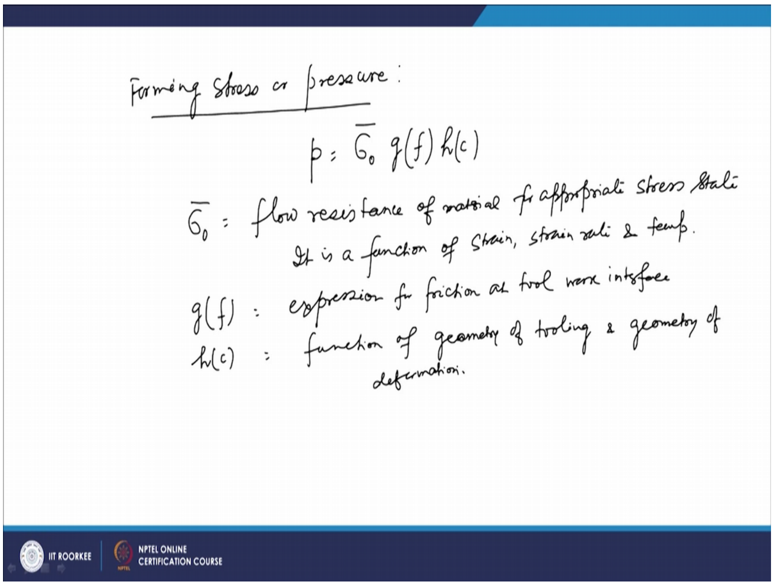

So, forming a stress or pressure which you have to apply that normally is said to be depending upon basically 3 terms and invariably you have 3 terminologies which define that what should be the forming load or pressure on that and that is basically defined as the term P equal to so this will be effective value of stress. So, that it is flow stress which is the average value of the flow resistance of the material and then you have a function g f.

So, this is basically for the taking into account the friction which is acting between the tool and die interface and also another function which will be there it will be basically working for the tooling and the geometry of the work piece. So, basically this if you look at the sigma this is known as the flow resistance of the material for appropriate stress state.

So, the material is subjected to you know different type of stress strain, it maybe uni-axial bi-axial there may be no chase and all that. So, based on that under that condition the material has certain flow resistance and that is basically divided I mean presented by this term sigma naught bar and it may be uni-axial or plane strain conditions or so. So it is basically a function of it is a function of strain; strain rate and temperature. So, as we know that this information has is being carried out at different conditions and these parameters are the ones which decide what will be the flow resistance of the material and that will be basically dependent upon the strain value or strain rate value or the temperature values, will discuss about how these parameters affect these value of the flow resistance of the material.

So, the this function g f actually this is expression for friction at the you know tool work interface. So, this is expression for friction at tool work interface. So, there is the friction at that surface where the tool and die is meeting and that is to be counted into while we try to find the load you know the forging load or the forming load or the pressure. Then the, this term h c, so this is also one expression and this is the function of geometry of tooling and geometry of deformation.

So, we have certainly the tooling arrangement and we have also the deformation geometry how it is and where we have to deform in what shape. So, this function will be accounting in that factor and normally we try to avoid this becomes very redundant you know normally its contribution is very minimal. So, normally we try to you know ah neglect this part that is h c.

So, this is how I mean now we have to see that how when we talk about the friction conditions, how they are going to affect how what is the effect of these friction conditions or friction between the tool and the work piece if it is, so how it is going to affect the you know load criteria.

We also must be we have the idea that when we go for the plastic deformation, in those cases your strain values are true strain values are quite in the higher side. So, we get the true strain value of about 2 to 4. So, basically normally when we draw these flow curves so, from the flow curves basically you I mean depending on the flow curve you will have the you know you are so, you will have the idea about finding these you know ah the forging or deforming loads.

And normally you have a larger value of typical value of strain from 2 to 4 which normally encountered in the case of the deformation analysis. Also you have you may feel to you may face even the large value of strain rates in many cases same as it may go as high as 100 you know per second. So, so normally you cannot do with the ordinary test what will be the behavior of these you know flow curve, how can you draw the conclusion to find the you know flow stresses and all that it is very difficult.

Further as we discussed that your temperature is also going to be important parameter in determining that what will be the you know what will be the flow stress because at as you know increase we increase the temperature then the flow stress requirement becomes smaller. So, at what temperature we are doing all these you know analysis at what temperature the test is being carried out.

So, there itself you can have you have to have this value of the you know flow stress. So, so these things are you know important basically you must have the idea about the true strain rate then temperature and all that. Now the thing is that when we try to look at the compression test of certain you know specimen; so, you have that also gives you some indication about how the forming you know behaviors vary.

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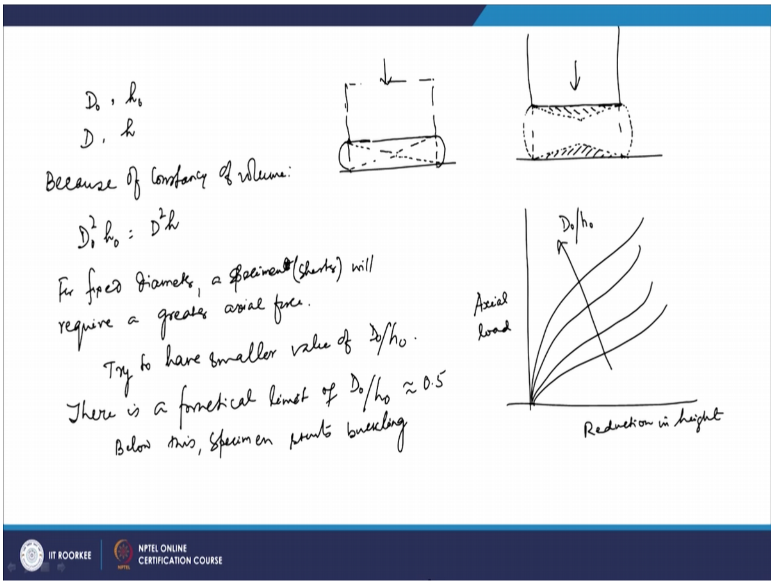

So, suppose you are going to do the you know compression of the problem in those cases, suppose what we see is that, suppose you take the example you will many a times you if you try to have the specimen like this and when you apply the you know pressure from here from the top you are applying the pressure. Now what happens that ah there is friction at this interface.

So, because of this friction of this interface you will have the resistance to flow at this place and you will have lesser resistance in these regions. So, what may happen is the you may have the you know presence of certain such kind of effect which is observed in many cases on these 2 sides and this is known as the barrel in effect. Now what happens due to that basically because of this you will have zone which is basically undeformed.

So, this will be the zone on both the sides because you have friction acting at both the places are the top as well as at the bottom and so, what we see is that you have a default zone at the you know interface, near that interface you have these as the you know undeformed zone basically and because of that normally what you see is you see the you know barreling type of effect if you look at the further the example.

So, that if suppose you have smaller specimen like this, so in those cases you will have again the barreling effect and in if you will see so, you have the pressure being applied from here and in this case the barreling may see something it may come up to the central parts.

So, very small part is so, most of the part is now these are the undeformed regions basically and you will see the barreling and barreling is not very much desired in the you know metal working analysis.

So, what is seen if you try to the see the you know in this case since you have So, the since we are doing the compression test. Now what happens that suppose you have the initial diameter as D naught and then height as h naught and it is converted to the height dia D and the you know height converted to h.

Now what we see is that normally because of the constancy of volume principle. So, you will have D naught square h naught will be equal to D square h. So, ah you know now this can be further used for the analysis for the finding of the forming load.

So, when the curve was plotted for the I mean load and deformation curve were plotted for the different value of the D naught and h naught then it was seen that your curve goes like this and it will move like that. So, when this where as we move in this directions so, the D naught by h naught value is increasing and what we see that this is the actual load and this is basically the reduction in height. So, what we see that with this increasing value of this D naught by h naught.

The curve sees a trend which has which is so, it will be you know bending the in the upward direction. So, that is what is observed. Then it is also observed that the for fixed diameter a specimen, so, I mean a specimen that is shorter that is a shorter is specimen will require a greater axial force..

So, that is what it is see in that if the there is h h naught is smaller in that case what you see that you require the more axial force which is there, which is evident from this curve.

So, normally you try to have the lower value of D naught by h naught. So, so try to have a smaller value of D naught by h naught; however, you cannot go this to this value of D naught by h naught you know below certain limit because if you go to that value below certain limit in those cases you have more chances of the buckling. So, there is a practical limit of D naught by h naught and that is normally taken as about 0.5.

So, basically ah you know instead of barreling the specimen will buckle. So, below this value the specimen starts buckling. Now so, we are discussing about the effect of this barreling and this is because of the you know friction which is occurring at this interface and in actual these friction which is there at the interface they are minimized. So there are ways to minimize this friction.

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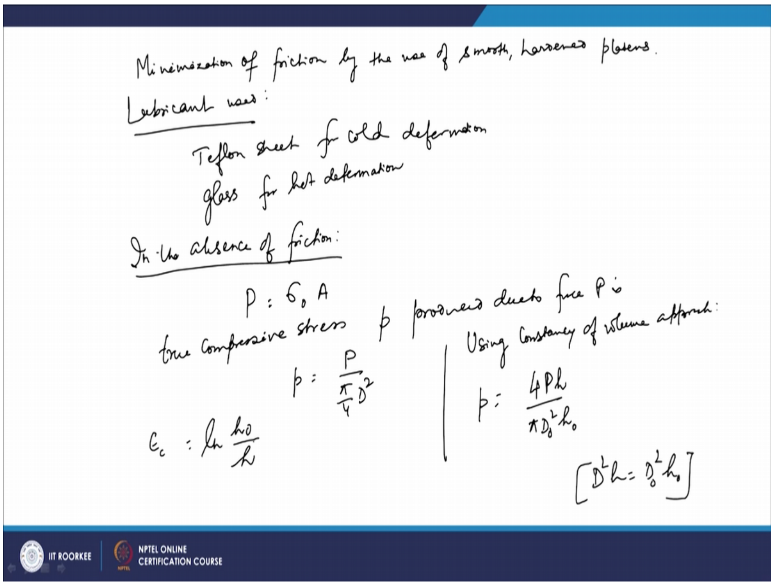

So, so, minimization of friction is done. So, that can be done by the use of the you know a platens or the dies. So, so by the use of smooth hardened platens. So, what we do is in those cases what we make we try to make the groups also towards the end so, that the lubricants are not lost.

So, so that way we try to retain the lubricant and further use it. So, that is how it is you know we try to neutralize you know you try to retain the lubricant and also we try to do the testing in the increment. So, we do it then further ah so, we do the you know the test in increment, so that you can also place the lubricant during the interval.

So, so the lubricant which is used so, lubricant which is used is different for solid and the you know for different materials. So lubricant used is normally we use Teflon sheet for cold deformation and we use the glass for hot deformation.

So, normally it is seen that you can reach the strain data of strain value of 1 without you know with only very slight you know barreling a you try to observe these values in the in such cases. Now when you do not have the friction so, in the absence of friction, so when you do not have the friction resistant force are very very small.

So, in those cases ah what we do is so, you have the P as sigma naught into A. So, that will be the uni-axial compressive force you required to yield the material and the true compressive stress that is P which will be produced because of this force produced due to force P. So, you can find it by dividing with the area. So, P will be P by pi by 4 D square because D is the diameter which has been achieved and since we are using the constancy of volume approach so, using constancy of volume approach you can have the value of P as 4 P h upon pi into D naught square into h naught because D square into h will be so, this will be D D naught square into h naught.

So, what we do is D naught square into h naught by h will be the D square so, h will go up. So, you can have the value of these you know P you know that compressive stress 2 compressive stress can be formed using these values. Now if when basically so, we know that the D naught and h naught are the initial diameter and the height and D and h are the final you know diameter and the height, so you can find the compressive stress also.

A compressive strain true compressive strain and that will be given as ln of h naught by h. So, this way you can find these 2 compressive stresses and strains. Now the thing is that when we are doing these testing of these specimen, then in that case basically we need to have the true strain rate So, basically where the cross at speed even though it is constant you cannot maintain the true strain rate as we are discussed in the past that when the cross at speed the constant one, but the strain rates vary.

So, so the because you have to maintain a constant true strain rate and for that for maintaining the true strain rate you have some mechanism and ah normally you have the servo control testing machine so, upto the value of ten per second you have the servo control testing machine which are used for controlling that is true strain rate because as we discussed that as the a will be decreasing so, in that case the true strain rate basically will be increasing.

So, upto that it can be controlled using that servo control mechanism and if it goes to the higher values then you have a equipment known as cam plastometer that basically tries to maintain the constant true you know constant strain rate values because you know once you are doing the testing then your strain rate should be the same one.

Now when we work for the basically the you know thin sheets in those cases normally we apply the plain strain conditions and what we do is you have the you know we do the analysis by keeping the you know dimension in one of the dimension as the one which does not change and when we discuss about the thin you know where we do the plane strain compression test for the thin sheets in those cases if you look at, so, for plane strain compression test of thin sheets.

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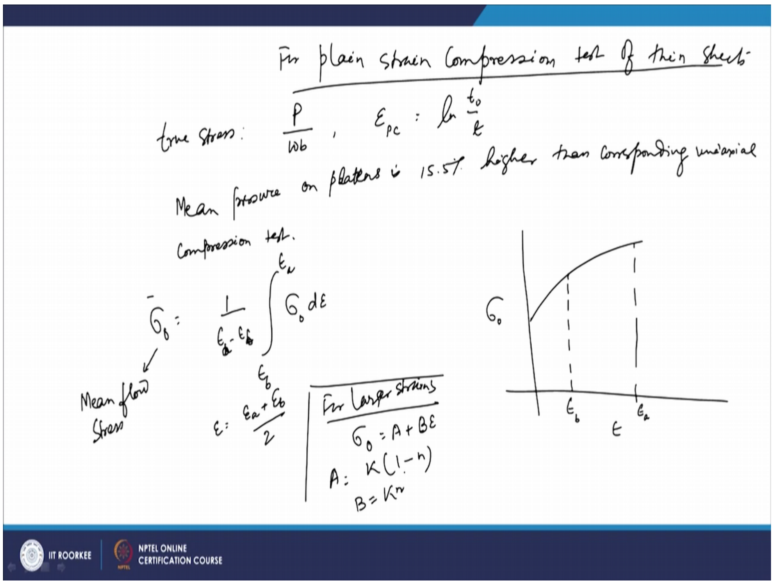

Now in those cases what we do is that you find the you know true stress and true strain. So, true stress will be found and that we found by find by the load divided by w into b. So, so, this way we try to find this P and similarly if you try to find the true plastic strain, so, in the compression and that will be again ln of t naught by t.

So, you know this way you find the you know true stress and true strain in the case of the plane strain you know compression test for the thin sheets and normally the you know mean pressure on the platens is actually, so, so mean pressure on platens is about 15.5 percent higher. Then if you do that in the corresponding uniaxial you know compression test and corresponding uniaxial compression test. So, this way you try to find these true stress and true strain values in the case of the you know thin sheets.

Now normally when what is the happening is that when we have the you know variation of flow stress is there with you know strain. So, normally with strain the variation of flow stress is normally neglected in the you know analysis of true hot working ah, but when there is a strain hardening present, so as we discuss about we will discuss further about the you know effect of temperature and its effect on the flow stresses.

So, when we talk about the you know hot working in that case we normally you know neglect the effect of this strain on the flow stress, but when we talk about the cold working so, in those cases certainly we have some you know there will be effect on the flow stress values and in that case the concept of the mean flow stress comes into picture and so if you look at the flow stress; so, this is a typically you know strain hardening material because with strain hardening the you know the forming load is required is basically increasing.

So, so, in the case of such materials what we do is we have the concept of having the mean flow stress and that is basically suppose you have 2 regions; so, this is epsilon b and this is the epsilon a. So, and suppose in those cases concept of the mean flow stress and mean flow stress is computed like you have 1 by epsilon b minus epsilon a and so, this is epsilon a minus epsilon b because epsilon a is larger and B is smaller and then you have epsilon b to epsilon a and then you have a sigma naught and d epsilon.

So, this is basically area under this you know curve. So, so, this is how you find the value of these you know flow stress requirement when the average mean flow stress which is required. So, this is your mean flow stress. So, from the value of a from the curve, which is you know get experimentally from there you can have it and also you can approximate these values by you know having the you know and the value epsilon as epsilon a plus epsilon b by 2.

So, so this way you can have the calculation of these flow stresses, also there we have studied that for many cases specially for the larger strains there has been another you know formula which is has been proposed for calculating the flow stress and that value is given as so, for largest strains. So, the proposed you know formula is sigma naught is a plus b epsilon.

So in those cases we have one is we have seen the earlier flow curve equations earlier one there was sigma were equal to k epsilon and that was the power law of and then we had other you know expressions of which was consisting of 2 terms.

So, in that on the similar line you have sigma naught will be equal to a plus b epsilon and it will be a is nothing, but you have k into 1 minus n. So, k is the strength constant which was found in those cases and b is k n. So, so based on that the flow stress is approximated for such analysis.

So, so, what we see that normally you must have the idea about the flow stress calculations and this you know accurate prediction of the flow stress is required so that you can then you can predict the forming load or the you know load by which you are going that the load which is going to applied to create the plastic deformation of the material and we will see that how this flow stresses they are basically governed because of the change in the temperature conditions or other stress rate conditions so, that we can study later on.

Thank you very much.