Plastic Working of Metallic Materials
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Lecture - 17
Forging Load

So in this today's lecture we will just find out how forging Load it varies with respect to the RAM travel so that means when a sample is kept may be a cylindrical sample script which you mean 2 angles and they may be the top ramp is moving down and then it causes the definition of the material. So with respect to distance how the forging load increases and we are assuming in this case there is a streaking friction.

Which is taking place so this will be something like a problem but we will see through the derivation and then finally we will calculate how this is determined.

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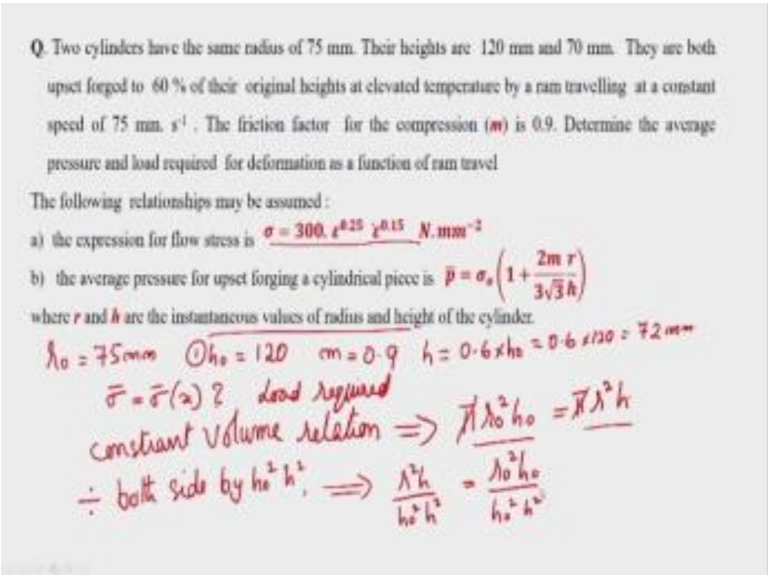

So the question is you have 2 cylinders having the same radius of 75 mm their heights are 120 mm and 70 mm they are both upset forged for one end you have this to 60% of their original heights at elevated temperature by a ram travelling at a constant speed of 75 millimeter per second, the friction factor for the compression in the compression is 0.9 and determine the average pressure and load required for the formation as a function of the ramp travel.

In this you are given this expression for the process of the material as a function of strain and strain trade because it is carried out at a particular temperature so since so that means sigma is

= 300 * Epsilon raised through 0.25 * epsilon dot Raised to y1 pi newton per millimeter square and the average pressure for upset forging a cylindrical piece the equation for that is given as P bar = the average pressure P is sigma 0 * 1 + 2m / 3√ 3 r / h.

$$\sigma = 300.\epsilon^{0.25}\ N.mm^{-2}$$

$$\bar{p} = \sigma_0\left(1 + \frac{2m}{3\sqrt{3}}\frac{r}{h}\right)$$

Where r and h are the instantaneous values of the radius and the height of the cylinder and σ_0 is your uniaxial process. So this is the question so let us just see how this can be done that you have the equation for the average pressure but what is happening is that the materials for learning and since it is at higher temperature is a function of strain as a strain rate so this is how it is not.

So what we have to do is that we will have to find out the relationship between the forging average pressure. If you know the average pressure of course multiplied by the instantaneous cross sectional area you can find out the forcing load but this should be as a function of ramp travel. So let us see that what are the inputs input is r0 is = 75 mm and we will take the first case it is h0 = 120 there are 2 samples are given state basically this is identified with respect to the geometry.

How the forcing pressure changes that is what but for the same reduction how it changes that is the main purpose of this and m is = 0.9 and so we have to say that it is upset for to 60% of the original height h is = instantaneous value is = 0.6 * h0 so that is = 0.6 * 120 which comes to 72 mm so what is required to found is that what is the average pressure as a function of say X this is what is to be determined and load required.

$$r_0 = 75mm \quad h_0 = 120 \quad m = 0.9 \quad h = 0.6 \times h_0 = 0.6 \times 120 = 72mm$$

$$\bar{\sigma} = \bar{\sigma}(x)?$$

So we will first generalized get obtained generalized relationship and then we will find out what are the values which we are going from this so in this particular case what is required is that you have to get the relationship between this the instantaneous the ratio of r by h so what we can do is that we can find out the constant volume relationship. So constant volume relationship is Pi r Square h 0 is = Pi r square h Pi r Square h.

So this is the relationship constant ¼ because this is your initial volume this part is your initial volume and this is your attend instant r and h keeps on changing so that is what is coming so from this we can just see a Pi is common. So we can say that if you divide both sides pi can get cancelled and dividing both sides by h0 square h square and doing a small manipulation you will get that r square h but h0 square * h square is = r0 square h0 by h0 square h square .

$$Constant\ volume\ relation = \pi r_0^2 h_0 = \pi r^2 h$$

$$Dividing\ both\ sides\ by\ h_0^2, h^2, \quad \frac{r^2 h}{h_0^2 h^2} = \frac{r_0^2 h_0}{h_0^2 h^2}$$

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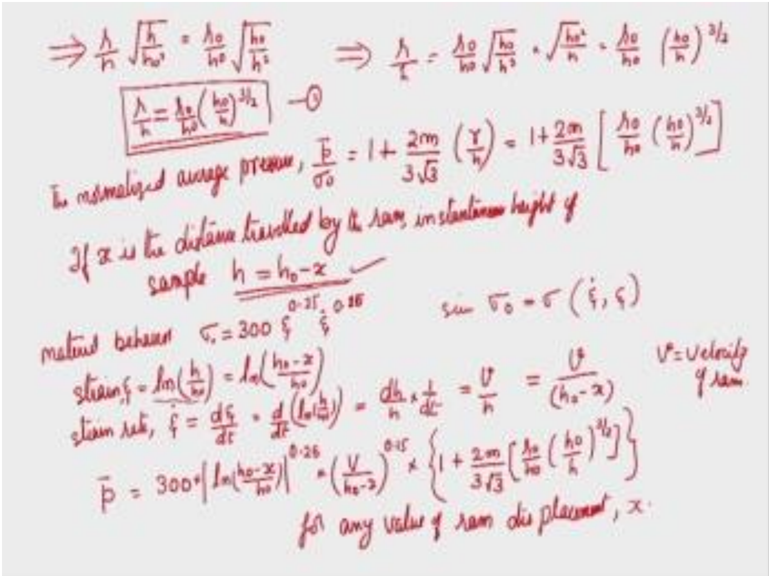

So this will implies that r by h * root of h by h0 square is = r0 by h0 * root of h0 by h square so this we are getting so we can just find out what is the ratio of r by h in terms of r0 and h0 that implies that r/h = r0/h0 * √h0/h square *√h0 square by h that will be = ro by h0 * h0 by h raise to 3/2 so we can get 1 relationship r/h is = in terms of r0 and h0 r0/h0 * h0/ h raise to 3/2.

Now our equation for the pressure if you just said do a normalized average pressure the normalized average pressure die pressure is = that is P bar by sigma 0 is = which is given from that we are taking the sigma note on the left side only 1+2m/3√3 * r/h so that if you do that the substitute this r/h * this can say that is = 1 + 2m/3√3 r0/h0 * h0 by h raise to 3/2 this is a relationship you are getting.

$$\frac{r}{h} = \sqrt{\frac{h}{h_0^2}} = \frac{r_0}{h_0}\sqrt{\frac{h_0}{h^2}}$$

$$\frac{r}{h} = \frac{r_0}{h_0}\sqrt{\frac{h_0}{h^2}} \times \sqrt{\frac{h_0^2}{h}} = \frac{r_0}{h_0}\left(\frac{h_0}{h}\right)^{\frac{3}{2}}$$

$$\frac{r}{h} = \frac{r_0}{h_0}\left(\frac{h_0}{h}\right)^{\frac{3}{2}}$$

$$The\ normalized\ average\ pressure, \frac{\bar{p}}{\sigma_0} = 1 + \frac{2m}{3\sqrt{3}}\left(\frac{r}{h}\right) = 1 + \frac{2m}{3\sqrt{3}}\left[\frac{r_0}{h_0}\left(\frac{h_0}{h}\right)^{\frac{3}{2}}\right]$$

Now let us find out the relationship between the instantaneous value of the height with respect to a ramp when the ramp is moving say X distance from the top surface when it is touching the top surface of the cylindrical billet and when it is moving by X distance what is the instantaneous height and we should also find out what is the instantaneous process area also.

Assuming there is no bearing that is one thing we have to see so if x is the distance if x is the distance travelled by the ramp instantaneous height of billet of sample h is = h0 - x and we also know the material obeys the this relationship that is the material obeys that behavior is at the highest temperature is its function of sigma and Epsilon and strain and strength rate 300 * epsilon race to 0.25 * Epsilon dot raised to 0. 15.

$$h = h_0 - x$$

$$material\ obeys\ \sigma = 300\ \epsilon^{0.25}\dot{\epsilon}^{0.15}$$

So you will find that in our question see if this part will behave this as for this behavior depending upon what is a strain and what is a strain rate so we are assuming that this is moving at a speed of 75 mm so at that particular height what is the strain rate you will have to find out but we can just assume because there is not going to be much of a difference we can assume that it is a constant rho strain rate so which is 75mm per for simplicity.

We can assumes and for strain rate equation basically what happens is that which is v/h so velocity has to vary with respect to the height may be there but since this velocity is constant at any instant that velocity sensor we can do our calculation based on that so in such case know what we have to do that σ_0 is a function of x through strain and strength. Since σ_0 is a function of strain rate and strain.

So we have to determine the strain at that instant for any value of it and we also have to find out the strain that for any value of it so that means train with respect to X that is what we have to find so that is = log X/H0 so this is = log H0-H/H0 this is right strain similarly strain rate epsilon0 is nothing but D epsilon/ DT.

$$Strain, \epsilon = \ln\left(\frac{h}{h_0}\right) = \ln\left(\frac{h_0 - x}{h_0}\right)$$

So that if you just take out this equation from this equation we will look at it so that is = D/DT of log H/H0 so we will end up with DH/H* 1/DT this is what so DH/DT is nothing but the ramp velocity V, so we will end up with it but it is so now this H if you write it because ramp velocity is constant so divided by H=C H0-X so H0-x you can write and where V is the velocity of the ramp V is = velocity of ramp. Now we can write this average pressure equation.

$$Strain\ rate, \dot{\epsilon} = \frac{d\epsilon}{dt} = \frac{d}{dt}(\ln\left(\frac{h}{h_0}\right)) = \frac{dh}{h} \times \frac{1}{dt} = \frac{v}{h} = \frac{v}{(h_0 - x)}$$

So average pressure equation will be if you just substitute these values in that and we can get it so far strain rate and other things if you do it so P is = you substitute the values of this one so we can stay that P bar is =sigma 0 come true if you have just substitute this we can write that is 300 * log X/X0. So when you take this way H0 is higher since it is a sample is being compressed your strain will show a negative value.

But when you are taking the natural logarithm of strain is immaterial whether it is extensional compression but it is the strain which has to be considered so in that case negative sign will not matter so we can just write this 300 * absolute value or mode of log H0-X/ H0 whole raised to say 0.25 * trend rate. So strain rate is what is that V/H0-6 this is a strain rate strain rate ratio in our question it is 0.15 * what was that this relationship 1+2m/3√3 * R0/H0 * H0/H Raise to 3/2 so this the expression we are having and this is for any value of x for any value of ramp displacement X this is a relationship the general equation we got it.

$$\bar{p} = 300|\ln\left(\frac{h_0 - x}{h_0}\right)|^{0.25} \times \left(\frac{v}{h_0 - x}\right)^{0.15} X\left\{1 + \frac{2m}{3\sqrt{3}}\left[\frac{r_0}{h_0}\left(\frac{h_0}{h}\right)^{\frac{3}{2}}\right]\right\}$$

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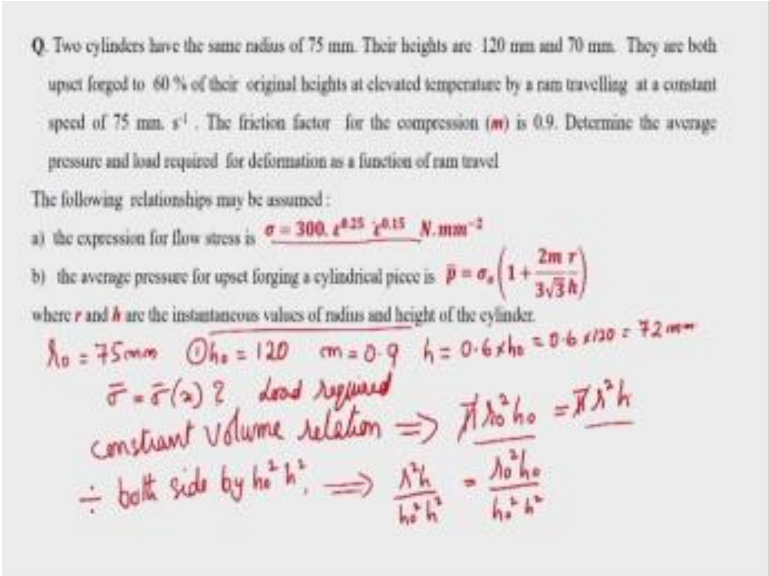

So that let us write it here once again so P bar = 300 * log H0-x/H0 * raised to 0.25 * V / Ho – x * 1+2m /3√3 * R0/ H0 * H0/H0-x raise to 3/2 so this is the expression now for finding the total order required now we have to find out the area so the instantaneous value of area with respect to ramp displacement instantaneous value of area in terms of x it is a similar how we found out by that R by its relationship.

$$\bar{p} = 300 \left| \ln\left(\frac{h_0 - x}{h_0}\right) \right|^{0.25} \times \left(\frac{v}{h_0 - x}\right)^{0.15} X \left\{ 1 + \frac{2m}{3\sqrt{3}} \left[\frac{r_0}{h_0} \left(\frac{h_0}{h}\right)^{\frac{3}{2}} \right] \right\}$$

The similar way we can write that is A is = m0 going that is = Pi R0 square * H0/ H0 - 6 is instantaneous value so now let us take care our first problem is R0= 75 both the case H0 = 120 so first case H0 = 120 and R0 = 75 mm so we can say that H0 - X so H = 120 * 0.6 = 72 mm or we can say H0 = H0-X this is what we are getting and M = M means 0.9. So let us say p bar = 300 * log 72 / 120 raise to 0. 25 this is 0.15 place 0.15 we forgot to put it the point one final we just it 0.15 *V = V=75 75 / 72 raise to 0.15.

$$Instantaneous\ value\ of\ area\ in\ terms\ of\ x, A = \pi r_0^2 \left[\frac{h_0}{h_0 - x}\right]$$

$$h_0 = 120m \quad r_0 = 75mm \quad h = 120 \times 0.6 = 72mm = (h_0 - x) \quad m = 0.9 \quad v = 75mm$$

Now we have to get that R/ H = 1 + R/H so that is = 1+ 2*0.9 / 3√3 * R0 75/120 * 120/72 raise to 3/2 this is that so if you just find out this value that is = 300 * 72/120 raise to 0.25 = 0.8454 * 75 / 72 raise to 0.15 that is 1.00614 * 1 + 0.3464 * 0.625 * 2.15657. So in 2006 profile and do 13464 + 1.006.4 2.8454 * 300 so we will get it as 374.07 Newton per millimeter square is the average pressure.

$$\bar{p} = 300|\ln\left(\frac{72}{120}\right)|^{0.25} \times \left(\frac{75}{72}\right)^{0.15} X\left\{1+\frac{2\times 0.9}{3\sqrt{3}}\left[\frac{75}{120}\left(\frac{120}{72}\right)^{\frac{3}{2}}\right]\right\}$$

$$300 \times 0.8454 \times 1.00614 \times [1 + (0.3464 \times 0.625 \times 2.15657)]$$

$$\bar{p} = 374.07N/mm^2$$

When it has been deformed to 0.6 of its initial height now we have to calculate the load, load is = P bar * A = 374.07 * Pi R0 square * H0/H0 - X = 374.07 * Pi * R0 was 75 * 75 square * H0 was 120/72. So that will come to that is = 11018699.44 newton that is 11 mega newton this is I will check once again whether this is right I have a doubt actually approximately around 11 mega Newton we are getting this is a first product.

$$Load\ \ \bar{p} \times A = 374.07 \times \pi r_0^2\left[\frac{h_0}{h_0 - x}\right] = 374.07 \times \pi \times (75)^2\left[\frac{120}{72}\right]$$

$$= 11018699.44\ N =\approx 11MN$$

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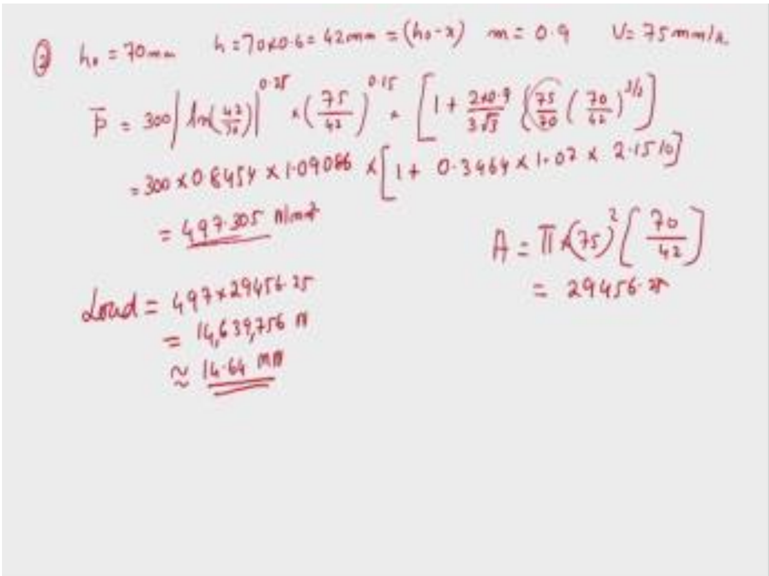

Now second one X0 = 70 mm H0 = 70 mm H = 42 mm that is 70*0.6 = 42 mm = H0 -x M = 0.9 M is 0.9 and V is = 75 mm per second so I just write that P is = P per eye pressure P bar is = 300 * log 42/70 raised to 0.25 * 75/42 extra 0.15 * 1 + 2 * 0.9 / 3 √ 3 * R0. R0 is75/70 * H0 H0 is 70 H0 – X is 42 raised to 3/2 let us see in this case this is = 300 * red by 70 Rock and -1 raised to 0.25 0.8454 * 75 / 42 and if I divide by 42 = raise 0.15 = 1.09086 * 1+√3 * 3 this 1 *

1.8 is = 0.3464 * 75/70 1.07 * 70 / 42 raise to 1.5 * 2.15 and 6 * 1.07 * 0.3464 plus one improve 1.09086*0.8454 300 this comes from 497.305 Newton per millimeter square it is that.

$$h_0 = 70mm \quad h = 70 \times 0.6 = 42mm = (h_0 - x) \quad m = 0.9 \quad v = 75mms^{-1}$$

$$\bar{p} = 300|\ln\left(\frac{42}{70}\right)|^{0.25} \times \left(\frac{75}{42}\right)^{0.15} X\left[1 + \frac{2 \times 0.9}{3\sqrt{3}}\left[\frac{75}{70}\left(\frac{70}{42}\right)^{\frac{3}{2}}\right]\right]$$

$$= 300 \times 0.8454 \times 1.09086 \times [1 + 0.3464 \times 1.07 \times 2.1510]$$

$$= 497.305\ N/mm^2$$

Here average pressure is higher causes because strain rate effect is coming into picture here the previous case knows the strain rate was lower here strain rate is much higher so that is one major problem is happening here it was almost 1.006 but here it is 1.1 it is coming and then multiplied by that that is what 374 × 1.1 that that is another one + here also it is coming this part also coming difference.

So you will find that the average pressure is higher but load may not be that higher because load is = you will have to find out this A is = Pi R0 that is 75 square * H0 70 / 42 so that is 70 / 42 is * 75 * 75 * 3.142 that is = 29456.25 = 497 * 2945 6.25 = * 490 497 you will find that 14639756 that is approximately 14.64 mega newton total load may not be high the other case you know 11 total load also is high here that is basically because of the strain rate effect in this case strain rate is much higher so that is the difference is coming.

$$A = \pi \times (75)^2 \left[\frac{70}{42}\right]$$

$$= 29456.25$$

$$Load = 497 \times 29456.25$$

$$= 14639756\ N$$

$$\approx 14.64\ MN$$

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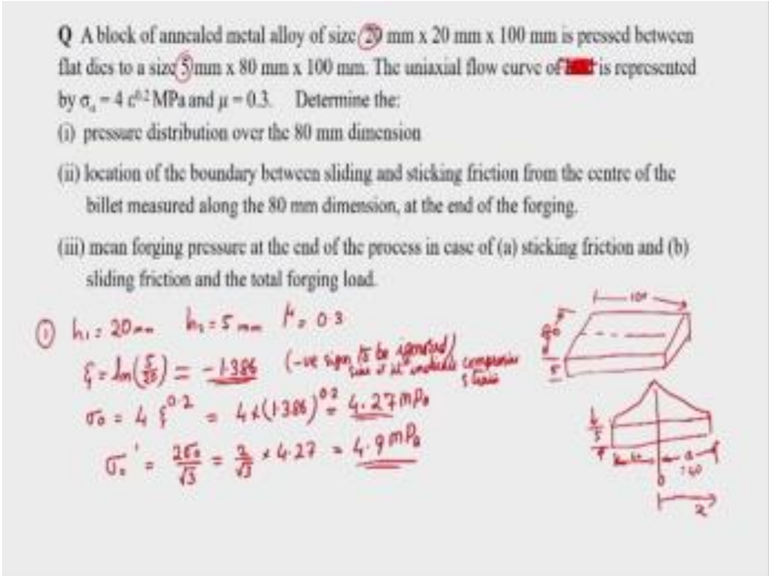

So let us come to another problem in this a block of annealed metal alloy of size 20 mm by 20 mm by 100 M is placed between flat dies to a size of 5 mm by 80 mm by 100 mm one of the length so that is the width of the die if it is between flat per the width of the remaining same height decreases and the length increases so that is what is happening height from 20 mm to 5 mm and this 20 mm that is the width of the dye which is kept in the die so that it becomes 80 mm and you see that the other length remains the same.

Along the width of the die it is not going along the length of the die it is not going to change so that it pairs it is a case of plane strain condition uniaxial flow curve of this alloy is represented by it is not lead you can just * of alloy is represented by sigma 0 * 4 * epsilon raise to 0.2 mega Pascal and you are having a sliding frictional coefficient of friction columns low coefficient of friction as 0.3 determine the pressure distribution of the 80 mm dimension.

So that is what is happening so here you have this 100 mm this is 80 mm and this is your so this is 100 across so if you just take this so if I just do like this is 5 by 80 this is 5 and we have to find out what is the distribution of pressure what is coming like this so this is a zero so this is your A value which in our derivation is quite simple but let us see what are the conditions pressure distribution of the 80 mm dimension location of the boundary between sliding and stitching friction from the centre of the billet.

Measuring the 80 mm dimension at the end of the 40 that mean it reaches to 5 mm this is what we have to calculate seconds 3rd is the name for the pressure that you have to integrate this pressure distribution curve from 0 to a and then find it out this is what we have to do this is a rectangular piece which is so that the given in first case H1 is = 20 mm H2 is = 5 mm mu is = 0.3 so we can find out in terms of height is = log H2 / H1 final by this one.

$$h_1 = 20mm \quad h_2 = 5mm \quad \mu = 0.3$$

So that means log 5/20 so that comes to may be -1.386 so this – has not worried you because it is the strain which is taking place in which direction whether sensor this – means it is compressive strain so that is what so before our calculation purpose this sign has no meaning so we will say that sigma 0 is to at the end of the deformation that means when it comes to Pi M sigma 0 is = 4 * epsilon rise to 0.2.

$$\epsilon = \ln\left(\frac{5}{20}\right) = -1.386$$

So that is = if you substitute the value is = 4 * 1.386 since it indicates compressive strength raise to 0.2 so that comes to1.386 raise to 0.2 * 4 = 4.27 mega Pascal. So we have to find out this sigma not dash which is nothing but 2 Sigma/ √3 is under plane strain condition to that is not that is = 2/ √3 in our derivation that sigma not is coming * 4.27.

$$\sigma_0 = 4\,\epsilon^{0.2} = 4 \times (1.386)^{0.2} = 4.27\,MPa$$

So that comes to 4.9 mega Pascal sigma not dash = 4.9 mega Pascal now we have to see that because it is along the 80 mm dimension it does not change the deformation plane strain condition on the 80 mm so only thing is that the other direction it is wrong acting but so this what we have to find out from a = 0 to the distance it is 40. We have to calculate so this is 40 so is = 40 and this is also 40 this is what we have to determine.

$$\sigma_0' = \frac{2\sigma_0}{\sqrt{3}} = \frac{2}{\sqrt{3}} X 4.27 = 4.9\,MPa$$

So what we will do is that first to say it is given let us find out what is the at the center where the maximum stress is coming at X = 0 so this the distance around X from the centre X direction so now we can say that at the center line of the slab as per the equation we derived earlier in our previous lectures so that equation for considering the sliding friction.

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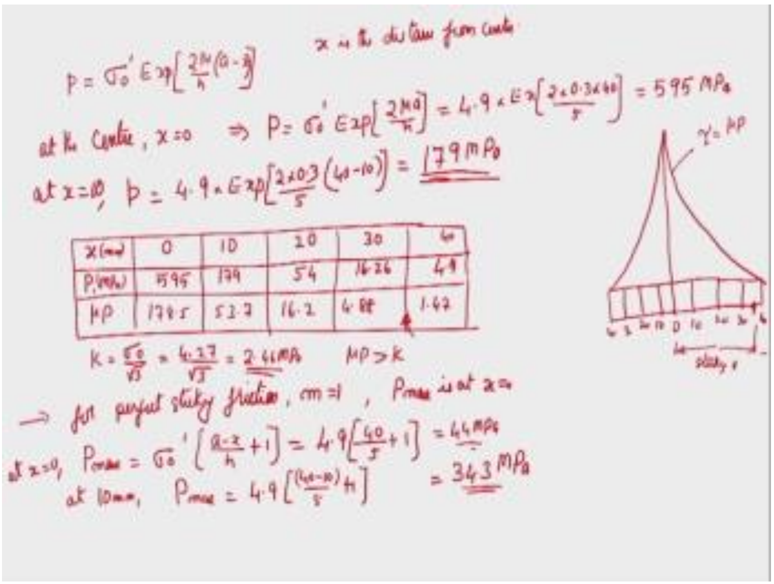

We can write it as P = sigma zero sigma not dash exponential to mu by H * A- X from X is the distance from the centre at the center X=0 so that means P =sigma 0 dash * T ratio 2mu a/ H sigma 0 dash is 4.9 that = 4.9 * exponential to 2 mu = 0.3 * 40/H H is = 5 that is = you will get 595 mega pascal and let us say that if this is 40 what we will do is a this is Euro this is 10 20 30 and 40 that will take 10 20 30 40.

$$P = \sigma_0' Exp\left[\frac{2\mu}{h}(a-x)\right]$$

$$at\ the\ centre, x = 0 \qquad P = \sigma_0' Exp\left[\frac{2\mu a}{h}\right] = 4.9 \times Ex\left[\frac{2 \times 0.3 \times 40}{5}\right] = 595\ MPa$$

Let us say at $x = 10$ P = 4.9 * exponential 2 * 0.3/5 A-X 40 - 10 40 - 10 that is 30 so that value you are getting it as I am just writing that value 179 mega Pascal similarly we can get it for the different values of x for example 20 and 30 and if you just write like that since I have done so that we can save some space I request you all to just work out with this problem and then come to that.

$$at\ x = 10, P = 4.9 \times Exp\left[\frac{2 \times 0.3}{5}(40 - 10)\right] = 179\ MPa$$

If we just to do that we can get it X in mm and P in mega Pascal so we can 0 10 20 30 40 we will get as 595 when it is at a 10 distance 179 decimal, we are deleting because of this value there is no point in the decimal value 20 is 54 30 is 16.26 and 40 is 0.9 so this is the things we have to just see that will have to calculate what is going to be dominated. So, for that purpose you have to look that in our discussion.

We also found that if as long as this μP is greater than k at some distance in the pressure increases to the interfacial shear strength is given by K which is = Sigma0/√3 then show that Sigma0/√3 is what is that K = Sigma0/√3 that is coming to 4.27/√3 so that comes to 2.46 mega Pascal. When the stresses the interfacial shear stress is mu = 20 if you calculate new P.

When the normal load is very high the stresses in the material reach that value which is greater than 2.46 so up to that value you will find that it is a string function which is tricky because interfacial shearing will take place or at some distance from the surface there be an internal sharing which is taking place. So there that is the condition for sticking friction so in this case if you look mu p for different conditions is 178.5 in this is 53.7 and in this case is 16.2, 4.88 and 1.47.

$$K = \frac{\sigma_0}{\sqrt{3}} = \frac{4.27}{\sqrt{3}} = 2.46\ MPa$$

So this is coming so mu p that is greater than K $\mu P > K$ is coming only at this end because K is 2.4 something that I want to hear already is coming between 30 and 40 somewhere here it will come mu p is greater than K till that time. So from this distance to this distance where mu P is greater than K you will have sticking fiction and beyond that it will have sliding friction.

So sticking friction prevails at the value of τ_i that is the interfacial shear stress is greater than the value of yield share stress of the material so K is the yield share stress of the material. So let us calculator for the case of sticking function in for sticking function for perfect sticking friction we consider that $m = 1$ and P_{max} is always at what you called as at $x = 0$ in this case when you look at it now you will find that here it is moving like this is the variation with if you consider that $\tau = \mu P$.

So this is for the case of $\tau = \mu P$ in our derivation sorry in fact this has to be curved maybe for a simple way I am just drawing just write the eccentric I heard wrong so for the perfect streaking condition know p max = if you look at the equation is = me up so this is =sigma 0 dash * A- X / H which we have already arrived in our case that is = 4.9 * a - x so X = 0. So that means 40/ 5 + 1.

So this is at x is = 0 so that will come to say 44 mph it is very less value and maybe at 10mm if you look at it your considering t-max = 4.9 *40 – 10 / 5 + 1 so that will come to 34.3 mega pascal so when you really look at that you will find that there is only very small amount.

$$at\ x = 0, P_{max} = \sigma_0' \left[\frac{a - x}{h} + 1\right] = 4.9 \left[\frac{40}{5} + 1\right] = 44\ MPa$$

$$at\ 10mm, P_{max} = 4.9 \left[\frac{(40 - 10)}{5} + 1\right] = 34.3\ MPa$$

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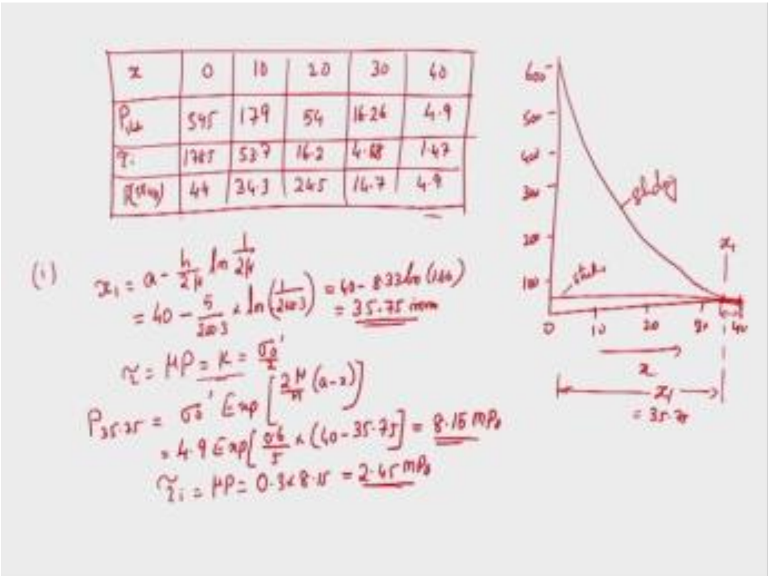

So considering the fully this one is there no so considering that with different 10 20 30 or 40 if you do that you will find that the same the values X P τ_i and P sticking and this is sliding so 0 10 20 30 40 I am getting like this so 595 this is 178.5 and here we are getting 44 and here 179 53.7 I will just copy 34.3 save the timer so 54 and 16.2 and 24.5 and that is 16.2 64.88 14.7 now here 4.9 1.47 and here for 4.9.

If you look at the pressure distribution curve you will see some interesting thing it is coming like this I am just telling this is from zero and this is a x value this is 40 may be 20 10 30, this let us say upto 600 so 300 100 200 400 500 you will find that something around this is so low it is coming like this and here it is something around here it is something like this it is coming at very low value small distance all other things it is this sticking function in other case.

It is sliding friction so if you look at this friction hill in the both cases you will find that this is the case of sticking friction so when the stresses reaches that k value it will be sticking and then the deformation of the material will be as per the satisfying sticking condition not the sliding condition will be somewhere here when a small distance. So most majority of this is satisfying the sticking condition so this is sliding and this is sticking.

So sticking because when the stress reaches the value of that of your interfacial shear strength it will shear and the other part will be sticking to that is what the main thing that so now let us find out the second problem on this, so this the distribution we are getting. So second part is the location of the boundary between the sticking and sliding friction that is very important what is this point this is X1 may be X1 is this that is what we have to find out.

So that is we have that relationship X1= A- H / 2 mu log 1/ 2 mu so that is = a =40 because this is the total length - H= 5 and 2 mu 2* 0.33 * log 1/ 2 * 0.3 so that is = 40 – 8.33 log 1.66 so comes to 35.75 mm this is = 35.75 so almost 3.25 mm is satisfying sticking condition sorry it is a sliding condition. So from the centre to the distance of 35.75 mm the material satisfies the sticking friction the remaining is always sliding condition.

$$x_1 = a - \frac{h}{2\mu}\ln\frac{1}{2\mu}$$
$$= 40 - \frac{5}{2\times 0.3}\times \ln\left(\frac{1}{2\times 0.3}\right) = 40 - 8.33\ln(1.66)$$
$$= 35.75mm$$

This 35.75 the is the demarcation line from with transform from sticking to sliding condition so at this point to is = which is = mu p= K =sigma 0 dash 2 so then I can say that p what is the pressure at that point 35.75 is = sigma not dash * exponential 2 Mu / H * a – x. So that we are getting it 4.9 * exponential 2 mu = 0.6 / h= 5 * 40 - 35.75 so this comes to 8.15 mega pascal in this case the stress at that point of the pressure at that point is for 8.15 is a is a pressure normal pressure so tau i that is a normal pressure at all is = mu P = 0.3 * 8.15 = 2.45 mega pascal interfacial shear strength is coming to this.

$$\tau = \mu P = k = \frac{\sigma_0'}{2}$$
$$P_{35.75} = \sigma_0' Exp\left[\frac{2\mu}{h}(a-x)\right]$$
$$= 4.9\ Exp\left[\frac{0.6}{5}\times(40-35.75)\right] = 8.15\ MPa$$
$$\tau_i = \mu P = 0.3\times 8.15 = 2.45\ MPa$$

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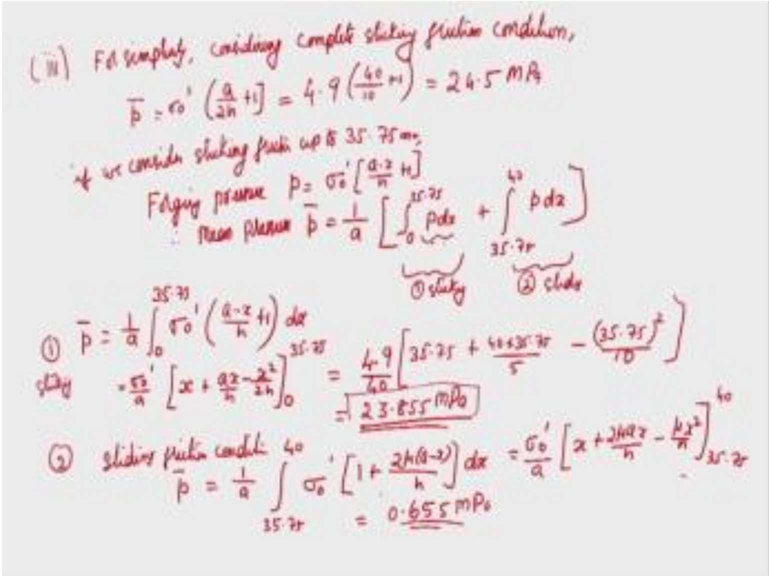

Now let us look at the 3rd one, 3rd component that is the main forging pressure at the end of process in case of sticking friction and sliding friction the total forging load so we can say considering the for simplicity now you considering all the sticking friction only a small amount is left. Now in that case P bar is = say for simplicity we can do like this for simplicity considering complete sticking friction.

The wholly small variation will be there sticking friction sticking friction condition then t bar is = we have that relationship also consider that is = a / 2h this also we have derived that is = sigma 0 sorry that is = 4.9 * 40 / 10 + 1 you get the pressure as 24.5 mega Pascal. So what you are getting so now if you are considering if we consider sticking friction up to 35.75 mm the forging pressure P is = sigma 0 dash 40 – 35 sorry we can integrate it you know and find out.

$$\bar{P} = \sigma_0' \left(\frac{a}{2h} + 1\right) = 4.9\left(\frac{40}{10} + 1\right) = 24.5\ MPa$$

So that is = A – X / H + 1 for mean pressure P bar is = integrated 1 / a * integrated form 0 to 35.75 / p dx this is sticking +35.75 to 40 p dx is sliding one sticking and this is 2 sliding this is mean for the pressure. Let us say that in the first case is P bar = 1 / A * integral from 0 to 35.75 and equation for that is =sigma 0 dash * A- X/ H + 1 * DX so this way we can write it as sigma 0 dash / A * X+ AX/ H - X squared / 2H 0 to 35.75 that is = 4.9 / 40 * 35.75 + 40 * 35.75/5- 35.75 square / 10 So that will come to something around 23.855 mega pascal.

Now the second case this is sticking this the average pressure that is sliding that is at the periphery the sliding is at the periphery so from centre to this Point where it changes from sticking to friction that is at 35.75 upto that point it is sticking further just sliding friction condition. There you have to Integrate with respect to that relationship so in that case for sliding friction condition P bar = 1/ a* integral from 35.75 to 40 relationship for the sliding condition is sigma 0 dash * 1 + 2MU * A- X * H * dx.

$$Forging\ pressure\ P = \sigma_0' \left[\frac{a-x}{h} + 1\right]$$

$$Mean\ pressure\ \bar{P} = \frac{1}{a}\left[\int_0^{35.75} Pdx + \int_{35.75}^{40} Pdx\right]$$

This we have derived earlier that is =sigma 0sigma 0 not dash / A * X + 2 mu A / H – Mu X square by H so that is from 35.75 to 40. Which will be getting as this comes to 4.9 / 40 * 40 – 35.75 + 2 * 0.3 * 40 * 40 – 35.75, so that if you just calculate all those I will just write it because we are running shortage of time so that is = 0.655 MPA so this 2 cases one is for the sticking condition we got this and for the other case this is the thing average mean pressure.

$$\bar{p} = \int_0^{35.75} \sigma_0' \left(\frac{a-x}{h} + 1\right) dx$$

$$= \frac{\sigma_0'}{a}\left[x + \frac{ax}{h} - \frac{x^2}{2h}\right]_0^{35.75} = \frac{4.9}{40}\left[35.75 + \frac{40 \times 35.75}{5} - \frac{(35.75)^2}{10}\right]$$

$$= 23.855\ MPa$$

$$Sliding\ friction\ condition\quad \bar{P}$$

$$= \frac{1}{a}\int_{35.75}^{40} \sigma_0' \left[1 + \frac{2\mu(a-x)}{h}\right] dx = \frac{\sigma_0'}{a}\left[x + \frac{2\mu ax}{h} - \frac{\mu x^2}{h}\right]_{35.75}^{40}$$

$$= 0.655\ MPa$$

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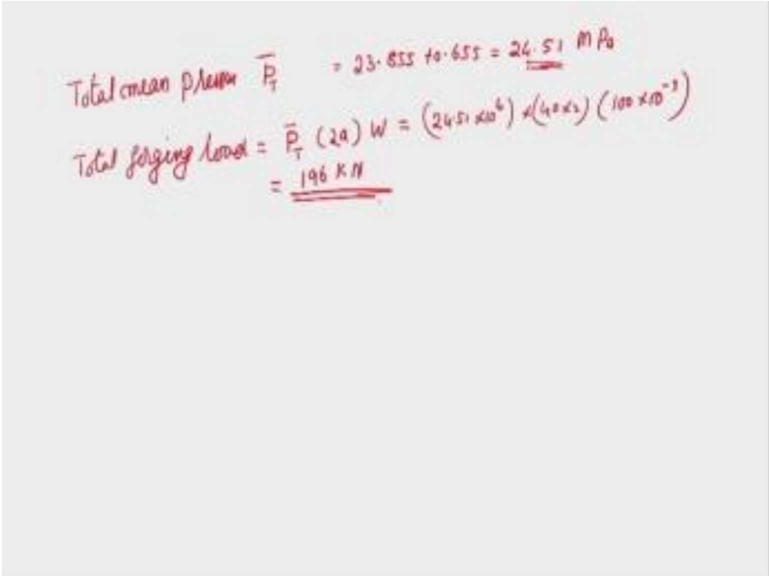

So can you take total mean pressure is = sum of 1 + 2 so that comes to 23.855 because it is rectangular + 0.655 you see that only small difference is there so for all Practical condition we can always considered as = take it entirely as sticking friction and do it in this problem because the variation is only very small may be how much it is 1 percentage or even less than that, so the percentage difference is 2.7 % only variation if you take this and this one.

$$Total\ mean\ pressure\ \bar{P}_T = 23.855 + 0.655 = 24.50\ MPa$$

So now this is the mean forging pressure this mean holding pressure multiplied by the area so total forging pressure not pressure total forging load p total bar * because this 2 sides know 2 a * width so that is coming 24.51 * 10 to the power 6 * 40 * 40 * 2 * W = 100 *10 power -3 so this coming through 196 kilo Newton we are getting that load so this how you have to found out.

$$Total\ forging\ load = \bar{P}_T(2a)W = (24.51 \times 10^6) \times (40 \times 2)(100 \times 10^{-3})$$
$$= 196\ kN$$

But is this particular problem what has happened is that most of them is taking care of sticking friction sliding friction is not taking place but if the surface was not that it was very smooth and other things naturally the sliding friction will be dominating in that case if you have a perfect with a very high level of lubricant and other things we should do it which is not possible with high temperature otherwise you may have to go.

For the lubricant at higher temperature above 700 800 you may have to use glass water at room temperature when you are doing this lubrication is will be more effective and is the forst result of the material is less. We can have a very good sliding friction, friction is high and in that case the dominating factor will be the sliding friction but in this particular case the frost is very less so that is why this of the material is very less that is why it is dominating the sticking friction.

May be in our this problems if the see instead of σ_0 = 4 * epsilon rho so this for the led but if it was aluminum you may find 100 120 or 80 and other thing and then you will find that the mu p will be very happy that k value will be very high then you have a much more this one may be in our assignment you should do this type of a problem thank you.