Principles of Metal Forming Technology

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Lecture – 30
Analysis of rolling load calculations

Welcome to the lecture on Analysis of rolling load calculations. So, we have discussed about the different types of rolling processes and, now will have the analysis about the load calculations in the rolling. So, let us first see that what happens in the case of rolling.

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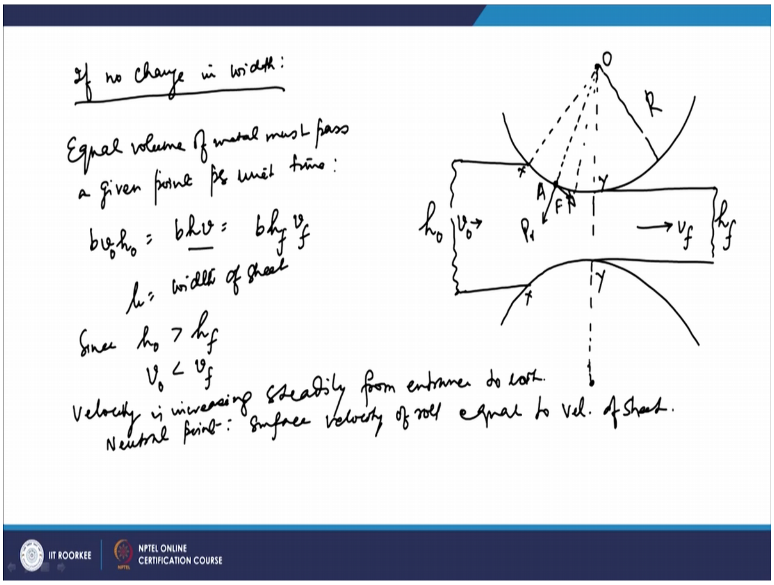

So, as we know that in the case of rolling you have two roles and so, and then you have this as the centerline. So, centerline connecting the rolls centre; now, you have a slab which is coming and into the contact of the roles and then they finally, you will have the exit of slab of this thickness. Now, what we see that we must know the deformation zone zoometry in the case of rolling, now this is the these are the centre of these roles.

Now, let the centre of the role be O and you have this radius as R. So, this is R is the radius of both of them. Now, the thing is that when we try to calculate the rolling load. So, it will be basically nothing, but the pressure divided by the area of contact and that will be nothing, but these length of contact projected area and then that multiplied by the width. So, width we assume that it does not change so, b into L P.

Now, we will find it anyway before that, now this angle which is formed from at the centre this angle is known as the angle of bite in the case of rolling. So, suppose this X X is that section where, it is you know in touch with the roll this is your Y Y from where it is exiting the path and, it is entering with the velocity v not and the initial height is h naught.

So, with h naught height and with v naught velocity, this you know slab or be let is moving in between into the roll. Now, it will be going inside these in between the rolls and, then ultimately it will be exiting and with exit while exit if you assume that h f is the final height of the slab. And then it is going at a velocity of v f that is your final velocities, this is v naught is the initial velocity before it enters into the roll and this v f is the final velocity of the roll.

So, what we see that if we are assuming; so, if no change in width results. So, in that case you know you are compressing the you know slab vertically and, then it is elongating in the axial direction and, what happens that there must be equal you know volume of metal so, equal volume of metal must pass given point per unit time.

So, this condition will tell you that b and it will be v naught and h naught will be b times h v and that will be b times h f v f. So, this will be at any particular instant inside the zone at any point you have instantaneous value of h and instantaneous value of v and this should be equal so, b is the width of the sheet.

And you know as we know that v is v value will be in between the v naught ant v f. Now, the thing is that what we see that when the sheet is trying to enter into the rolls, now what we see that if you try to look at now, as the h naught is more than so, since h naught will be so, if you are compressing, it is more than you know hf.

So, v naught will be you know less than v f. So, v f is basically increasing it means that, when you are going into the sheet is going out of the rolls, it has a higher velocity. Now, the thing is that this velocity which is increasing it must steadily increased from the entrance to the exit and at one point along the (Refer Time: 06:22) surface of the roll what will happen that this velocity will be basically equal so, the velocity with which it is moving it will be similar to the velocity of the roll and, that point is known as the neutral point or neutral you know we call it as the no sleep point.

So, velocity is basically increasing steadily from entrance to exit. Now, it means that at one point, once it moves at that point this velocity you know velocity of this you know velocity which is there at any point, it is same as the velocity of the surface at the surface of the roll. So, sheet velocity is same as the roll velocity. So, so that point is known as neutral point.

So, this point where the sheet so, at this point you have a surface velocity of roll equal to velocity of sheet and, this point is indicated somewhere maybe at some point on that that is known as n that is neutral point. Now, we will see that how this you know how you do the for you know a calculation of the forces, which are acting at different points on this in that deformation zone.

So, what we see is that now you have two forces which are acting on the metal now, suppose this is the point A, now what happens that you have a radial force that is acting and this force is basically P r. And similarly you have a tangential force also that is acting and this force is the f so, that is basically you know frictional force which is acting.

Now, if you look at and analyze the forces which are acting, when it is this sheet has contacted these rolls at that point the frictional force basically is acting towards this neutral point and, when it leaves the neutral point reason basically it is a plane. So, so till the neutral point this frictional force has the direction towards the neutral point.

So, basically this sheet is allowed to go in between these rolls, because of this value of these you know the frictional force. So, frictional forces is basically assisting this sheet to go into there is no frictional force, it will not be going inside the in between the rolls. So, friction is required and if this no friction, if will not be you not going inside or in between the rolls.

Now, when it is going from the neutral point I hate, now from there the direction of this frictional force is changing and, it will be towards the neutral points so, basically the direction of these neutral, you know frictional force will be towards the neutral point and, this is reversing once it goes from the neutral point towards the delivery you know reason.

Now, when we talk about the component of this P r so, if you talk about this its component in the vertical direction that is basically the rolling load so, it is the load with which it is basically you know pressing against the metal. So, that is how you calculate this rolling load. And it is also that load by which because it will try to separate these two rolls together so, it is also known as the roll separating forces.

Because this is the horizontal component and that will try to so, that is why your rolls are basically you know rigid and, they are having support. So, but they have to have enough support because, otherwise they will be you know instant they will be pushed apart. So, that is why it is also known as the roll separating forces. Now, what we have you know a point that is specific roll pressure and, that is basically the roll pressure divided by the contact area and, we have to find this contact area between the between the rolls.

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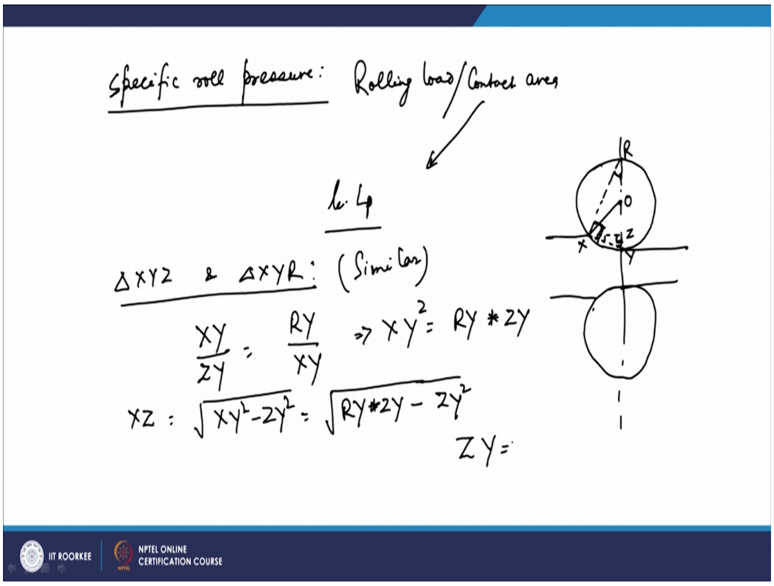

So, if you try to find the you know so, if you take the specific roll pressure. Now, what is this specific roll pressure? This roll pressure is rolling load divided by contact area. So, that is now what is the contact area? So, you have b that is width which is they are which is not changing. So, b is they are and then that will be multiplied with the projected arc of length so, arc of contact that is L P.

So, this contact area will be nothing, but b times L L. So, that b we know and how to calculate this L P, now for finding that L P, you can further see the previous figure and, in that figure you can see that if you look at this figure. Now, in this figure you can see that you have you just you know take from here; they line so, so that can further be seen maybe you can draw.

So, you have two rolls and this is the you know central line of the rolls and, you have this is coming and, then it is going like this. Now, in this case this is your O and if you have this as this one is X point and this is also X. And this way you have this point as Z. And this is the point which is known as Y so, this is we have already seen Y.

And this point is you know this was A basically so, we have nothing to do with that. Now, what we see that you if you take these two so, this is you know if you take this as R. Now, what we see that we are going to have the two triangles X Y Z and another is X Y R so, triangle X Y Z and triangle X Y R.

So, if you take these to you know triangles, what we see is that in X Y Z this is the right angle and since being this is the diameter this is a right triangle. So, this angle is equal to this angle, similarly you know you have this angle as the common 1 and so, so this angle triangle Y X Z will be same as triangle X R Y. So, that way what we see that by using the A A A method all the angles are respective angles are equal so, the two triangles X Y Z and the X Y R they are similar.

So, what we can get if you take the X Y which is you know X Y which is in front of this you know right angle triangle. So, X Y and X Y is the in front of this angle and, this will be divided by this is equal to this angle so, this will be Z Y so, X Y will be divided by Z Y. Now, again it will be you can take this R Y, now R Y is the in front of these you know 90 degree angle, angle R X Y and this will be same as this angle is 90 degree so, in front of that you have X Y side so, it will be X Y.

So, you can from here you can write, that X Y square will be R Y into Z Y. Now, what you cans get X Z which is there. So, X Z will be nothing, but X Y square minus Z Y square. So, it will be X Y squared minus Z Y square, now X Y square is R Y into Z Y so, it will be R Y into Z Y minus Z Y square. So, what we get it will be R Y Z Y will be common R Y minus Z Y.

Now, what is Z Y? So, if you take Z Y Z Y is nothing but so, if you take this is your Z. So, this Z this is your Y. So, Z Y is nothing but this is your h naught and this is your h f so, it is h naught minus h f by 2. So, this is the total reduction this side also. So, so basically your Z Y is h naught minus h f by 2. So, now the thing is that we can have the expression for X Z so, you can write X Z.

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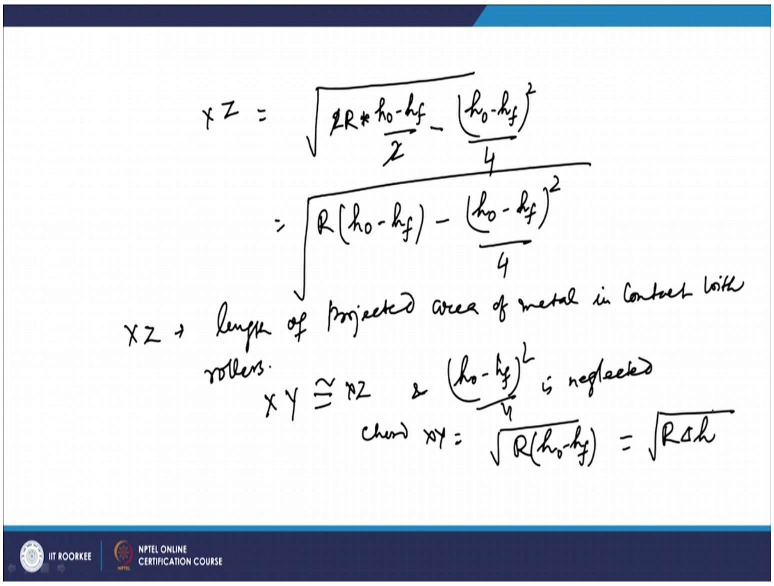

So, X Z can be calculated and exactly you have seen that under root R Y into Z Y minus Z Y square. So, you have under root Z Y is basically h naught minus h f by 2 and you have R Y. So, you have if you look at this expression this is so, this was we had taken this R and this is Y this is nothing but 2 R so, so R Y is 2 R. And then you have this Z Y is h naught minus h f by 2.

So, this is your first term minus and then you have Z Y square. So, this is as h naught minus h f by 2 square. So, it will be h naught minus h f square by 4 so, that comes out to be so, this 2 and 2 will cancel so you will have R into h naught minus h f minus h naught minus h f whole square by 4. So, that is what you get the expression for the X Z.

Now, this X Z is basically known as the length of the projected area of the metal. So, X Z is length of projected area of metal in contact with rollers. So, once you know that then that basically will be multiplied with the b and that will be give you total area. So, that will be you know multiplied again with specific roll pressure.

So, again what we see in this case we get this X Y. So, if you look at this X Y basically this X Y will be normally equivalent to you know X Z because, this h naught h f by 2 is also and also that h naught by h f by 2 is very very small and so, as X Y so this is your this is your X Y, X Y is basically will be equal similar to the X Z so, that is why we write that X Y is will be somewhat similar to X Z. And also this term h naught minus h f square by 4, this is basically neglected as compare to because this is small and further it is square will be further is small.

So, and soon h naught minus h f square by 4 is neglected. So, we can find this chord X Y, it will be basically R into h naught minus h f So, so that is why this cord X Y can be approximately said to be R delta h. So, so we get this R delta h and, we get this specific roll pressures.

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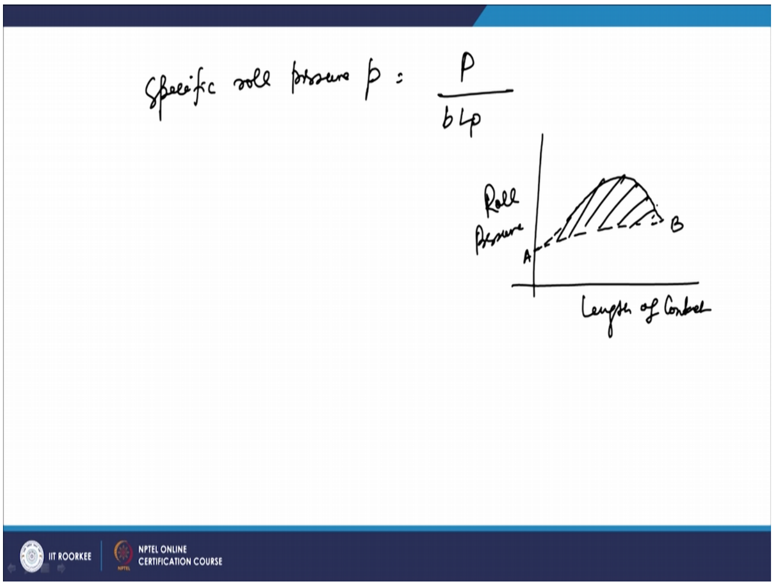

Once we get that we can get the specific roll pressure P so, specific roll pressure P it will be the rolling load divided by b times L P. Now, if you try to find the distribution of this roll pressure along the you know arc of contact, then what is seen that the pressure will raise to a maximum, you know it will be maximum and the neutral and then it falls.

So, if the roll pressure is calculated and that is your length of contact. So, so this is how your actually this is for deformation and this is for overcoming this frictional forces. So, this is your A and this is B and this is the total you know forming load, which has can you calculated which is under the whole curve, but this curve which is headed that will be for our coming the frictional force, which is there and then this is for the deformation. So, that is how you calculate the total rolling load.

Now, further what we see that we have seen that when the roll is going inside, in that case because of these frictional force which is towards the neutral point the c t is basically allowed to go in between the rolls. So, the there are two forces you have one is the force, which is the component of f, if you have the f it is component 1 is there 1 is so, if you try to analyze the figure. So, if you have these as the roll.

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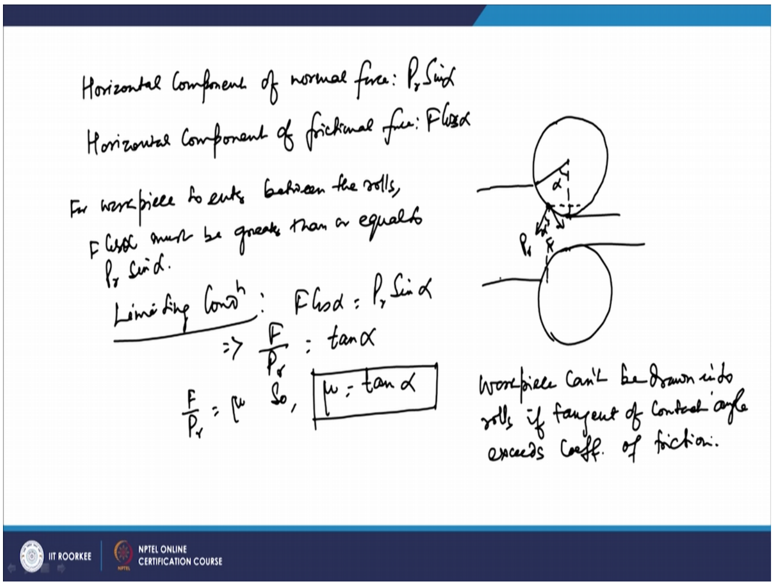

So, let us take next one you have the roll and at this point so, suppose this is how it goes and then finally, it will move from here. So, let us assume that it goes like this, now in this case what we see is that at this point we had seen that this is your P r and this is how your f goes.

Now, the thing is that this P r it is horizontal component so, this is your angle now the thing is that you have horizontal component of this normal force, now you can refer to this earlier picture here.

So, this is your if you take so, this is being the angle alpha, now angle alpha total angle is known as the angle of bite. Now this it is P r and it is horizontal component if you try to find, now its horizontal component will be opposing the entry of the c t in between the rolls and the so, you have this as R. So, this will be P r cos alpha you look at that way.

So, so your this angle so, is being this angle as alpha this will be also alpha. So, this horizontal component will be P r. So, P r cos of alpha will be the vertical component and

P r sin alpha will be the horizontal component. So, that will be your P r sign alpha. Similarly you have f acting as that and this being alpha so, your F cos alpha will be it is so, this angle being alpha its f components will be F cos alpha here.

So, you have the horizontal component of the frictional force that will be F cos alpha, now the thing is that F cos alpha you know must be greater than or equal to P r sign alpha. So, that the (Refer Time: 26:43) enters into the rolls. So, the for work piece to enter between the rolls, now what we should be happen that this P r cos alpha should be less than or F cos alpha cos alpha must be greater than or equal to P r sine alpha.

So, so that is why the limiting condition is that the should be equal that F cos alpha will be P r sign alpha. So, what we get is F by P r as sin alpha by cos alpha that will be tan alpha.

Now, what we can see that F by P r basically that will be nothing, but mu so f by P r is mu so, from here you can get mu as tan alpha so in fact, what can be what we can conclude from here, that the work piece cannot be drawn into the rolls if the tangent of the contact angle is you know exceeding the coefficient of friction. So, in that case the work piece cannot be drawn into the rolls.

So, work piece cannot be drawn into rolls, if tangent of contact angle exceeds coefficient of friction. So, this is the you know condition for so, limiting value and based on that what should be the maximum you know you know how it has to enter in between that. So, that can be you know so, what should be the coefficient of friction because of which it has to must enter into it.

So, that you know condition can be derived by this formula, that further you can have the expression for you know further this mu.

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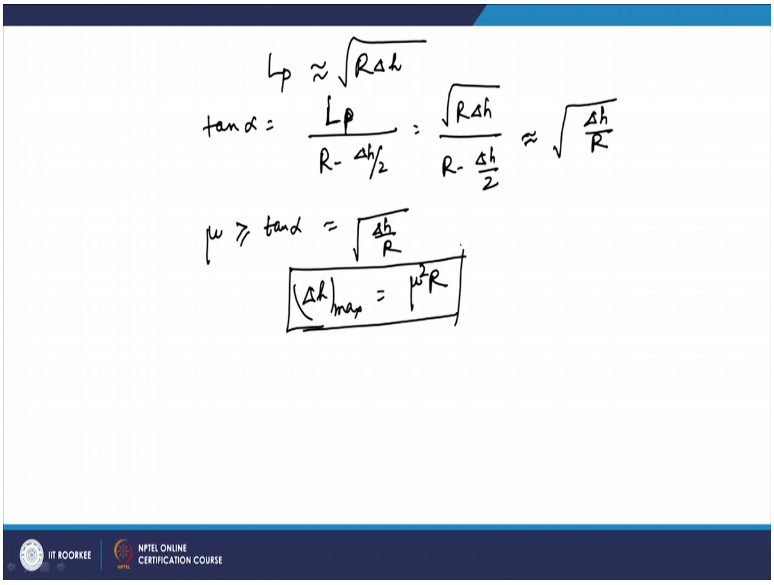

So, what we see that we have seen that L P was taken out to be R delta h under root. Now, the thing is that delta h is taken as the draft which is there in the rolling. Now, what we see that from the figure if you if you draw the inferences from the figure, now if you look at the ten alpha.

So, it will be nothing but this by this. So, it will be X Z upon O Z in that case no so, if you try to find this tan alpha. So, tan alpha will be the horizontal component that is L P L P and divided by the vertical component and so, tan will be L P upon R minus delta h by 2 so, that is what ten alpha is L P we have calculated as R delta h under root divided by R minus delta h by 2.

So, you can write it as equal to somewhat under root delta h by R, if the delta h by 2 is neglected in that case you can take this delta h by 2. Now, the thing is that depending upon the limiting condition for this coefficient of friction what we have achieved, we can write that mu has to be more than equal to tan alpha and tan alpha is nothing, but equal to under root delta h by R.

So, delta h by R maximum so, delta h maximum for that it is to be maximum value can be mu square R. So, what could be the maximum you know redaction delta h maximum that can be found out using this formula mu square R so, based on that if you have a problem, where you have been given the radius of the rolls and the coefficient of friction the maximum reduction which is possible can be found out using this formula.

So, so that is how you can calculate. So, you can further do another analysis for the rolling load calculations and, when we talk about the effect of frictions and you have further taking the friction hill generated into account you can have the expression for the rolling load calculations and every time, you have to have this I mean average specific pressure required, then you have the width and also the L P.

And based on that and depending upon the other conditions, you can have the calculation of rolling load in those situations. So, that is how for different situations, you can calculate the you know rolling load for the rolling applications.

Thank you very much.