Fundamentals of Manufacturing Processes
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Lecture - 29
Metal working processes: Wire Drawing

Hello. I welcome you all in this presentation related with the subject Fundamentals of the Manufacturing Process. And we are talking about the Metal Working Processes. And today regarding the metal working processes will be talking about, the wire or bar drawing process.

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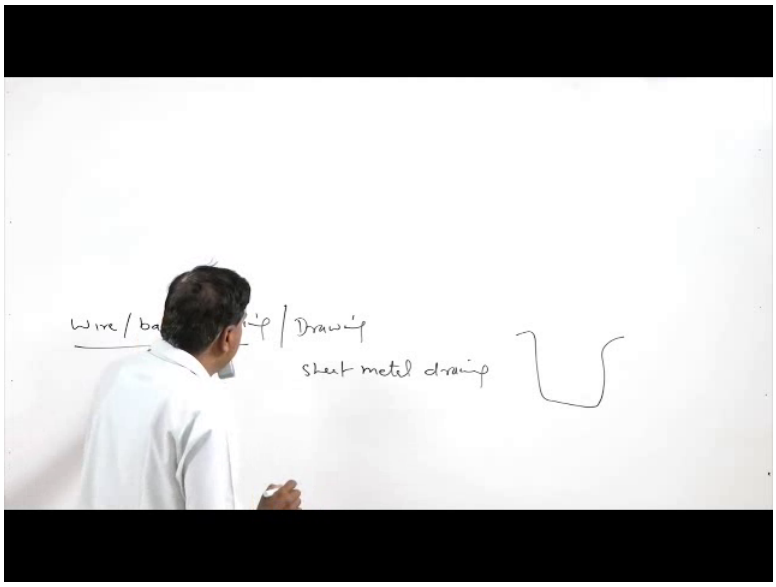

So, it is also known as the drawing, but to distinguish it with the sheet metal drawing, wire drawing, is mentioned specifically. So, sheet metal drawing is used for making the cup shape products , but here wire drawing and bar drawing is used for making the rods or the wires of the a smaller diameter.

So, in order to distinguish the drawing of the sheet metals more specifically, wire drawing or the bar drawing is used.

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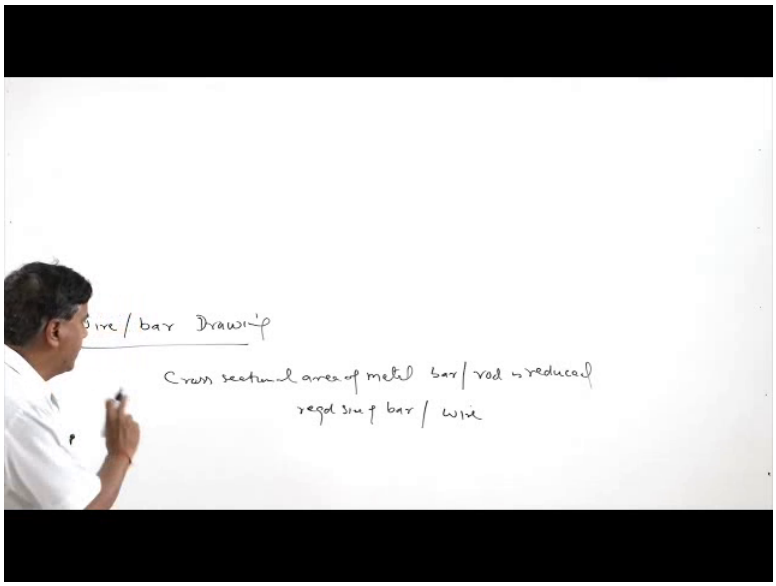

So, in this process basically, the cross sectional area of the metal bar or the rod is reduced. So, that we can get the required size of bar or we can get the required size of the wire. So, basically in this process the cross sectional area of the metallic bar or the rod is reduced. In order to get the bar of the desired diameter or of the cross sectional area, for this purpose it uses one typical die like this.

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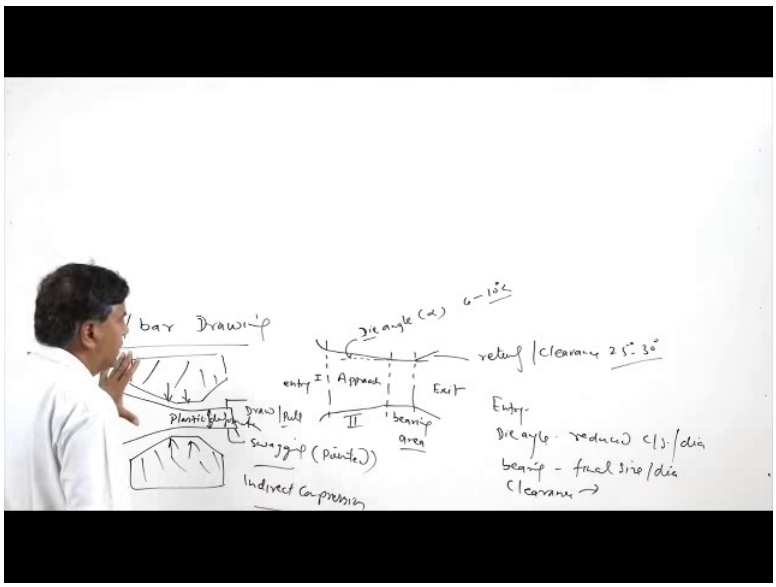

So, here if we see there are few sections; this is the first one, this is the another one and this is the third one. So, therefore, zones this is one, we can say the entry zone and this is the approach one.

Here basically, the reduction in the cross section takes place and the final size, this is the bearing area. So, the final size is determined by this and this is the exit zone and these are the, there are different angles, which we can say; this is one angle which is called the die angle, normally represented by alpha and it is value, mostly like say varies from 6 to 10 degree and here this is the exit. So, here the relief or clearance angle is given, which is quite highlight 25 to 30 degree. So, basically in this process, in general the cross section goes in like this of the die. So, the first of all the wire which is to be drawn of course, it will be of the larger diameter. So, initially it is mid pointed like this. So, that it enters through the die and this is made by the swaging process.

So, basically, it is a operation of reducing the cross section in very localized manner before the dawning itself and this end is held or gripped in order to draw, it draw or pull it. So, when the one end; which is a one end of the bar, which is to be drawn is inserted through the die and then it is drawn. So, basically, it is pulled with the help of suitable mechanical arrangement. So, when it is pulled, it leads to the application of the indirect compression. So, basically we are pulling, but due to the geometrical shape of the die the metal of the bar is subjected to the indirect compression and because of this indirect compression, here the plastic deformation takes place.

This plastic deformation actually reduces the diameter of the bar from the large diameter, like say the D naught to the A, smaller final diameter corresponding to the diameter of the die at the bearing zone. So, basically if we see the entry zone, facilitates the smooth entry of the pointed or the swaged. The draw bar or the rod which is to be drawn in case of the; and then giving the die angle. This second zone, where metal is a gradually reduced in terms of the cross sectional area or the diameter then in the bearing area, the final size or the diameter is determined and then we have the relief or the clearance.

So, clearance helps to come out means a smooth exit of the drawn wire from the die. So, these are the constructional details related with the die and the role of the different components. So, as we have seen there is a reduction in diameter of the die reduction in

diameter of the bar, after the drawing. So, the extent of the reduction will depend upon the die which is being used and the die angle, which is there.

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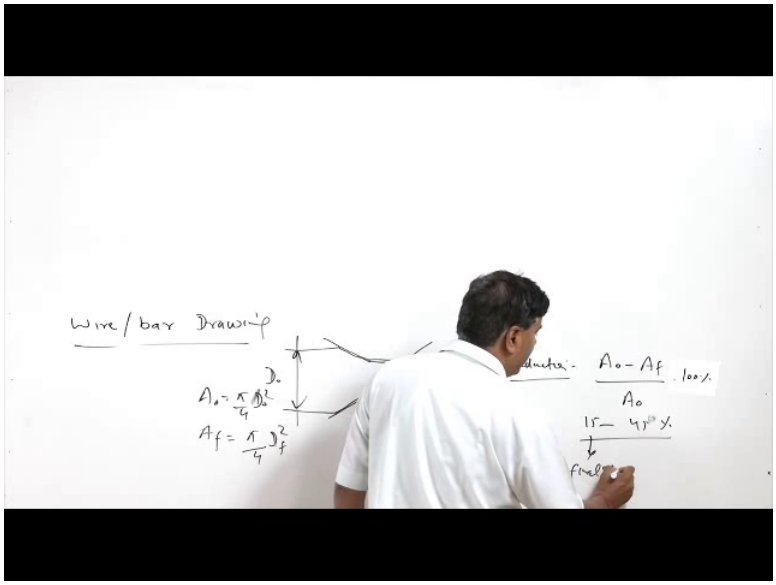

So, when the wire is drawn through the die like this. So, this is the rod and here it is cross sectional, cross section or the diameter will be reduced.

And then it will be finalized in this zone and then it will be coming out. So, this reduction is expressed in terms of the percentage initial cross sectional area the final cross sectional area divided by the initial cross sectional area. So, the initial cross sectional area is obtained from the A naught is equal to pi by 4 D naught square and the A f final cross sectional area is obtained from the pi by 4 D f square and these are used to calculate the reduction percentage, which is taken place as a result of the. So, this will be determining the D f and this is the D naught.

So, the reduction percentage, it can vary in case of the wire drawing process from 15 to 45 percentage, but depending upon the purpose.

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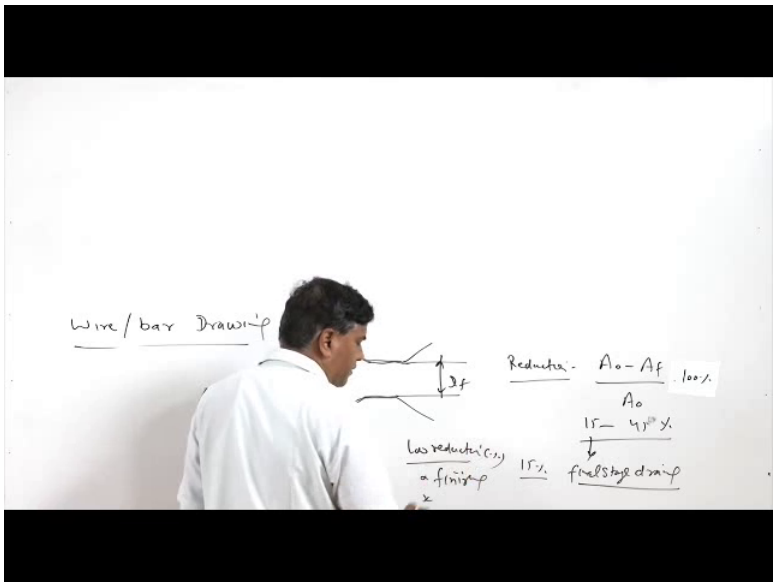

The lower values means low reduction like, 15 percent is preferred for the final stage drawing, because it helps to get the final size, which is desired, it is smooth. So, it offers the better control over the dimensions as well as it results in the smoother surface finish. So, basically the low reduction percentages are used for finishing stage. So, it gives the better surface finish as well as closer control over the dimensions, while the high reduction percentages are used for the initial stage of the drawing, where major change in the dimension is achieved another parameter or the term which is here, related with the reduction.

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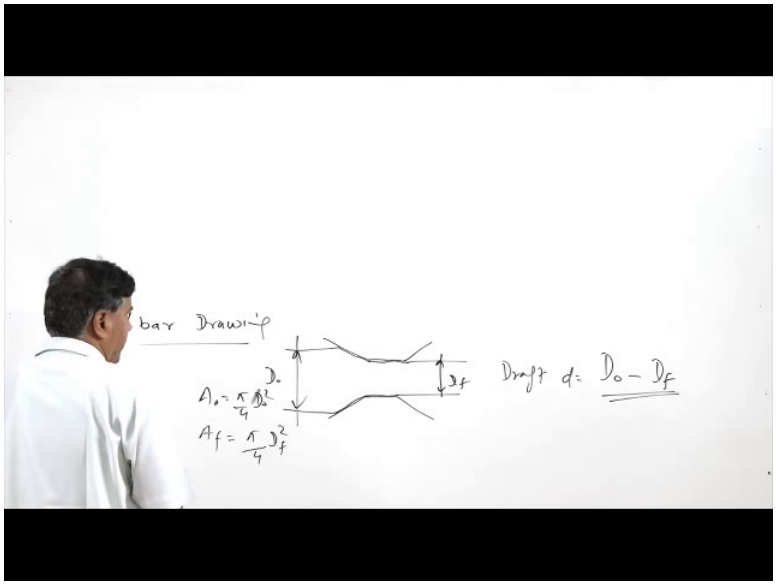

With the change in cross section is the draft, which is draft D, is obtained from the difference in the initial diameter to the final diameter.

So, this is a simple difference in the diameter of the diameter, change in the diameter which is achieved after the wire drawing. Now, we will see the steps which are used for the drawing purpose like say; if the wire, if this is the bar, which is to be drawn in some of the fined wires like this.

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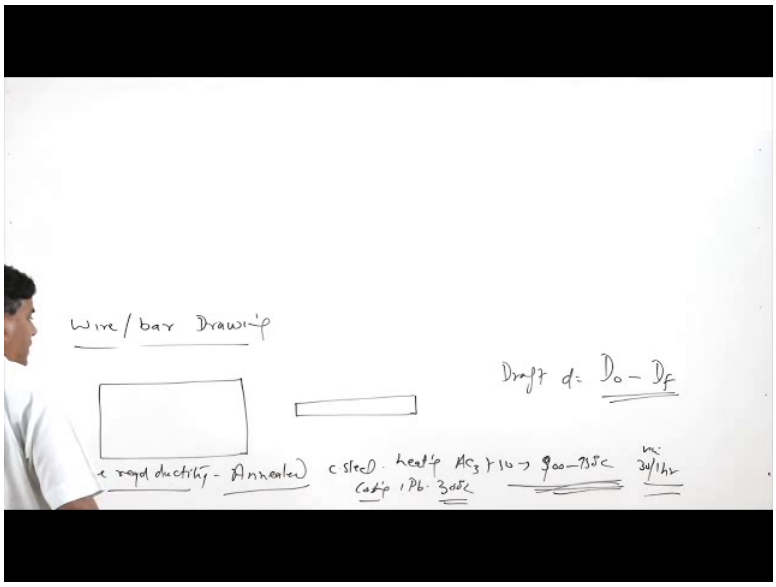

So, what we need the first step is to ensure that is to ensure required ductility. So, for this purpose, it may be required that the metal is annealed properly; so depending upon the kind of metal systems annealing. Say, for the carbon steels annealing are carried out by heating the bar above the AC 3 temperature plus 50 degree.

So, say depending upon the carbon concentration, it may be like say 900 degree centigrade to the 950 degree centigrade. So, depending upon the carbon content in the steel, there can be very wide range for the annealing, w which will be used for inducing the ductility and after heating, at this temperature for say 30 minute to one hour, depending upon the diameter 30 minute to one hour, depending upon the diameter. It is subjected to the cooling in led bath. Like say, at about 300 degree centigrade. So, that it induces the required ductility in the metal if the metal is not ductile or it is having prior work hardening effect. So, for that purpose requires a ductility is induced.

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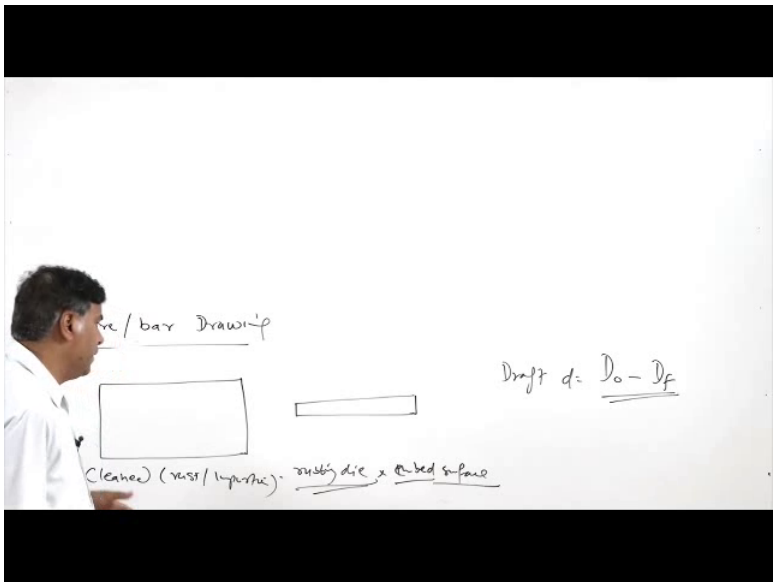

Another important thing is that, it is properly cleaned, because if the wire is having the, like rust or it is like, say, other impurities are present in the surface of the wire which is to be drawn, then these will be rubbing with the die surface. So, the die A, they will be it, these will be causing the roughening of the die or wear of the die and another thing, these will get embed. So, these will get embed with the surface of the drawn wire; so in order to which will be leading to the increased surface roughness of the wire which is drawn. So, in order to avoid the unnecessary die wear and roughening of the drawn bar or the drawn wire, the surface of the bar or the large diameter wire, which is to be drawn is cleaned.

And the third thing, which is used is the lubrication.

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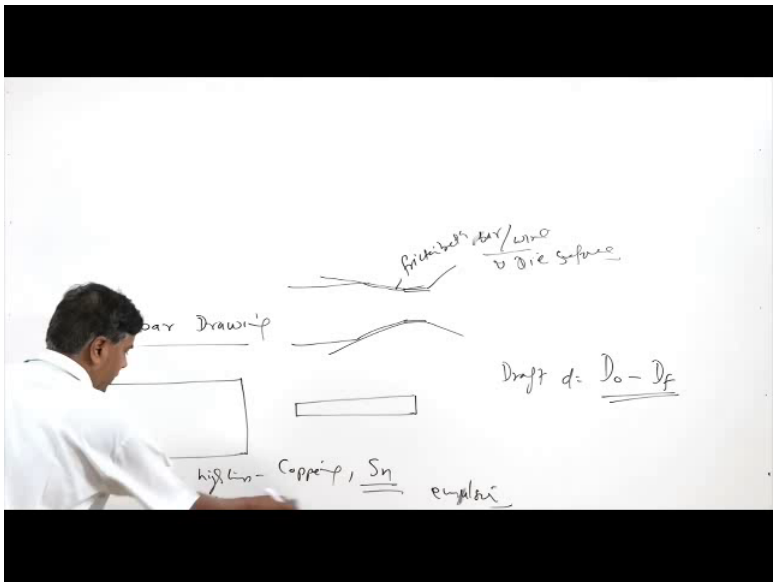

We know that there is a lot of a, because of the reduction in cross section of the die and the relative movement of the wire during the drawing process, the wire or the bar which will be moving through the die lot of relative movement under the pressure will be leading to the friction between the bar, which is being drawn or the wire which is being drawn and the die internal surface. So, in order to reduce this frictional effect and unnecessary, the power required for the drawing, basically the lubrication is carried out.

So, there are different methods to apply the lubrication depending upon the temperature conditions, under which the wire drawing is carried out. Like say for the high temperature conditions coppering is used and sometimes even the Sn is also used for the lubrication purpose, but for the low temperature conditions, but for the low temperature conditions, another thing is like sulling, is also carried out and then like emulsions. Emulsions are also used for the low temperature conditions. The basic purpose of this is of applying the lubrication is to reduce the friction between the bar or wire and the die surface.

So, that movement of the wire, which is being drawn inside the die, can be smoothen and the power required for a wire drawing purpose can be reduced. Now, we will see the effects which are imparted onto the wire which is drawn after the wire or the bar which is drawn after the drawing process.

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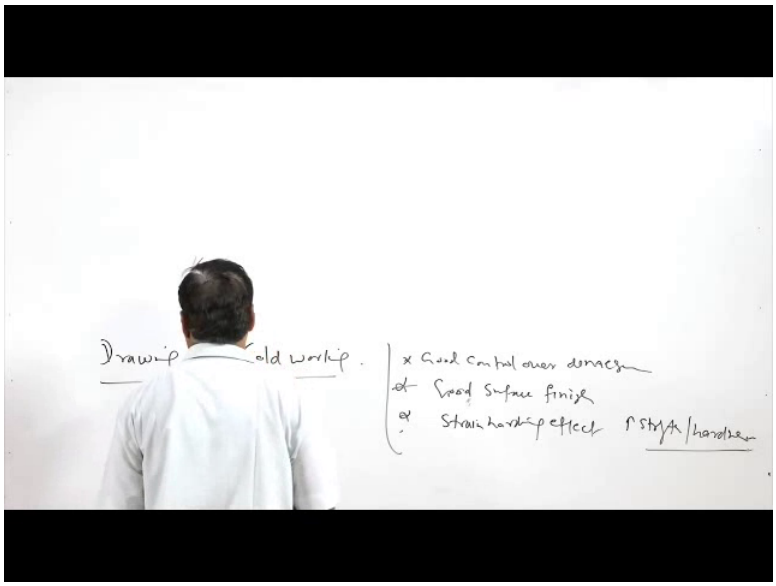

So, here we need to consider one important thing mostly this drawing, which is either the wire or the bar drawing. It is mostly the cold working process and hot working processes are rarely used. So, whenever the cold working are used, it results in the good control over the dimensions, this is one thing. The second, it results the good surface.

Good surface finish, since this is carried out under the low temperature conditions, below the re crystallization temperature. So, it offers the strain hardening effect. So, because of the strain hardening, the strength and the hardness of the drawn wire, hardness of the wire, which is drawn increases. So, these some very positives, some of positives of the wire drawing process as far as the better sites are concerned, but if the conditions for wire drawing are not favourable.

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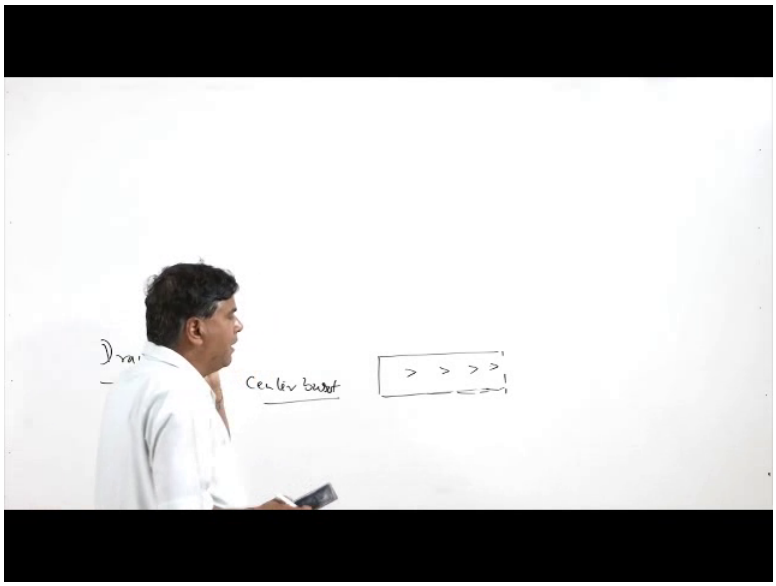

Then these will result in some issues also for example, that center burst is one of the defect which is observed in case of the wire drawn, and in this case center burst will be leading to the development of the cracks or these are several marks which are there in the drawn wires, and now especially under the upsetting conditions these will open up in form of the cracks.

There is another aspect apart from the center bursts related issues, and this happens probably due to the differential, the deformation in the wire which is being drawn in course of the drawing.

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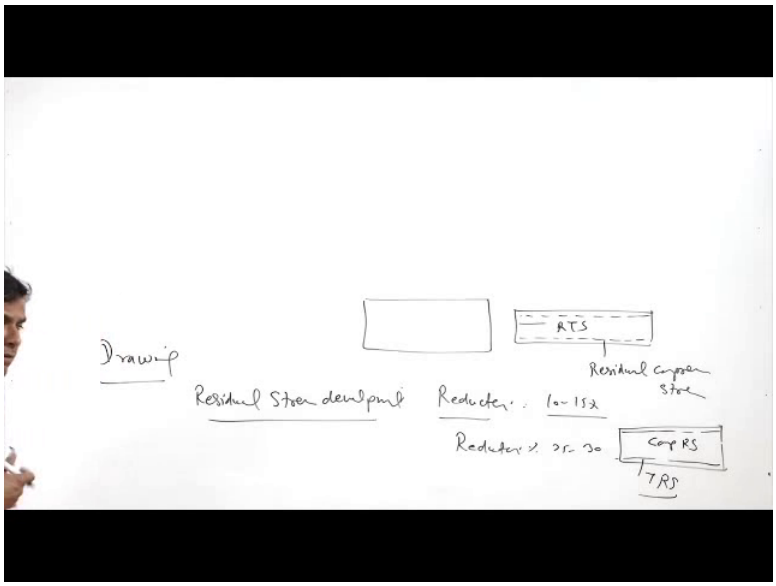

Another issue or you can say the effect, which is observed the residual stress development. So, that the kind of the residual stresses which develop A in the wire drawn, wires like say the initial diameter and the final diameter; so when the final diameter depending upon the extent of reduction which is being achieved; so as per the reduction percentages.

Like for the low reduction percentages are normally the surface layers have the residual compressive stresses. While the internal sections have the residual tensile stresses and the reverse is observed. When the reduction percentage is high reduction percentage, is like A 25 to 30 or even higher than the reverse trend is observed where in the near surface layers of the drawn wires have the tensile residual stresses. While the centre has the compressive residual stresses. We know that it is always favourable to have the compressive residual stresses at the surface, because it increases the resistance to the corrosion. It improves the tensile strength and it improves the fatigue performance of the wires.

So, it is always good to have the compressive residual stresses as compared to the tensile residual stresses. So, this difference in these residual stresses again, develop primarily due to the differential deformation, which is experienced by the metal in course of the drawing.

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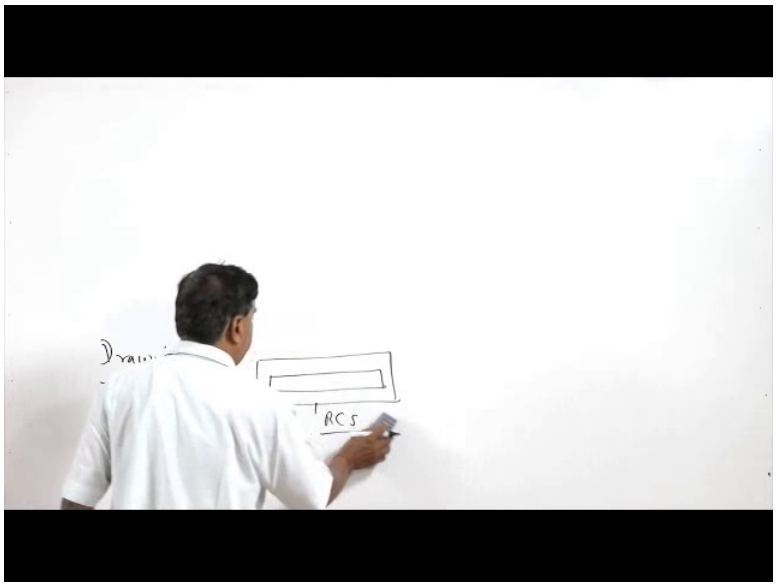

So, and if you see here, if you consider any case, if there is a more flow of the metal at the centre and the less, at the less, at the surface, then it leads to the residual compressive stresses and while if the reverse is reverse happens, then it will be causing the tensile residual stresses at the surface. So, now we will be looking for some analysis aspects related with the residual stresses as well as what happens and how it is actually achieved.

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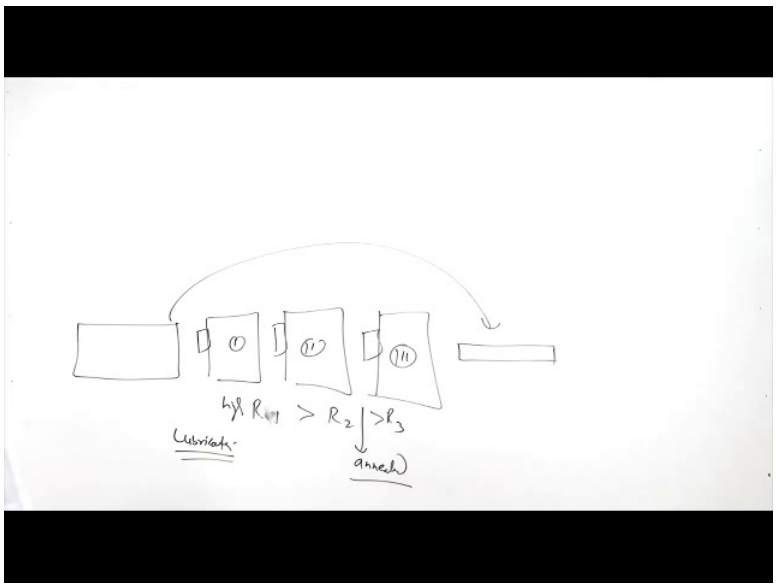

Like say, if the diameter is very large, then probably the, and the final dimensions which are desired are very fine as compared to the initial one. So, that the transformation from

the large diameter to the small diameter in one go is not actually possible. So, what we do basically, the wire is drawn in number of stages, in order to achieve the final, the drawing. So, in that case, there will be number of the dies, which will be used like this and the wire will be drawn sequentially, from this will be used for like say somewhat high reduction percentage at this stage; one stage, two stage, three. So, if we see R 3, sorry. R 1 will be greater than R 2 will be greater than all means less than R 1. So, R 1 will be greater than the R 2 and R 2 will be greater than the R, R 3.

This is somewhat reducing reduction, percentages are used in order to achieve, because in this course, the metal will be work hardened. So, sometimes like, if the material is work hardened too much, then in between, the stages, the material, maybe annealed in order to induce the ductility in addition to the drawing; it through the different stages. Now, what we need is the lubrication; so before each stage of the drawing. Now, the things are lubrication is done of the wire or of the bar, which is to be drawn and I now, I will plot one schematic to show, how the drawing is carried out.

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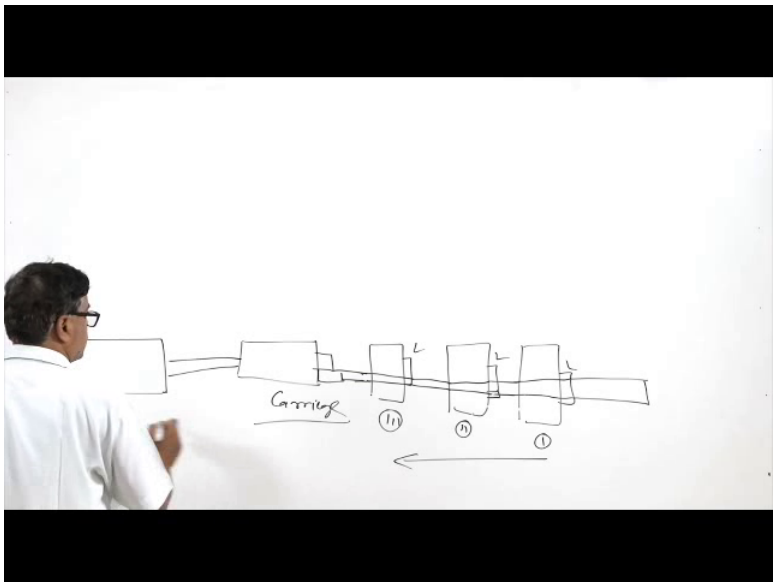

So, for example, here is the mechanical arrangement, which will be used for pulling the carriage, is this one which will be holding the wire, which is being drawn and then here, we will have the die. This is lubrication arrangement, another die, another lubrication arrangement, another die, another lubrication arrangement like this. So, basically the wire, which is to be drawn is inserted from here and then it is first lubricated, then it is

drawn and reduced in the diameter, then again it is lubricated here and then again it is drawn. So, there again, there is a reduction in cross section. So, this is how it will be keep on drawing and then here, what will we having; this is the end where here it will be connected to the carriage.

So, basically, this is the carriage, which will be holding the wire and it will be pulling the wire. So, it will be passing through the different dies like say, the die 1, die 2, die 3 and before each time of the drawing, it will be lubricated through the suitable lubricating arrangement. And accordingly the drawing percentage means reduction; percentage will be varying from stage 1 to stage 2 and then from stage 2 to stage 3 and then, this carriage is now pulled with the help of the prime mover or suitable hydraulic arrangement or some other mechanical arrangement, which is used. So, this is a kind of schematic, which is used the wire or the rod, which is to be drawn is inserted and then sequentially, it is drawn in the different dies, in stages, in order to reach the final dimensions, which are desired.

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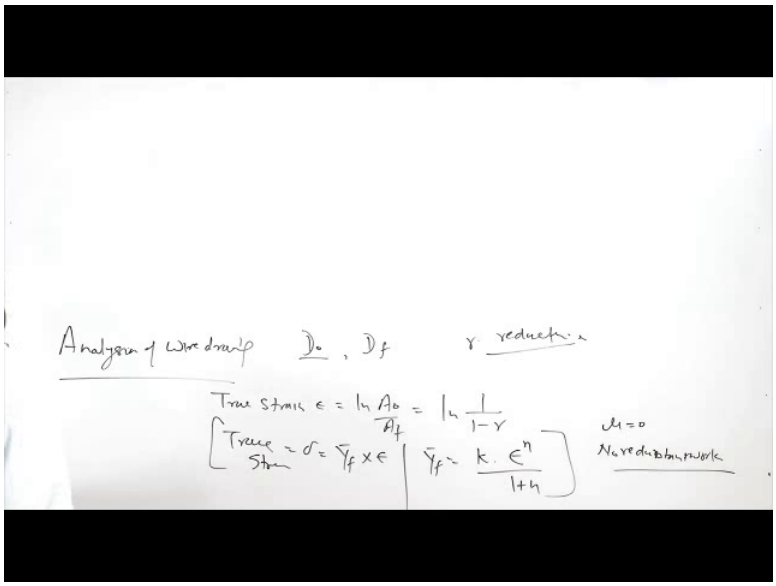

So, now, I will look after the analysis part of the analysis of the wire drawing process. So, now, we know that, there is initial diameter D naught and the final diameter D f. So, using these, we can calculate the number of things. So, for determining the true strain, what we use basically and the log of A naught divided by A f, which is also written as log of 1 by 1 minus R. R is the reduction percentage. R is the reduction percentage as I have

shown earlier and then the true stress is calculated, using the average flow stress multiplied by the true strain and an average flow stress is obtained using the simple equation.

Like strength coefficient multiplied by the true strain, raised to the power n that is the strain hardening exponent divided by 1 plus n. So, n is the strain hardening exponent and this is the average flow stress. So, this is the case for determining the true stress for the case, which will for the case when we assume that the mu between the wire which is being drawn in the die surface is nil. And there is no redundant work, there is no redundant work considering that, there is a redundant work and there is a friction, then we need to use little bit more, a consideration of few more factors which include the factors like the friction coefficient and the geometry of the deformation geometry or the redundant deformation geometry.

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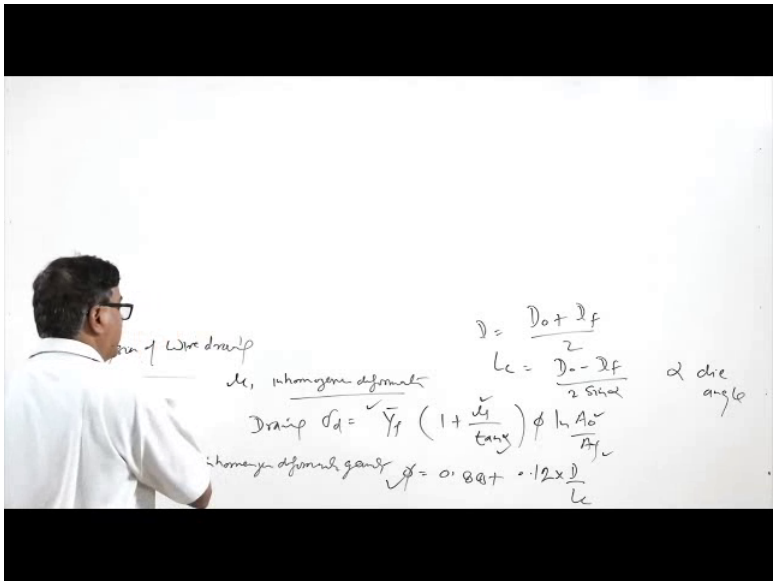

So, when the friction is considered an inhomogeneous, deformation is also considered leading to the redundant work. In that case, we get the drawing stress. Drawing stress sigma D is given by the equation Y. This is the average flow stress into 1 plus Mu divided by 10 alpha into phi log of A naught divided by A f.

So, here the phi is the phi, basically, accounts for phi accounts for the inhomogeneous deformation geometry which is given with the help of like phi is equal to 0.88 plus 0.12 into D by L c. L c is the length of the contact and the D f. D is the average diameter. So,

average diameter of the wire, which is drawn like say D naught divided by. So, D naught plus D f divided by 2 is used for calculating the average diameter and Dl length of the contact is obtained using the relation like D naught divided by D f twice of the sine alpha.

So, now, alpha is the die angle as I have made earlier and the D is the average diameter. So, this is what is used for calculating the phi, which accounts for the inhomogeneous deformation geometry and rest of the parameters are known like average flow stress mu friction coefficient alpha is the die angle and the initial and the final cross sectional area and phi can calculate. So, this can be used for determining the drawing stress. Now, drawing stress multiplied by the drawing area gives us the drawing force.

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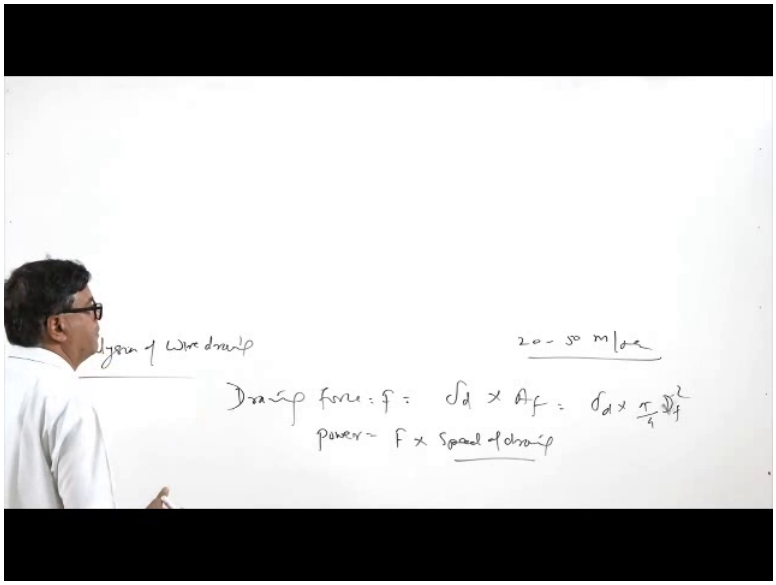

So, if we see the drawing force is obtained using the simple equation, drawing force is obtained force f is obtained from the drawing stress multiplied by the final cross sectional area and we know that final cross sectional area sigma D multiplied by pi by 4 the D f that is the final cross section, final diameter. So, this is how we can determine the drawing force and to determine the power basically, to determine the power consumed in the drawing process.

The force multiplied by the speed of the drawing the speed at which the metal is being drawn. So, normally like it, may be it may range from the 20 to 50 meter per second, it will depend upon the number of parameters like the metal system the die angle etcetera.

So, this is how it can be used for calculating, the power, which will be consumed in the drawing process

Now, here I will summarize this presentation. In this presentation I have talked about the purpose of the wire drawing and what are the factors that effect in determining the success of the wire drawing. And thereafter, also we have seen that how the different aspects related to the stress and power and the reduction ratios related with the wire drawing can be determined to understand the way, by which wire drawing will behave and wire drawing acts during the deformation process.

Thank you for your attention.