Manufacturing Processes - 1
Prof. Inderdeep Singh
Department of Mechanical & Industrial Engineering
Indian Institute of Technology, Roorkee

Module - 01
Lecture - 06
Swaging & Wire Drawing

Very good morning to all of you, today we are going to start another important aspect of manufacturing technology, that is swaging and wire drawing. Before we start our discussion on swaging and wire drawing. We will have a brief overview of what we have discussed till date. We have had a series of lectures on manufacturing processes. We started our discussion with powder metallurgy. We had 3 lectures on powder metallurgy, after that we started our discussion on metal working or metal forming processes.

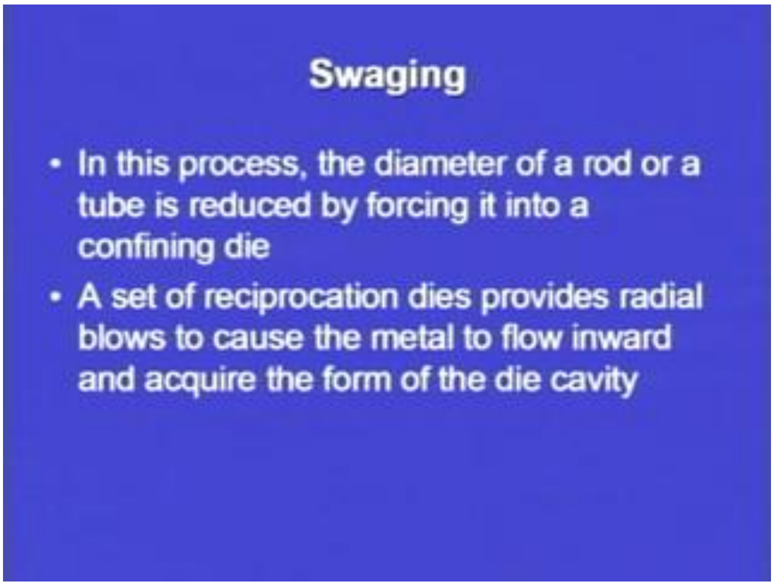
In metal forming, we have had till now two lectures. In first lecture we discussed regarding the basic fundamental of metal working, in which we discussed plastic deformation, what is plastic deformation? How does plastic deformation takes place in metals? Then we discussed the various different types of metal working processes, just a brief overview. Later on we went on to discuss the relative advantages and disadvantages of hot warm and cold working processes. Then in the subsequent lecture, we started our discussion on various metal working operations.

The first process that we discussed was forging. We saw that what are the various operations in forging? Like upset forging, precision forging, impression die forging, open die hammer forging, and auto forging. We saw what are the basic principles of these operations? And how where, and for what materials these operations can be applied? So, today we will discuss regarding the principle of swaging, the operation of swaging, and the operation of wire drawing. So, what is swaging, and what is wire drawing?

These are two metal working operations, in which we change the shape of the raw material into its final product. Swaging is a process, where the basic principle is similar to the forging operation. Here we apply compressive forces from all sides of the work piece. In case of forging we have seen, we have in case of open die hammer forging, there is a metallic piece which is pressed from top and bottom we have a another die. So, die punch type of or a die hammer type of arrangement is there, in which a metal piece is pressed from two directions. But in case of swaging, swaging is also sometimes called rotary swaging.

In rotary swaging, we press the work piece from all the directions, and this die punch type of arrangement is rotating. So, along the periphery along the periphery of the circle, there are punches or there are die sets which press the material from all directions simultaneously. The action of these punches can be controlled by camps or any other type of mechanism. So, we will discuss what is swaging? What are the different types of shapes that we can make use of swaging? And what are the basic principles of wire drawing?

(Refer Slide Time: 03:44)



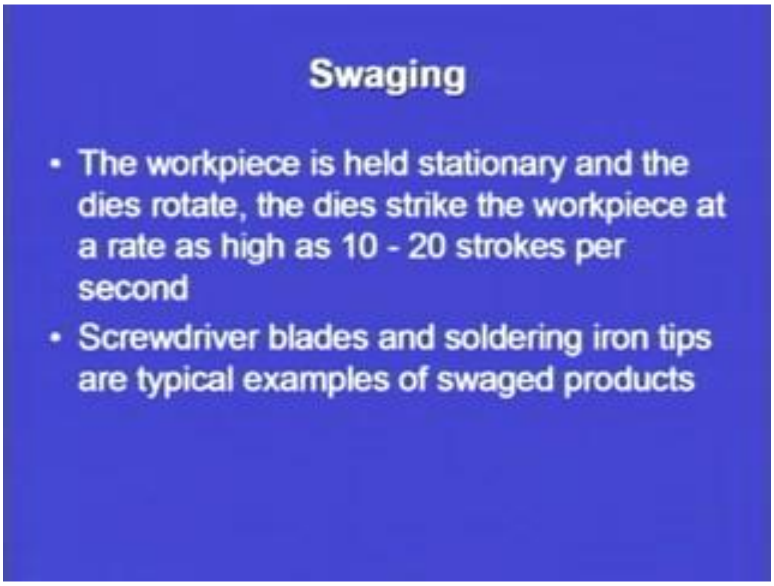
Now swaging, the basic principle of swaging is that in this process, the diameter of the rod or a tube is reduced by forcing it into a confining die. So, confining die will have the dimension, according to the final dimension of the rod or the tube that we want. If we want to make use of a tube, we will make use of a mandrel in that process. So, basically swaging is a process in which the diameter of the rod or a tube will be reduced by a forcing it through a die.

So, what will be the material of the die? What is the shape of the die? That we will see in the part of this lecture. So, in case of swaging, a set of reciprocating dies provide radial blows to cause the metal to flow inward and acquire the form of the die cavity. Now, the die cavity is there, and a set of reciprocating dies are there. So, the dies will have a reciprocating motion, and radial blows will be given to the job.

Now, suppose we take one example, the example can be that there is a rod or there is a tube on which we want to put some impression or we want to engrave something on the periphery of that rod. So, we can subject it to a process of swaging. For example, the cables if we want to put something on a cable or put some special type of feature on the cable, we can use the process of swaging. So, radial blows are given, radial blows means along the radial direction from all the directions, we will give the radial blows, and we will be able to reduce the cross section.

Also we are able to impart some kind of special features on to the periphery or on to the circumference of the tube or the rod on which we are performing the principle of or the operation of swaging. So, set of reciprocating dies provide radial blows to cause the metal to flow inward, and acquire the form of the die cavity. Now, die cavity will give the shape that we want to produce using the operation of swaging. The shape that we want to make will exactly be replicated into the form of a die cavity.

(Refer Slide Time: 05:58)

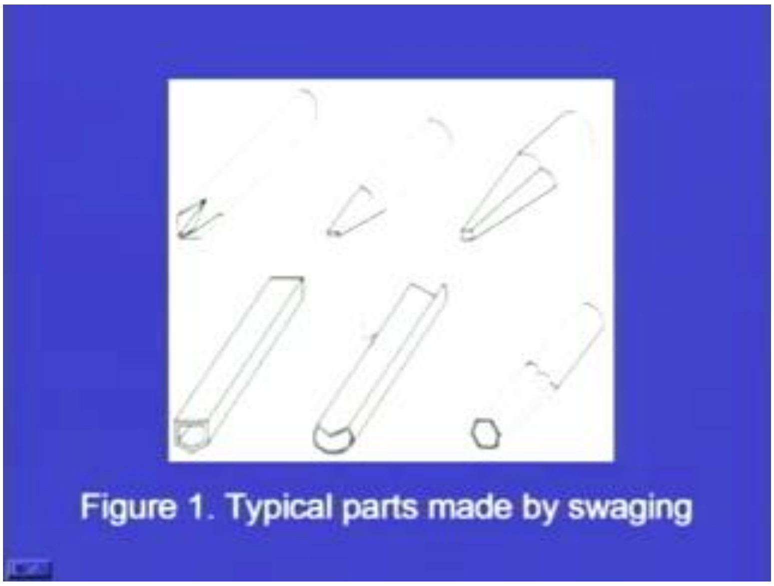


In case of swaging, the work piece is held stationary and the dies will rotate. Already in the brief introduction of swaging process, we have discussed that the dies in this case are rotating in a circular fashion. The dies strike the work piece at the rate as high as 10 to 20 strokes per second. So, we can see that per second we can have 20 strokes. So, the volume of production or the rate of production using the process of swaging is comparatively high as compared to the other metal working operation.

So, 10 to 20 strokes per second can be given in order to change the shape of the raw material into the final product. Now, some of the examples or some of the application areas of swaging are as follows. Now, screwdriver blades soldering iron tips, all of us use screwdriver. So, the screw driver blade we see that they it has been given a flat shape, the one end is circular and circular cross section and the other end is having a flat cross section.

That flat cross section is used to wind or unwind the nuts or the bolts or it is used for fixing up the screw, so that flat portion can be made using the process of swaging. Similarly, all of us have seen soldering iron. So, soldering iron also is given the shape using the process of swaging. In the next part of some of the slides we will see that what are the various shapes that we can make using the process of swaging?

(Refer Slide Time: 07:40)

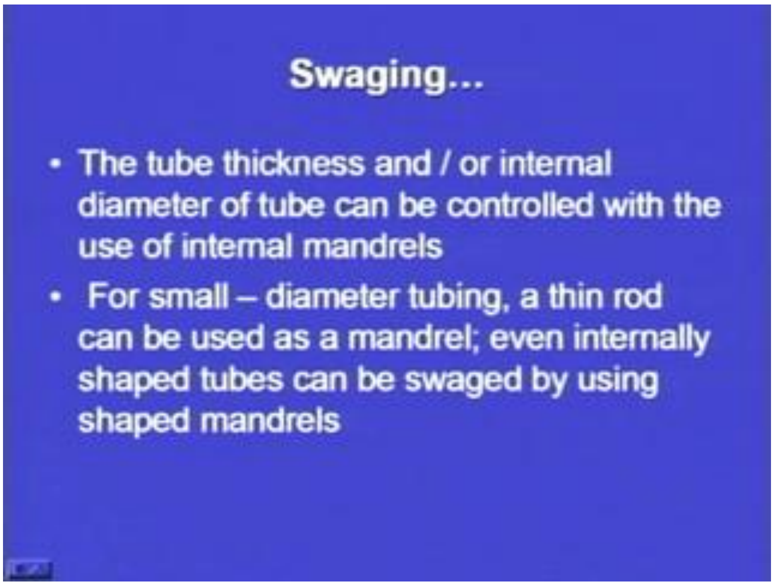


Now, these are some of the shapes that can be made using the swaging operation. We can see that, this is the cross section that has been made using the swaging operation. Now, some of you may wonder that how this kind of shape can be given. This is given by the shape of the die. A die will be made, which will have the impressions or the cavities which are exactly the replication of this shape that we want to make. Now, these dies when they will strike on this work piece, this job will be a straight cylindrical type of raw material. So, this will be given this shape with the help of the reciprocating die type of arrangement.

Similarly, we can see this is just similar to the case of a screwdriver blade that we have already discussed, this is the circular cross section, and here we have a flat cross section. So, this flat cross section can be made using the principle of swaging. Here we can see another shape has been made using the principle of swaging, where there are four phases from this square section we can see that this type of four phases can be made using the principle of swaging.

Moreover we can see, this hexagonal type of arrangement can also be made using the process of swaging. Here we can see another cross section has been developed, and some kind of internal shapes can also be given using the process of swaging. So, swaging basically the very versatile process, in which we can develop different types of shapes depending upon the requirements of our final product. This slide shows the typical parts made by swaging operation.

(Refer Slide Time: 09:24)



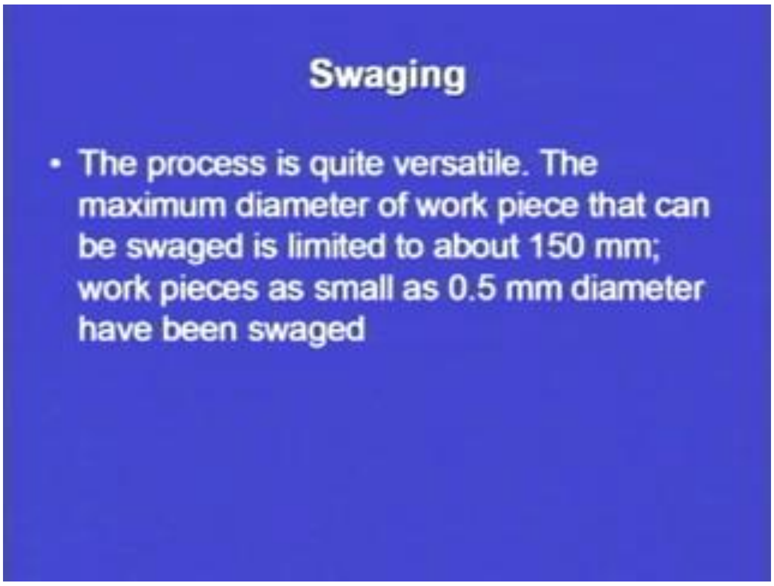
Now, coming on to the basic principles of swaging, the tube thickness and or internal diameter of tube can be controlled with the use of internal mandrels. So, now when we want to control the internal diameter or we want to control the thickness of the tube, we can use the mandrels. So, these mandrels can be of different shapes, suppose we want to give a particular shape at the inner cross section or the inner side of the tube. So, that can be given using a shaped mandrel.

We have a slide to discuss and to show that what are the various types of internal features or the internal cross sections that can be developed using the principle of swaging? So, now the tube thickness or internal diameter of the tube can be controlled with the use of internal mandrel, so different types of internal mandrels can be used. For small diameter tubing, suppose we want to make a tube which is having the internal diameter very, very small.

So, in that case we may use a different type of a mandrel, if we want to give a shape to the inner side of the tube or the inner section of the tube we will use a different type of a mandrel. Suppose, we want to make a tube which is very thin or the diameter is very, very small, then we can use different type of a mandrel, what type of mandrel will be used there? For small diameter tubing, a thin rod can be used as a mandrel.

So, the rod diameter will be very, very thin, even internally shaped tubes can be swaged by using the shaped mandrel. So, as in the first point we have already seen that we can make shaped shapes or shaped tubes inside the shape will be given towards the inside periphery of the tube. So, that we will see that what are the various types of shapes that we can give? So, using shaped mandrel we can give internal shapes also.

(Refer Slide Time: 11:32)

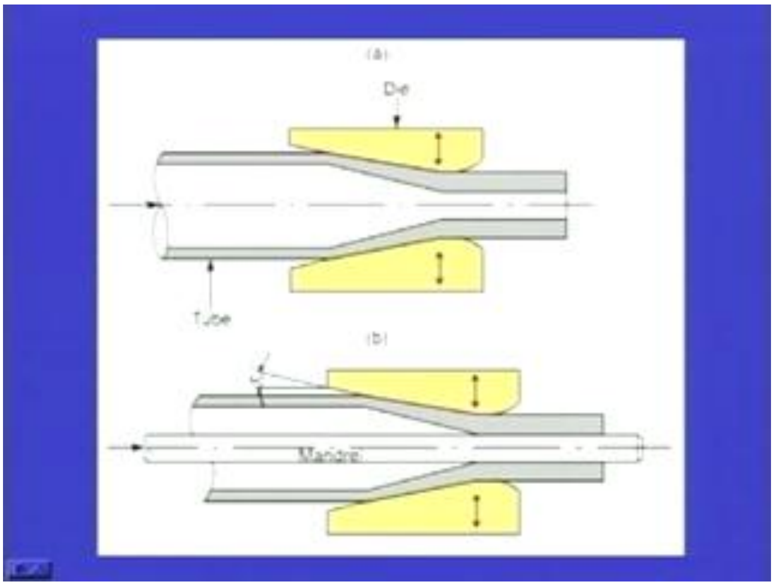


So, swaging is the process is quite versatile. It is a very versatile process as we have seen in one of the previous slides that, what are the different types of shapes that we can make use of the process of swaging? So, when we can make use of different types of shapes, in case of swaging the process itself becomes very versatile. Moreover, shaped mandrels can be used to give internal features to the tube that also adds versatility to this process.

The maximum diameter of work piece that can be swaged is limited to about 150 millimeter. So, the maximum diameter there is a limitation, we can only swage the tubes or the rods whose diameter is less than 150 millimeter. So, limited to 150 millimeter the diameter or the maximum diameter is limited to 150 millimeters, but the work piece is as small as 0.5 millimeter diameter had been swaged.

So, we can see that there is a range of diameter, in between which we can subject the rods or the tubes to the swaging operation. Towards the maximum side, the limit is at 150 millimeters, and towards the lower side the limit is at 0.5 millimeter. So, we can swage the rods between 0.5 millimeter and 150 millimeters.

(Refer Slide Time: 12:55)



So, now this diagram briefly explains the principle of swaging, though this is not a very complete diagram. We can see that the die has been shown, this is the die which is there, this yellow colored portion is the die portion, and this is the tube that is being swaged. So, we can see this is coming from this direction, and going out from this direction. So, what is the basic cross section of a die? That we will see in a subsequent slide.

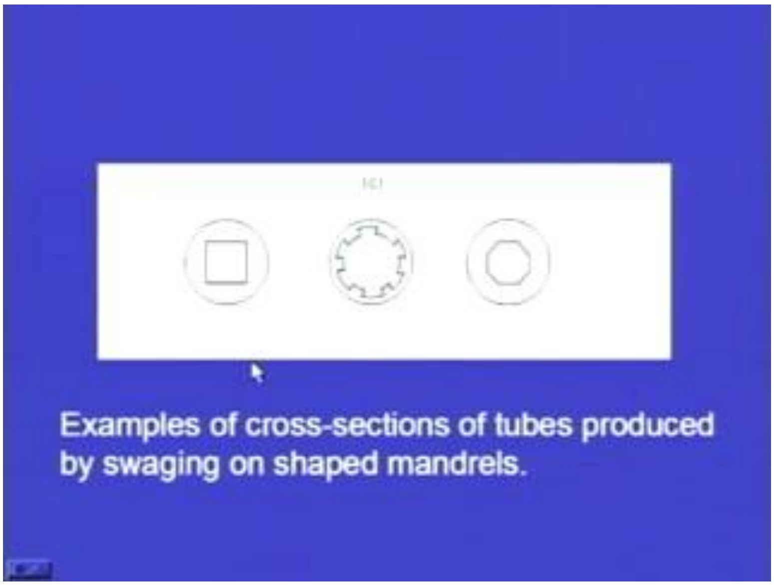
But, here we can see the tube is getting swaged with the help of a die, these dies basically are rotating. So, here the rotation has not been shown, it has only been shown that there is a die, in between which the tube is passing. So, here we can see that the thickness is varying. The thickness of the tube here, if we compare with the thickness of the tube here it is different. So, if the thickness is more than that two is crossing the die.

So, here the thickness is more, and here the thickness is less. Moreover, whatever final dimension that we want to make using the swaging operation is dependent upon the opening that we provide. So, here we see that there is an arrangement where we can fix the opening. So, this dies can be moved top and bottom or this can be this opening can be controlled using a mechanism, so that we get the desired shape or the desired size of our final product.

Similarly, this is another case here we can see that there is not much variation, and using a mandrel in this case, case a, there is no mandrel that has been used. In case b, there is a mandrel that has been used. So, what is the use of the mandrel? We using a mandrel we get a uniform cross section, and the thickness is also uniform. So, using a mandrel we get a uniform thickness of the tube that we are making using the process of swaging.

So, these are two diagrams that explain the basic principle of swaging where the die type of arrangement is there, and the die opening is controlled. Depending upon the die opening, we get the final shape of the product that we want to make using the principle of swaging. So, here we can see there is an angle alpha; this also gives how that material is going to enter into the die cavity? If the angle is more or less, it depends that whether the entry will be smooth or the entry will be abrupt. So, this angle has is also another designed parameter for swaging operation.

(Refer Slide Time: 15:51)



Now, as already we have seen that internal shapes can also be given using the shaped mandrels. So, here in this diagram, diagram c we can see if we want to have a outer periphery as our circular cross section, and inner side we want to have a square cross section, we can make this type of a tubing also, but we need to have a shaped mandrel. So, all of us are very intelligent enough to guess that what should be the shape of the mandrel that should be used for making this type of a tubing arrangement.

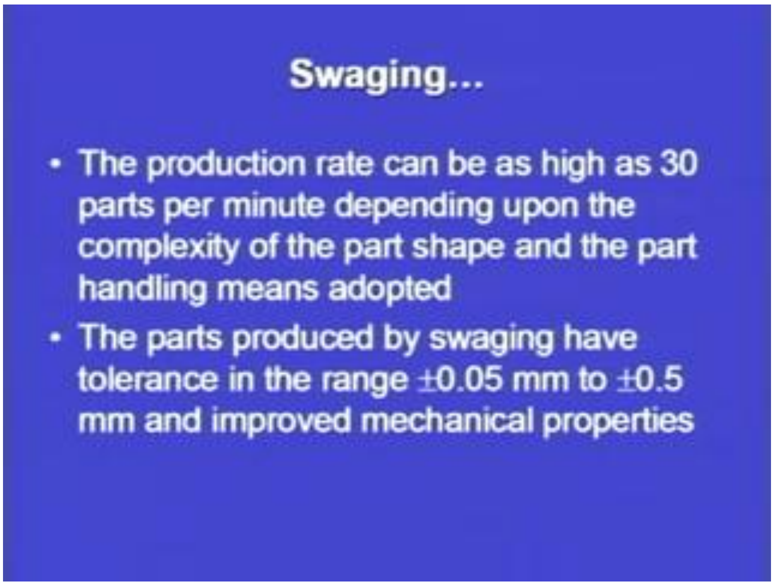
Moreover, if we want to make a very complicated, this seems to be very complicated, but this type of internal features or internal geometric dimensions can also be created using the principle of swaging, but what is required. The only requirement is a shaped mandrel, a shaped mandrel will be of this shape, and from all sides pressure will be applied by the rotating dies. And we will be able to get this form of tubing, and this type of internal shape we will be able to produce using the principle of swaging.

Moreover, if you want to make this type of a cross section it may not be too clear, but there are different edges, this is one edge then this is second edge, this is third edge, fourth edge, fifth edge, sixth edge. So, if we want to make this type of an internal feature inside the tube that can also be made using the internal mandrels. And these mandrels will be called as the shaped mandrels. So, these are some of the examples of the cross sections of tubes produced by swaging on shaped mandrels.

So, the shapes of the mandrel already I have told, here also this is the shape of the mandrel, here this is the shape of the mandrel, and here this is the shape of the mandrel. So, shaped mandrels will be used, and the swaging will be done from all the direction along the radial direction and reciprocating dies will be used to pressurize from all the directions.

So, this is thus we can see already we have already addressed this thing that this is a very versatile process. Depending upon the requirement we can choose the shape of the mandrel, we can choose the shape of the die, we can give external features also, we can give internal features also, we can make screwdriver blades, we can make soldering iron tips, different types of processes can be the process can be varied and different types of products can be made using the principle of swaging.

(Refer Slide Time: 18:39)

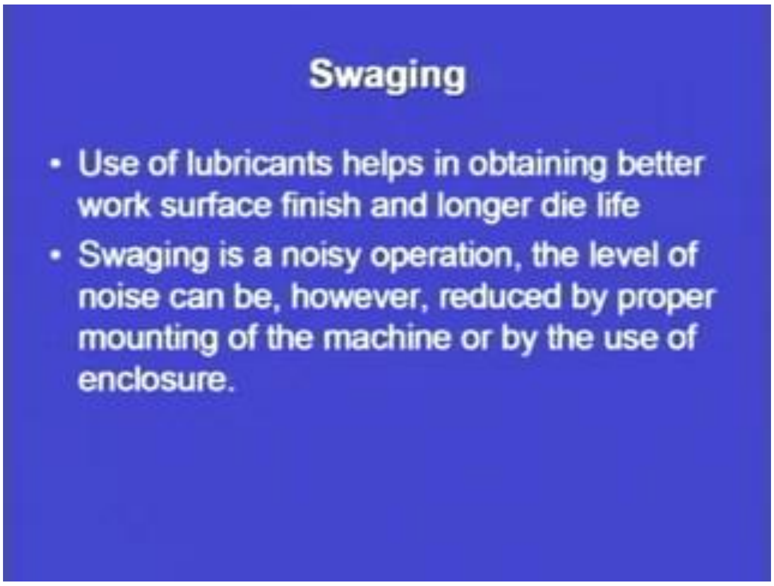


Now, continuing our discussion on the swaging process, the production rate already addressed is very good, it is high. The production rate can be as high as 30 parts per minute depending upon the complexity of the part, and the part handling means adopted. Now, the part which we are subjecting to the swaging operation, it can be handled in a number of ways, it can be automatically handled, it can be manually handled. Moreover, the shape is also an important parameter as we have seen in one of the previous slides, that the internal shapes can be given using the shaped mandrel.

So, there we can see there was a very simple cross section that was a square cross section, and there was a very complicated cross section also. Now, depending upon the complexity of the shape that we want to make, we have to choose a process. Moreover, the production rate will also depend upon the shape of the product that we want to make, as well as on the handling. If the handling is automatic, we can think of achieving a very high production rate, but in case of manual feeding or manual loading of the stock, the production rate may be comparatively less as compared to the automatic feeding.

So, the two important parameters that define the production rate in case of swaging or the complexity of a job that we are handling, moreover the means of handling that either it is handled automatically or it is handled manually. The parts that are produced by swaging have the tolerance in the range of plus minus 0.05 millimeter to plus minus 0.5 millimeter, and they have the improved mechanical properties. So, the tolerance range is also given. So, it can be, in between the range of plus minus 0.05 to plus minus 0.5. And the mechanical properties will also improve in the raw material, when it has been subjected to the operation of swaging.

(Refer Slide Time: 20:44)



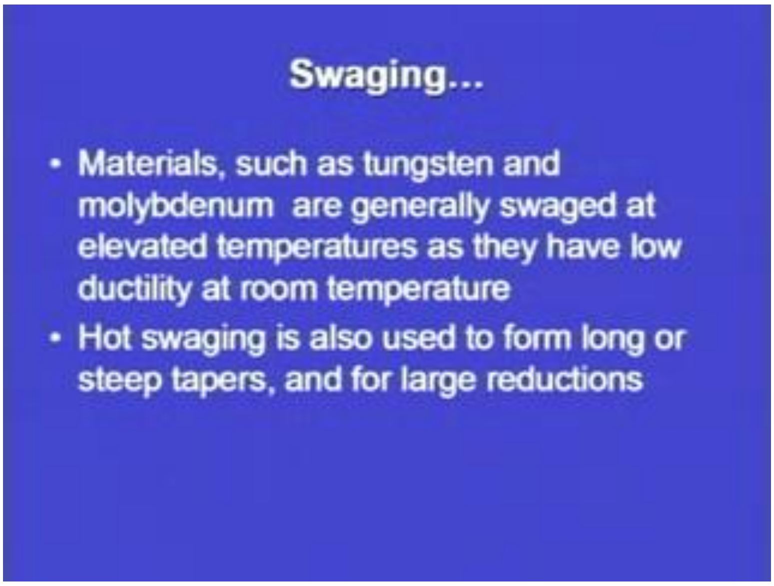
Another important aspect is the use of lubricants. So, why lubricants are required, wherever we are using a die arrangement, the die needs a lubricant otherwise the wear will reduce the life of the die. Moreover the surface finish of the product that we will get will not be up to the desired level. So, use of lubricants help in obtaining better work surface finish and longer die life, so already this has been discussed.

If you want to have extremely high surface finish, and we want to have the die life of one thousand units or two thousand units depending upon the material of the die that we have chosen, we decide to use a lubricant. So that, the cost of the die is spread over a large number of parts and the economical justification of the products can be made. Now, swaging is a noisy operation. So, wherever the swaging machines have been installed, the noise is too much.

So, the level of noise can however be reduced by proper mounting of the machine or by the use of an enclosure. So, the process of swaging is a noisy operation as already I have read out. So, this can be controlled either by the use of proper mounting or by the use of an enclosure. So, suppose in an industry, there is a section that is dedicated towards the swaging machine, it can be enclosed or the section where it the swaging machines have been installed, acoustically designed buildings can be there, where noise absorbers are there, so that it does not make too much of noise.

And the workers, who are working are not influenced by the or not affected by the noise that is being produced by the swaging operation. Now, materials we have already seen what is the principle of swaging? What are the various types of shapes that we can make use of the swaging operation? What are the limitations in terms of noise, etcetera? Now, we are coming on to another important aspect that what are the different types of materials that can be swaged?

(Refer Slide Time: 23:02)



So, materials such as tungsten and molybdenum are generally swayed at elevated temperatures as they have low ductility at room temperature. So, in one of the previous lectures where we discussed the basics of plastic deformation and metal working, we have seen that there are 3 different types of metal working operations, that is cold working, hot working and warm working. So, wherever the ductility is sufficient in the material, we directly go for a cold working operation, because it has some relative advantages and disadvantages as compared to the warm and hot working.

But, wherever the ductility is not there, there we heat the metal to an elevated temperature, so that some kind of ductility is imparted to the material for plastic deformation. So, while swaging also, sometimes we have to work at an elevated temperature, specifically for materials like tungsten and molybdenum, wherever we have to swage a material that is tungsten or molybdenum, we will raise the temperature a bit, so that we are able to get some ductility for plastic deformation. Hot swaging is also used to form long and steep tapers, and for large reductions.

So, reduction basically is that we are changing the cross section from one level to another level. So, the reduction is the reduction in the cross sectional area. So, whenever we want to have a large reduction, there we will go for an elevated temperature working or hot working operation; wherever we want to have a small reduction in the cross sectional area, we may go for cold working operations. Now, depending upon the level of reduction that we want to have in the cross sectional area. We will make a decision that should we go for a hot working operation or should we go for a cold working operation.

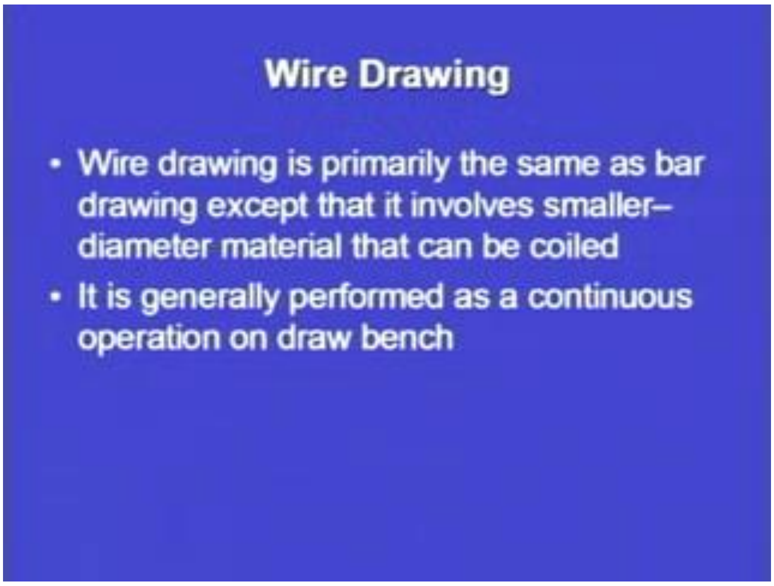
So, just too briefly review what we have discussed in swaging operation? We have seen what is the basic principle of swaging? What are the different types of shapes that can be made using the swaging operation? What is the die and tube type of arrangement in swaging? What are the limitation areas of swaging? What are the limitations of the operation of swaging like noise? And then we have seen that what are the different types of materials that can be swaged? And at how that warm working and cold working aspects can be incorporated into the swaging operation?

(Refer Slide Time: 25:45)

So, now we come on to the second section of this lecture that will be dedicated towards wire drawing. So, wire drawing is also another important manufacturing process, in which we reduce the cross section of a wire from one level to another level. So, it depends that how much cross section we want to reduce. As we have seen yesterday in one of our lectures on forging, that the cross section is not reduced in one stage itself, the cross section is reduced in the number of stages. So, here also in case of wire drawing, we are not going to reduce the diameter of the wire or the tube in one stage only, but it will be subsequently reduced in a number of stages.

So, in this session or this part of this lecture we will see, what is wire drawing? What are the different types of wire drawing equipment? And we will try to understand the principle of wire drawing in detail. So, all of us sometimes use guitar we have, if we have not used guitar we have at least seen the guitar, the strings of the guitar or the wires of the guitar how they are made. They are made using the principle of wire drawing. There are other types of wires that are in our daily use, which are made using the process of wire drawing.

(Refer Slide Time: 27:03)

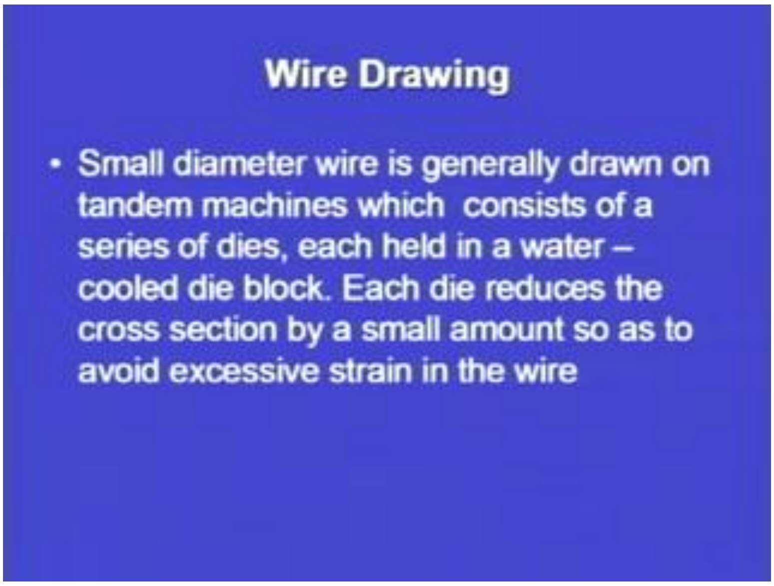


Now, wire drawing is primarily the same as bar drawing except that it involves smaller diameter material that can be coiled. So, some of you may wonder that what is the difference between a wire drawing and a bar drawing. So, basic difference is in the form of the raw material that is being used. In bar drawing the diameter is more, in case of wire drawing, smaller diameters wire that can be later on made into the form of a coil or used in case of wire drawing. So, it is generally performed as a continuous operation on a draw bench.

So, when we discuss the drawing equipment where we will see, what is basically a draw bench? So, it is generally performed as a continuous operation. So, continuous operation is an important point to mention here. In forging we have seen that we make products that are discrete in nature. So, discrete products means that in one stroke of the hammer or a number of strokes of the hammer, first we will make one product, when that product is ready it is a discrete product, we will take it out from the die place it in the bin.

Again we will use the operation another product will be made, and it will be taken out and put into the bin. In this way, we make number of products, number of discrete products in the forging operation. Whereas, in case of a wire drawing operation, it is a continuous operation means that we may be able to make a kilometer long wire while using the principle of wire drawing. So, a 1 kilometer or 2 kilometer or even 5 kilometer long wire can be drawn using the principle of wire drawing principle as it is a continuous operation.

(Refer Slide Time: 28:51)



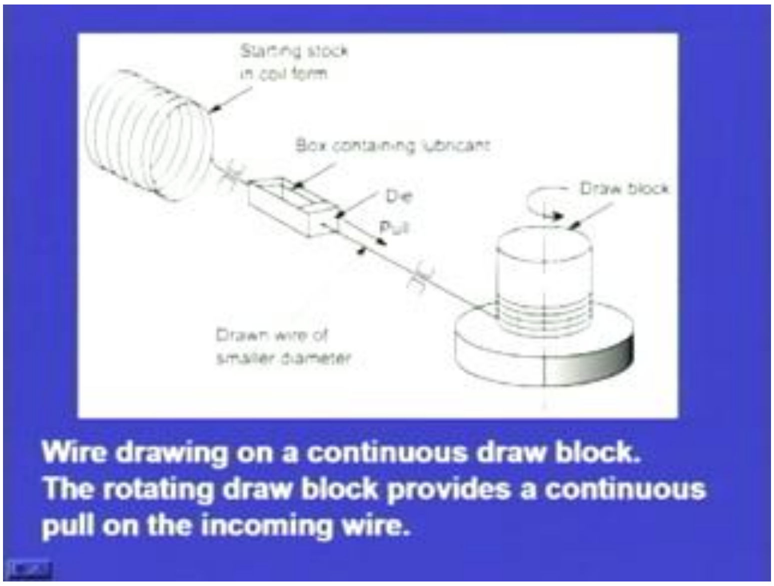
Now, in case of wire drawing smaller diameter wire is generally drawn on tandem machines. Tandem machines already I have told that there will be a series of machines, in which the smaller diameter wires will be drawn which consist of a series of die, each held in a water cooled die block. So, cooling arrangement is also there in order to avoid any kind of thermal shock or thermal failure of the wire. So, small diameter wire is generally drawn on tandem machines which consist of a series of dies, series of dies means the diameter will be reduced in a number of stages.

In one stage, we are we will reduce some section of the diameter, then another die will be used, then another die will be used, and when a subsequent dies are used, the diameter will be reduced from suppose x level to the y level. So, y level is the diameter that finally we want to achieve. So, from x we will come on to y, but at different stages using number of dies at each stage. So, we will have a cooling arrangement here. So, each die reduces the cross section by a small amount, so as to avoid excessive strain in the wire.

So, now some of you may wonder that what is the need of putting so many dies or what is the need of reducing the cross section at different stages? Why not to go in one stage only, we can reduce the diameter. Although that is also possible, but there is a limit to the reduction in the area. If we go for large reductions, suppose we would say that we are going to reduce the cross section by 60 percent.

There are chances where large strains will be developed, and the wire may fail. So, in order to avoid the failure of the wire, we have to go in subsequent steps. We are not going to go for a very high reduction in area to the tune of 60 percent we will see that what are the limits for the percentage reductions? That is possible in case of wire drawing operation.

(Refer Slide Time: 31:01)



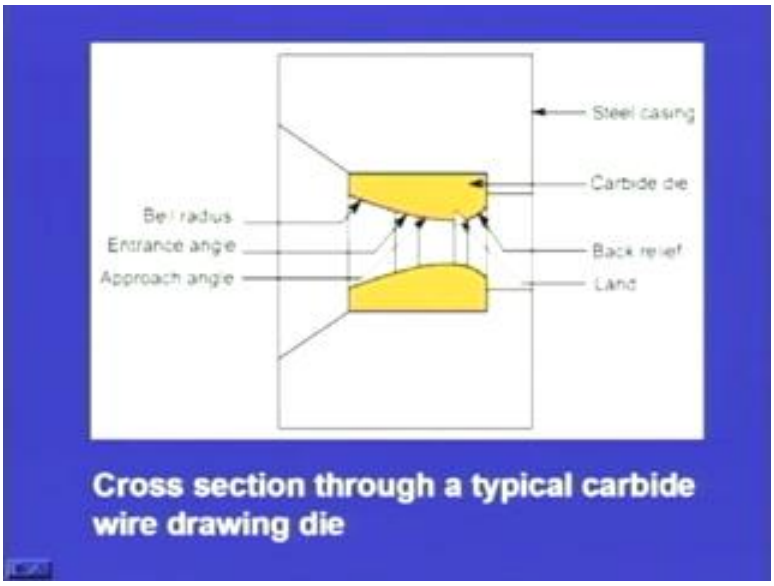
Now, this is basically a wire drawing arrangement, here we can see I will just read out the labels that have been given to this diagram. This is the starting stock in coil form, this is the starting stock; this is the diameter which we have to reduce to this diameter. So, this is the starting stock in coil form, then this is coming through this deformer box containing the lubricant, this is the lubricant. Then there is a die, the opening of the die will decide that how much reduction we are going to get in this diameter.

So, then there is a pull, we have a formulation or analytical formula to calculate the die pull that we will see in the subsequent slides. So, this is a die pull which is been exerted. So, this is the drawn wire out of smaller diameter. So, here we see that there is a larger diameter, this is coming; this is picking up the lubricant from here. Then this is passing through this die, and there is a pull that is being exerted by this draw block.

So, this draw block is rotating, the sign of rotation is shown here. This draw block when it rotates, it pulls the wire from here, and this is the drawn wire of smaller diameter. So, from bigger diameter we are achieving a wire of a smaller diameter. So, this is a wire drawing on a continuous draw block, so this is a continuous draw block. So, there is no limitation. So, whatever is the amount of wire that we can wind on this draw block, this will be able to go for that much continuous operation.

So, it is not a discrete operation, it is a continuous operation the wire will be coming from here getting the reduction or getting reduced in this die arrangement, then it is being pulled by this draw block. So, the rotating draw block provides a continuous pull on the incoming wire. So, continuous pull is being applied on this wire that is coming from the starting stock or in the coil form. So, here we see that this is the basic arrangement for wire drawing.

(Refer Slide Time: 33:10)



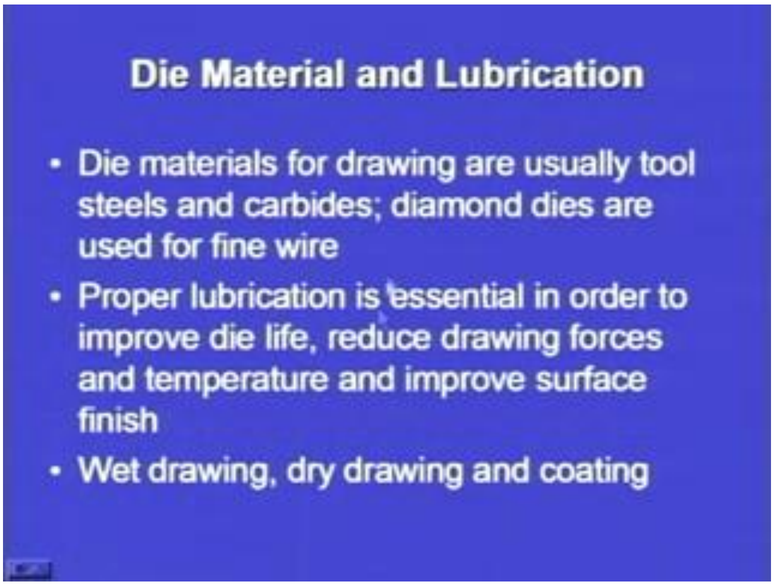
Now, this is another shape of the die that we are seeing here, just to read out how the diagram has been labeled. This is the steel casing this bigger portion, this is the steel casing, in between the steel casing there is a carbide die. So, this yellow portion this gives the carbide die, then there is a back relief angle that has been provided, there is a land that has been provided. This land will decide the size of the wire that we will get after the wired drawing operation. Then there is a bell radius here, there is an entrance angle, and there is an approach angle.

So, this diagram we can say that this is showing the cross section through the typical carbide wire drawing die. So, this is that wire drawing die, and this is made up of carbide, but carbide we you can see that only a small portion is the carbide this is yellow portion and the rest is a steel casing. So, why this is so? This is so, because carbide being costlier as compared to steel is not given the die is not completely made up of carbide, only the portion that is responsible for the reduction in the cross section of the wire that is being subjected to the wire drawing operation is made up of carbide.

Then this other portion that can be asked regarding this labeling or regarding this diagram is that what is the importance of giving these angles like entrance angle and approach angle? Now, this entrance angle and approach angle will decide the pulling load or the die pulls. So, if we are not providing adequate or the optimal angles, then the die pull may be excessive or we may require more forces to pull the wire. And if the forces required will be more, the power required to operate the machine will be high.

So, in order to facilitate the easy entry of the wire into the die, and a reduction in the pulling forces or the die pull, we use these types of arrangements or we use these types of design guidelines or design parameters in the form of these angles. So, this diagram basically gives the cross section through a typical carbide wire drawing die.

(Refer Slide Time: 35:44)



Now, coming on to the die material and lubrication, we have seen that the die, what is the cross section of the die? What are the different angles that are given to the die? How the die is labeled? What are the different portions of the die? There is an approach angle; there is a relief angle towards the end. Then there is a land, different portions have been shown, but the material of the die is also very, very important. Then the weather should we go for lubrication, lubrication should be there or it should not be there, that is also another important aspect of wire drawing operation.

So, die materials for drawing are usually tools steel and carbides. So, we make use of tool steels in order to make wire drawing dies or sometimes we make use of carbides. So, in that diagram that we have seen or that I have shown for wire drawing operation that there it was a material was made up of carbide, and the casing was made up of steel. But, sometimes we may directly use a tool steel to make a die. Another operation where we want that a large number of or the large length of the wire has to be drawn, there we can use diamond dies, and diamond dies are also sometimes used for very fine wire.

So, if the diameter of the wire that we want is very, very fine at that particular case, in that particular situation or in that particular condition we may choose diamond die or the material of the die can be chosen as diamond. So, we can see that there are 3 different types of materials that can be chosen to make the die. So, these are tool steels, carbides and diamond. Now, proper lubrication is essential in order to improve the die life, reduce drawing forces and temperature and improve surface finish. So, in this point there are 3 important aspects, why lubrication is required?

First point is yes lubrication is required, why it is required? In order to improve the die life. If no lubricant is there, the rubbing action or the friction between the wire and the die may lead to the abrasion or may lead to the wear of the die surface. So, in order to improve the life of the die lubrication is an important process that should be carried out. In our diagram of simple wire drawing operation, we have seen that the wire that is coming from the coil is getting lubricated before it enters into the die. So, lubrication is an important aspect to improve the die life.

Similarly, I have told you the drawing forces are also important, we need to reduce the drawing forces in order to reduce the power requirement. So, in order to reduce the drawing forces, we should lubricate the wire or we should lubricate our dies. Moreover, instead of having the lubricating action, sometimes the wire will also have another action that is the, the lubricant will have another action that is the cooling action. So, it is not that the lubricant will have only the process of reducing the wear, the lubricant can also act as sometimes the coolant. So, in order to decrease the temperature that has been generated during the operation, the lubricant can also act as a coolant.

So, another important aspect is that it will the lubrication will help us to keep the temperatures within the control. Then in order to improve the surface finish of the final product that we are getting, we have to lubricate our raw material or we have to lubricate the dies. So, proper lubrication is important in order to improve the die life, in order to reduce the temperature, in order to reduce the pulling forces, and in order to reduce, in order to improve the surface finish or in order to reduce the surface references, surface reference will be reduced, and the surface finish will be improved.

Now, there can be 3 types of lubrication that is possible. So, what are these three types of lubrication? This is wet drawing, dry drawing and a coating. So, just to have a brief explanation of these lubrication processes. In case of wet drawing, the total arrangement that is the die and the wire will be submerged or will be immersed in the lubricant. So, this can be a liquid type of lubricant or it can be some kind of oil which will act as a lubricant, and which will help to improve, and in order to improve the performance that has already been discussed. The die life will be more; the surface finish will be good; the temperatures will be under control.

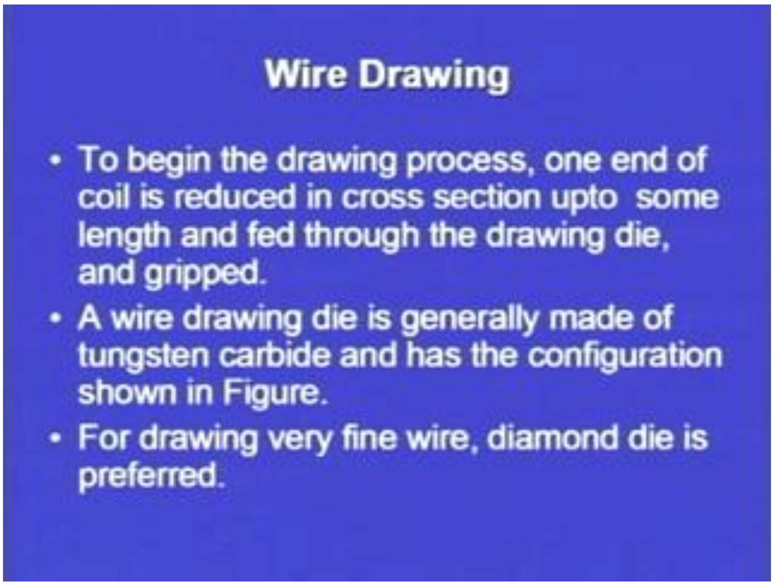
And the other important aspect that is the pulling forces will also will not be too much. So, in wet drawing all the assembly will be under the action of the lubricant or will be immersed in a liquid lubricant. In case of dry drawing, the wire that is being passed inside the die will be covered with the lubricant, that lubricant can be in the form of soap. We apply a soap or any kind of a solid lubricant on the wire before it enters into the die cavity. So, it will have, it will carry a film of the lubricant when it is going through the process of reduction of area.

Then, there is another type of lubrication that is possible that is coating. So, we may apply some kind of surface coating which may be made up of any material like copper or tin, and these materials will act as solid lubricants. So, when the wire is being subjected to a reduction that is the wire is passing through a die. These solid lubricants will help to improve the performance of the die in wire drawing operation. And that drawing operation will be improve, what will be the improvement that will be noted? That improvement that will be noted will be in terms of die life, surface finish, temperature and drawing forces.

So, we have seen that the material of the die that we choose, and the lubrication that we choose. Moreover, the process of lubrication that we choose, we will decide that what will be the surface finish of the wire after it goes the wire, after it undergoes the wire drawing operation. So, after wire drawing whatever wire that we get will depend upon the type of the die or the material of the die, moreover the lubrication that has been provided during the wire drawing operation.

Now, wire drawing we will just try to understand, we have seen what are the basic diagrams for wire drawing process? What is the die material? What is the lubrication? What is the type of lubrication that is possible or the lubrication process that is possible? Then what is wire drawing?

(Refer Slide Time: 43:17)

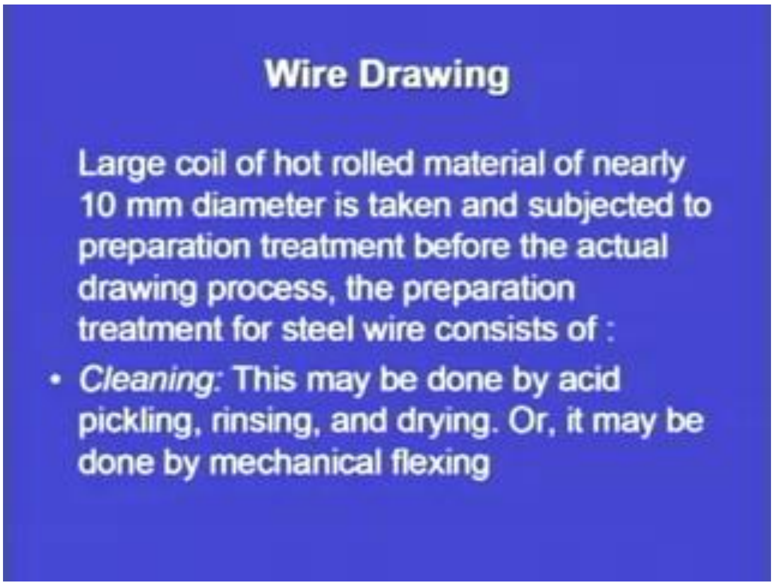


To begin the drawing process, how wire drawing is done? To begin the drawing process, one end of the coil is reduced in cross section up to some length, and fed through the drawing die and gripped. So, how the operation actually is performed, we have seen in one of the previous diagrams that the wire is coming from the coil, and it is getting submerged into the or immersed into the lubricant then it enters into the die cavity, and it is pulled by the draw block that is a very basic diagram.

But, how in actual practice we perform the wire drawing operation? In actual practice, some length of the wire is reduced in cross section, it is passed through the die, and then it is gripped. A wire drawing die is generally made of tungsten carbide, and has the configuration as shown in figure. We have already seen in the figure that how the die is going to look like. Then the material also is specified here, most of the times the die that is made for wire drawing operation is made up of tungsten carbide.

For drawing a very fine wire, a diamond die is preferred. Already in die material and lubrication we have seen that there are 3 types of materials out of which we can make a wire drawing die that can be tool steel, that can be carbide or that can be diamond. So, diamond basically is used for drawing wire, which is of very small diameter or a very fine wire. So, in order to start our operation we have to reduce the diameter, we have to pass it through the die and finally it is gripped.

(Refer Slide Time: 45:03)

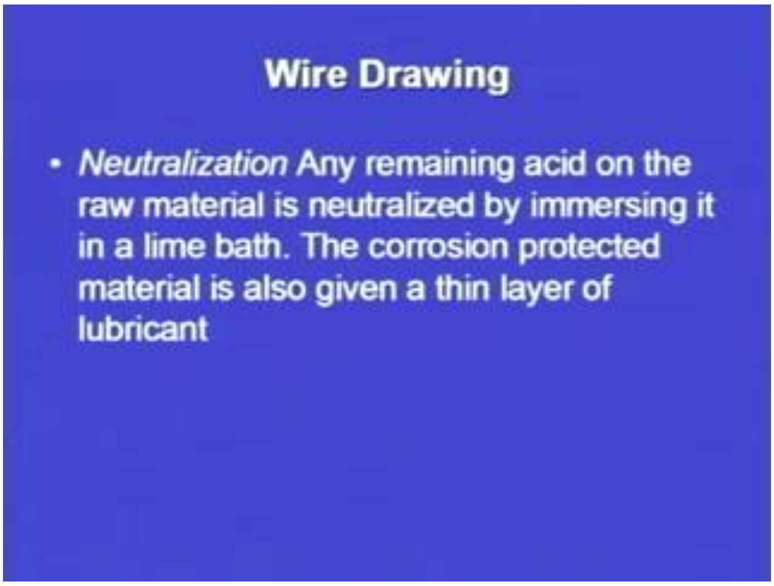


So, now large coil of hot rolled material of nearly 10 millimeter diameter is taken, and subjected to preparation treatment before the actual drawing process. The preparation treatment for steel wire consists of. So, it is not that whatever wire we take, we are directly going to subject it to the wire drawing operation. It needs certain treatment before it can be subjected to the wire drawing operation. So, now a large coil of hot rolled material of 10 millimeter diameter, it is taken and it is subjected for preparation treatment before actual drawing process.

So, what are these treatments that are given? So, if a steel wire is being used for making the final product that is the final wire will be made up of steel. So, the two operations that are done before the wire drawing operation are this is cleaning. First operation is cleaning before the wire drawing; this may be done by acid pickling. So, acid pickling is a process that can be used for cleaning the wire, before it is subjected to wire drawing.

Then it can be subjected to rinsing and drying, it may be done by mechanical flexing also. So, in order to clean the wire before it is subjected to the wire drawing operation, we can go for all these processes that have been mentioned like, acid pickling. It can go for rinsing or drying or it can go for mechanical flexing. So, these processes have to be carried before the wire is subjected to the final drawing operation.

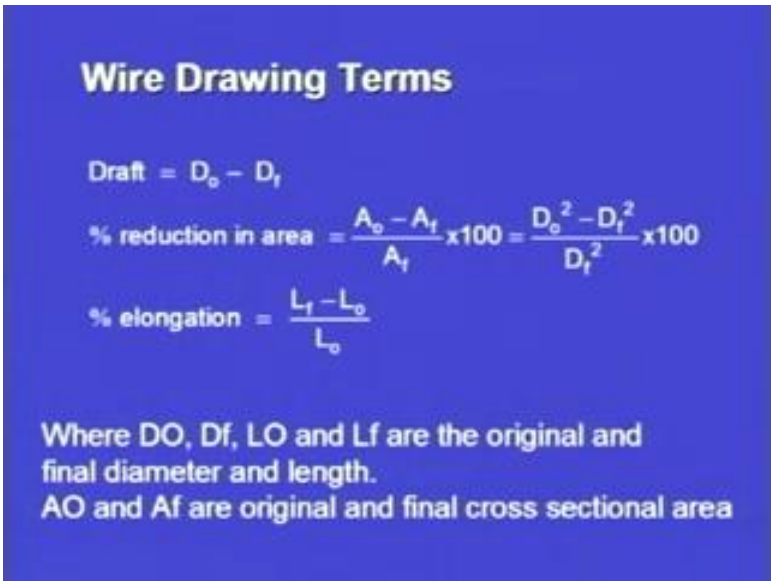
(Refer Slide Time: 46:41)



Then the another operation or the another treatment that has to be given, before the wire is subjected to wire drawing that is the neutralization operation. So, in neutralization any remaining acid on the raw material is neutralized by immersing it in lime bath. So, we have seen in first operation of cleaning, we are using acid pickling. So, any remaining acid that is there on the wire that can be neutralized by immersing the wire into a lime bath. The corrosion protected material is also given a thin layer of lubrication or a thin layer of lubricant.

So, any material that has to be protected from corrosion can be given a layer of the lubricant, so that it do not corrode or it do not rust. So, we have seen that before the wire is subjected to the operation of wire drawing, we have to clean it and we have to neutralize it. So, cleaning and neutralization is important if we want to get the wire or the final product according to our desired specifications, according to our desired quality level, and according to our desired tolerance level. So, these are some of the analytical terms in relation to wire drawing.

(Refer Slide Time: 48:00)

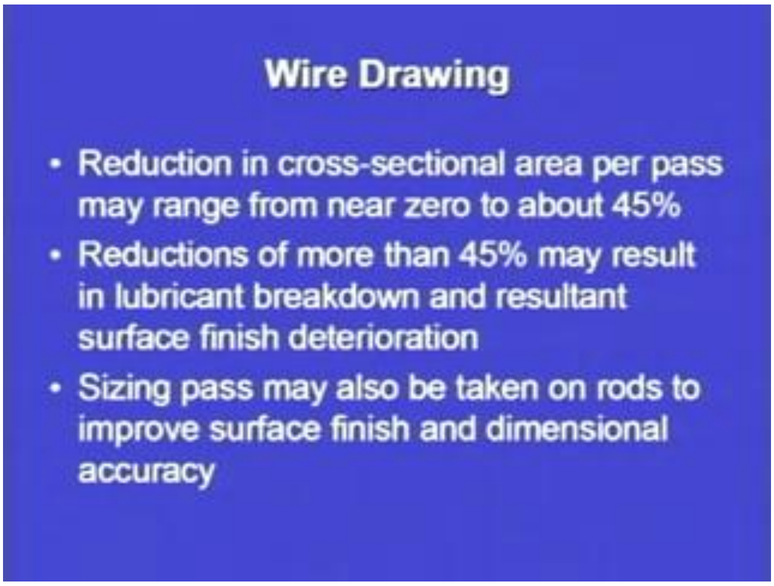


So, what are the wire drawing terms? First one is the draft that is D o minus D f. So, what is D o and D f? D o and D f are the original and final diameter. So, the draft can be defined as the difference between the original and the final diameter. Similarly, percentage reduction in area is given by A o minus A f divided by A f multiplied by 100, which can be written in terms of the diameter, in terms of diameter by equation can be written as D o square minus D f square divided by D f square multiplied by 100.

So, what is D o and D f? Already we have seen D o and D f are the original and final diameter. Similarly percentage elongation, percentage elongation is given in terms of the length. So, percentage elongation formula can be written as L f minus L o divided by L o. So, here another important term is coming that is Lf and L o, what is L f and Lo? It has been written that L f and L o are the final and the original diameter of original length of the wire. So, we have seen that there are three important wire drawing terms that have to be used during the process of wire drawing.

The first one is draft that is given by D o minus D f, then the percentage reduction in area that is given by D o square minus D f square divided by D f square multiplied by 100. And the percentage elongation that is given by L f minus L o divided by L o. Just to review what is D o and D f? What is L o and L f? D o, D f, L o, L f are the original and final diameter and length. A o and A f are original and final cross sectional areas. So, these wire drawing terms are useful when we go into the analytical formulation or wherever we calculate the percentage reduction in the area or wherever we calculate the pulling forces or the die pull.

(Refer Slide Time: 50:23)



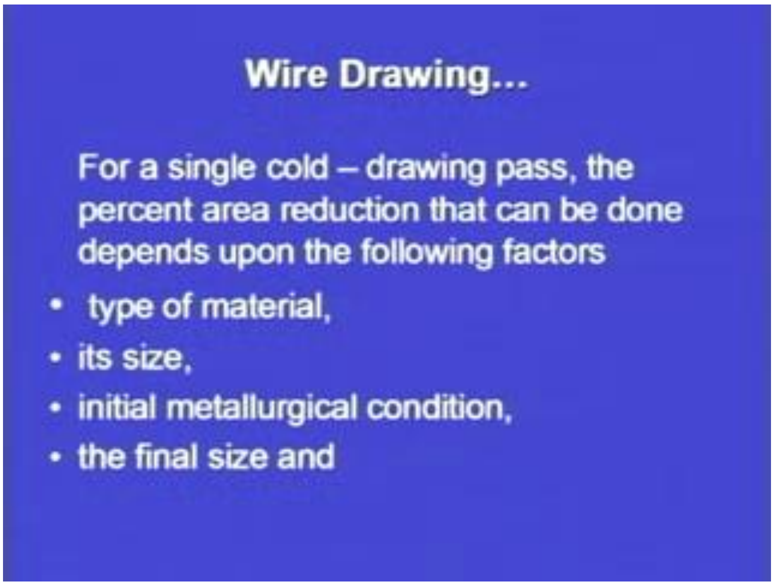
Now, wire drawing the another important aspect is the reduction in the cross sectional area. So, in one of the previous slides we have seen that we cannot reduce the cross sectional area in one stage itself, it has to be reduced in a number of stages. So, now a reduction in cross sectional area per pass may range from near 0 to about 45 percent. So, the reduction in cross sectional area can be range ranged from or the range for reduction in cross sectional area is from 0 to about 45 percent. Reduction somebody may question, somebody may ask that why the reduction is limited to 45 percent only? Why not go beyond 45 percent?

So, reduction of more than 45 percent may result in lubricant breakdown, and resultant surface finish deterioration. Although we can go for reduction or percentage reduction of more than 45 percent also, but there are problem areas, there are certain limitations attached with the selection of reduction area more than 45 percent. So, what are these problem areas? These problem areas are that the surface finish or the quality of the wire that we will get may not be that good may not be according to our desired quality standards. Moreover the lubricant or the coating that has been provided on the wire may tear off.

So, the lubricant breakdown or the coating breakdown may take place, and the resultant finish may not be up to our desired level. Moreover after the reduction we have a sizing pass also, in sizing pass we take care of the size of the material, this is not going to go for a reduction in case of sizing pass, the reduction will be very, very minute or sometimes there may be no reduction also. In sizing pass may also be taken on rods to improve surface finish and dimensional accuracy.

So, the importance of sizing pass is to improve the surface finish and the dimensional accuracy. If some surfaces profiles are not according to our desired level, we can make use of a sizing die, we can give a sizing pass to the wire, so that our dimensional accuracy is good, as well as the surface finish is good according to our desired levels.

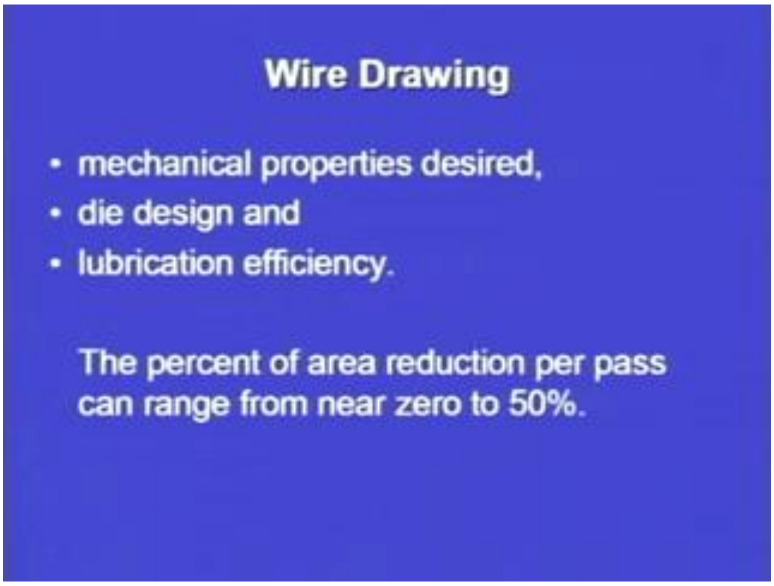
(Refer Slide Time: 52:58)



Now, wire drawing for a single cold drawing pass, so wire drawing can also be done at an elevated temperature depending upon the material for which we are subjecting the wire drawing operation. So, for a single cold drawing pass, the percentage area reduction that can be done depends upon the following factor. So, we have already put a limit that it can be from near 0 to about 45 percent reduction, but for a single cold drawing pass, the percentage area reduction depends upon a number of factors, what are these factors?

The percentage reduction depends on the type of material already we have seen, because the strains are quite high. So, it depends that whether that material is able to sustain that much amount of strain or not. So, the type of material will decide the percentage reduction. Then its size will decide the percentage reduction, initial metallurgical conditions will decide, moreover the final shape that we want to make that will decide that how much reduction we should have in a single pass.

(Refer Slide Time: 53:59)



Then the mechanical properties desired sometimes if we subject a material to single pass only, and we are not reducing the cross sectional area in a number of passes. Then the mechanical properties of the final product may be different, when we have made the same wire at number of stages. So, we it depends that what type of mechanical properties we want to achieve in our final products, and we have to decide that whether it should be a single pass process or it should be a multi stage or multi pass process, moreover the die design and the lubrication efficiency.

So, number of factors will decide that how much percentage reduction should be given in a single pass in cold drawing process. So, the percentage of area reduction can go per pass up to nearly 50 percent, we have put the limit from 0 to 45 percent, but it can go up to a maximum of 50 percent also. Now, it depends upon all these parameters that we have seen the initial size, the final size, the final mechanical properties that we want to get, the final surface finish that we want to get or what is the design of the die? What is the lubrication efficiency? Whether we are able to get proper lubrication or not?

So, all these parameters will decide that what should be the percentage reduction in area in a single pass. So, the percentage of area reduction per pass can range from near 0 to 50 percent. So, here we come to the end of this lecture on swaging and wire drawing. Although some portion of wire drawing like die pull, tube drawing that we will discuss in our next lecture that will be dedicated towards sheet metal operations. So, in order to summarize, what we have discussed today? We started our discussion with a brief review of what has been discussed in our previous lectures.

Then we started with discussing the process of swaging, what are the different types of shapes that we can make using the swaging operation? We discussed the versatility of the swaging operation then we went on to discuss the basics of wire drawing operation. In wire drawing we saw that what is the shape of the die? What is the material of the die? Why lubrication is given? What are the different types of lubrication arrangements that can be given different types of lubrication processes? Then we went on to discuss the fundamentals of wire drawing, and the fundamentals of percentage reduction of area. So, that is all in this lecture on swaging and wire drawing.

Thank you.