Fundamentals of Manufacturing Processes
Dr. D. K. Dwivedi
Department of Mechanical & Industrial Engineering
Indian Institute of Technology, Roorkee

Lecture – 27
Metal working processes: Forging

Hello, I welcome you all in this presentation related with the subject fundamentals of the manufacturing processes and we are talking about the metal working processes among the metal working processes, I have already talked about the rolling process.

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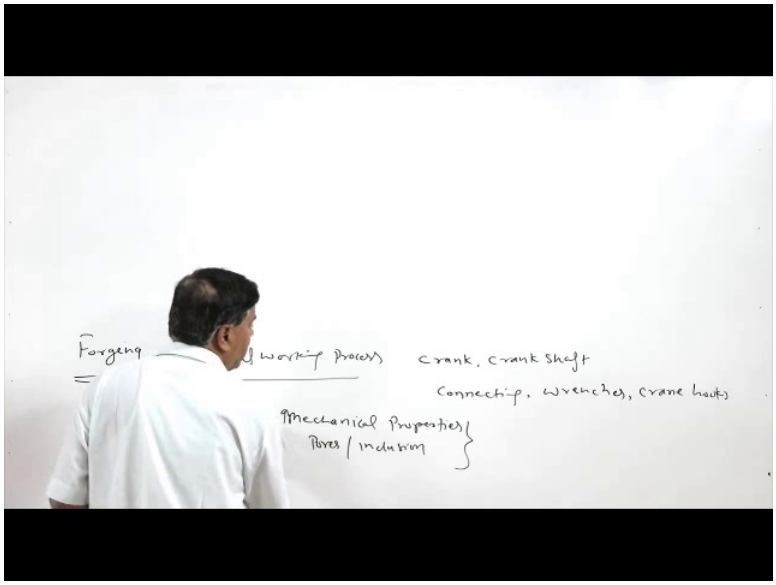

And today I will be talking about another important process which is called forging. This is a very important metal working process which is used which is of the great commercial importance because it is extensively used for making and the variety of the products which are extensively used like a crank; crank shafts for automobile then connecting rods wrenches which are used for assembling and dissembling purposes crane hooks.

So, there are so many components which are made of by this forging process and advantage is that it improves the mechanical properties and results in very sound and at the dense products. So, improved mechanical properties as well as a like the pores and inclusions, etcetera, if they are there; they are closed and homogenized. So, it improves the density and the soundness of the products which are made by the forging process; we

will go through the first through; the basic approaches which are used in forging process and thereafter we will talk about the different types.

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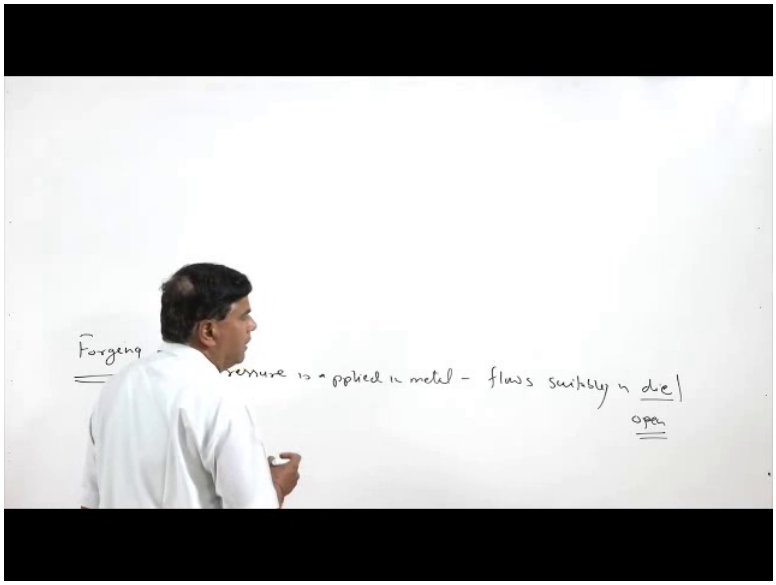

So, basically in this one; the pressure which is mostly the compressive force is applied in metal. So, it flows or deforms plastically. So, the metal flows suitably either in die or in open a space if it is the die, then we get the impression or the shape which is desired and if we the flow is in open; this is called open die in that case the flow is to be regulated through the controlled manipulation of the metal deformation in order to get the shape which is desired there are 2 broad categories or broad approaches which are used in the forging processes and these are called the drawing out and upsetting.

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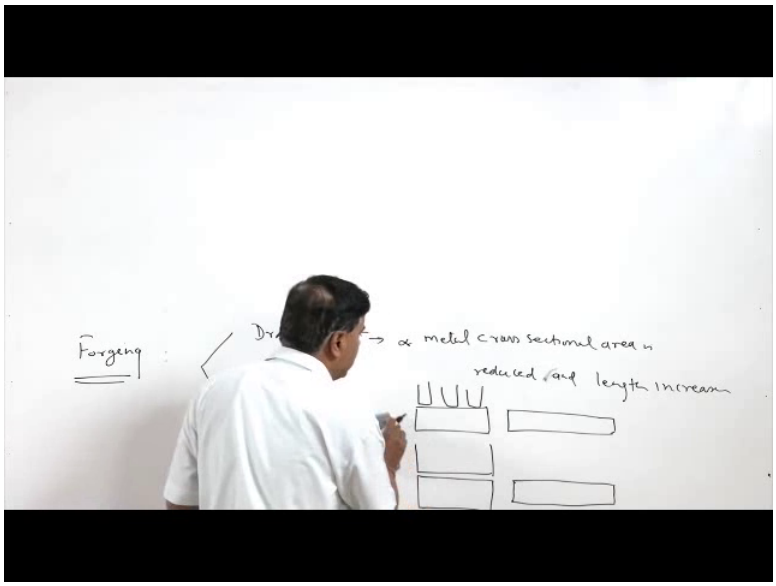

So, in the forging whenever there is a plastic flow of the metal depending upon the way by which thus desired shape is being achieved by the application of the force we say it the drawing out or the upsetting force; these are the 2 broad categories, in case of the drawing out process of the forging basically the metal cross sectional area is reduced and or the length increases. So, basically the job along it is in a; during the drawing process and so here like the job is like this.

So, if we are either applying the hammers continuously like this. So, the section is reduced and the length is increased in this manner. So, this is one case or we can apply the force through the ram directly onto the plate which is of the larger thickness and after the application of the force the section thickness is reduced and the length is increased.

So, basically the cross sectional area is reduced and the length is increased.

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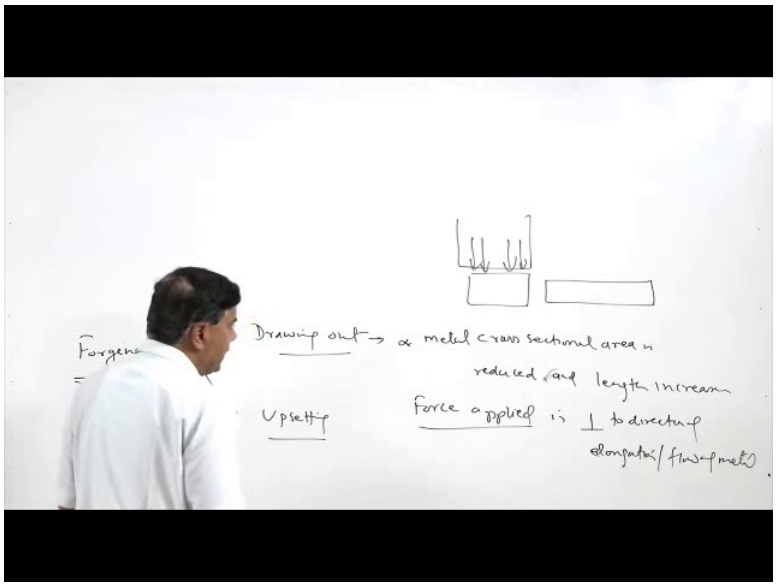

So, if we see here the force applied the application of the force is here perpendicular to the direction of elongation or flow of the metal or flow of metal. So, like this piece is subjected to the force in this manner with the help of the ram or the open die.

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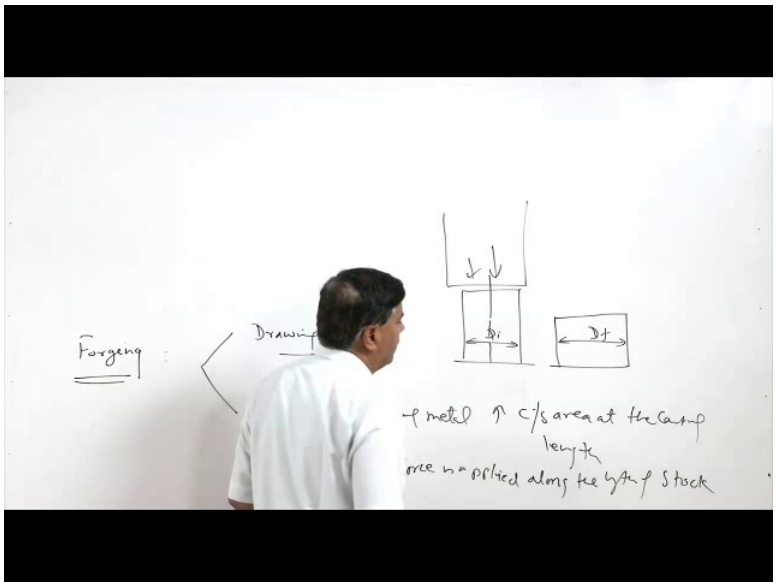

So, here it compresses and reduces the thickness and thereby increases the length while in case of the upsetting just reverse happens and in case of the upsetting the flow of the metal or the plastic deformation increases the cross sectional area at the cost of length

basically length reduces and increase in cross sectional area takes place and another thing the force is applied along the length of the a stock or the job.

So, to understand this if the job is like this in the beginning with the application of the force perpendicular to this the length is reduced this manner and increase in diameter takes place. So, this is what we can write like this also like significant reduction in length and increase in diameter. So, initially if the diameter was di and this the increase in a after the upsetting are this increase takes place with the significant increase in the diameter.

So, this is what is called the upsetting and the force is applied in the direction or in the length direction of the job. So, these are the 2 broad categories. So, actual a forging processes may be either singly or in combination be using and the flow of the metal either the drawing out or the upsetting may be achieved or combination of the both can be used for a achieving the desired shape and the size of the component.

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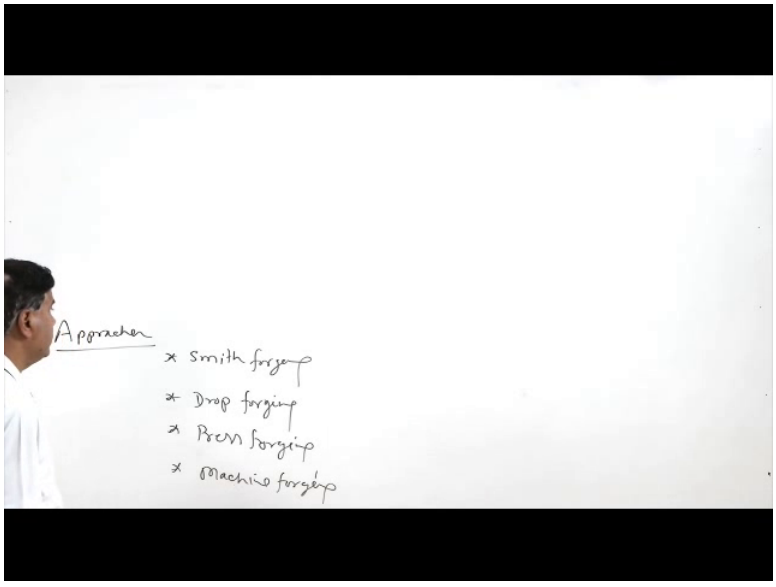

So, they are depending upon the approaches or the methods being used the forging processes are categorized as a smith forging drop forging press forging and machine forging. So, smith forging I will talk one by one about all these types of the forging processes smith forging is basically like the black smith which in villages earlier; this is the traditional method black smith used to heat the metal stock and heated metal stock is repeatedly beated to manipulate to manipulate the flow of molten metal.

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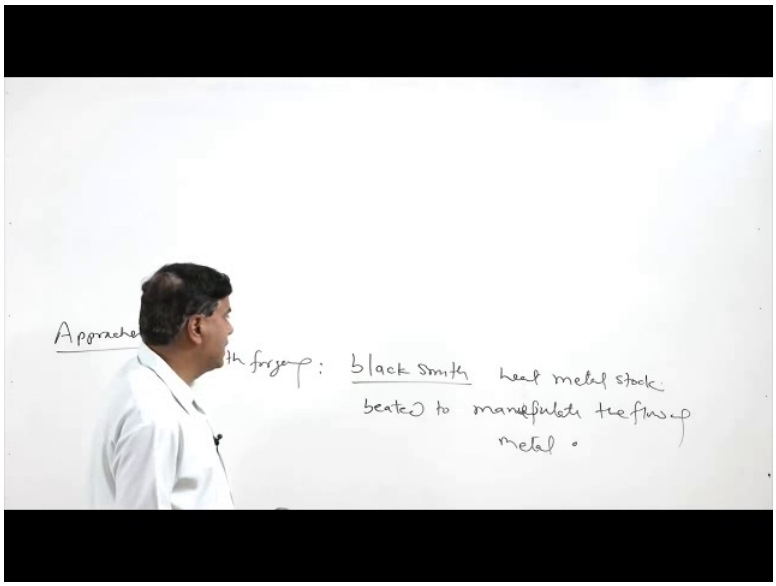

So, as to get the desired size and shape; so, here the controlled manipulation of the metal by beating it by beating the hot metal using the hammer which is mostly manually operated.

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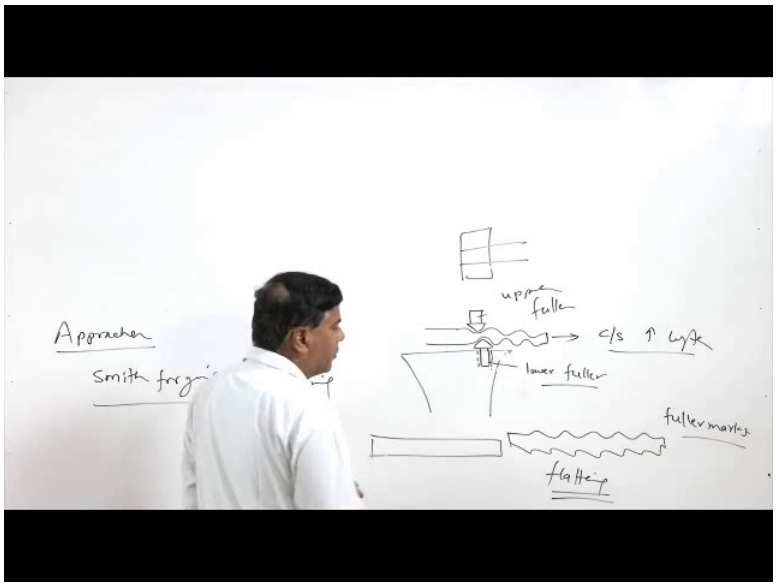

So, hammer is used to beat the metal. So, that desired manipulation is achieved. So, one typical the process which is called fullering in black forging a sorry smith forging process a wherein over the anvil say this is the anvil having the hole in which the fuller is placed like this over the anvil and so this is the lower fuller and over this like this. So,

another fuller is placed here like this and the metal is beaten with the help of the hammer in this manner.

So, basically the stock is placed over the lower fuller and this is the upper fuller and the hammering is done of the upper floors. So, that metal flows in the length direction this reduces the cross section and increases the length. So, in this way what we get basically we get the stock with the reduced thickness and increase the length; obviously, it will have the fuller marks. So, in order to smooth in the surface in order to flatten the surface basically the flattening is done. So, that all these; the fuller marks can be taken care of and the reduced thickness can be achieved.

So, that required cross section can be achieved if you see the control of the flow of the metal due to the impact of the hammer is important and that needs to be manipulated very carefully and therefore, that is the shape.

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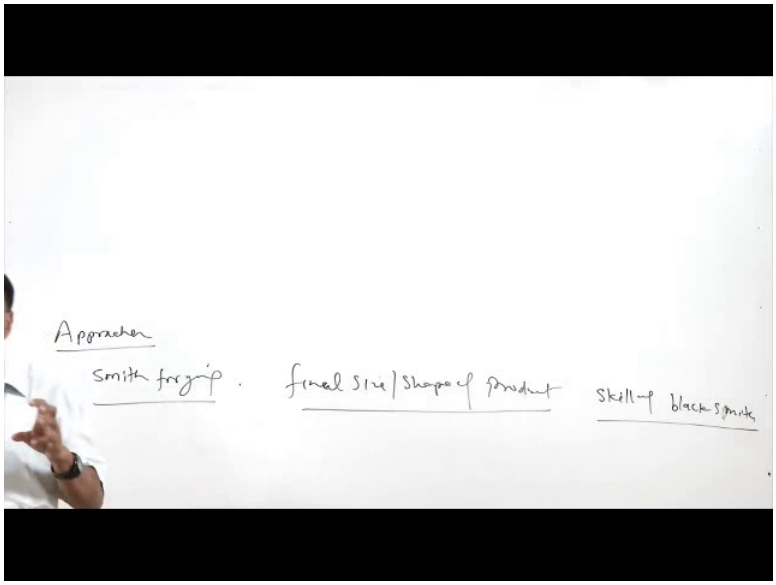

The final size and the shape of the product which is obtained through black smith a largely depends upon the a skill of the black smith; a skill of the black smith how carefully and how properly he manipulates the flow of the metal due to the in continuous impact of the hammer that is what is regulated in order to achieve the desired size and the shape.

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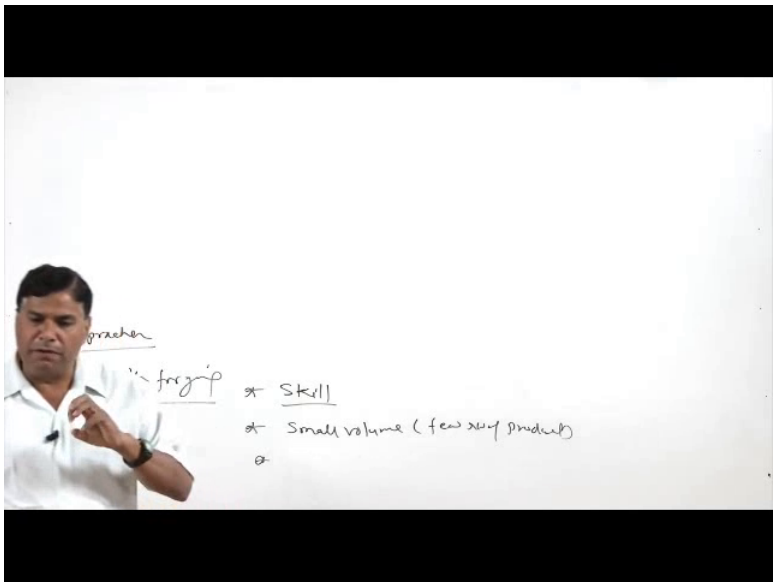

So, for this process black smith process; sorry; smith forging process the skill of the operator or a skill of the black smith is important another thing is that this process is a good for the for the a small volume means when a few number of the products are to be made not for the very large volume because if you have to make very few number of the products, then making the die will be in will be a costly issue. So, it will be important that instead of you making the die for making few products better to use them smith forging process.

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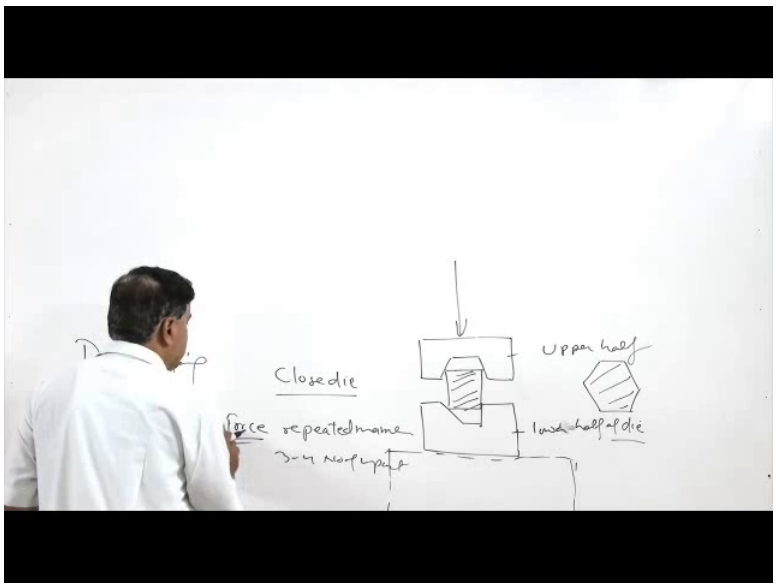

So, that it can be made economically another process forging process is the drop forging process in a smith forging process basically and the flat surface is are used. So, the flow of the metal is not metal is not confined in particular place, but it is open to for the flow the sidewise. So, that sidewise flow of the metal is regulated in such a way that we can get the desired size and shape.

While in case of the drop forging close dies are used. So, here according to the shape of the product to be made will have to make the die like this; this is the upper die and say this is the lower die. So, this will be placed over the table of the press and here; we will be placing the stock or the material like this. So, basically with the help of the press this; this is the lower half of the die and this is the upper half of the die.

So, after placing the metal between the dies when they are open now upper die is now the force is applied through the upper die onto the a stock until the die closes. So, here the force is applied in repeated manner repeated manner these three to four number of the impacts are applied onto the stock with the help of the upper half of the die. So, that the die is closed once the die is closed we will be getting the product of the shape like this.

So, this will be the product this may not be the final product. So, in order to get the final product we may have to make the number of the dies with the gradual changing change in the shape. So, for that purpose a systematic procedure of shaping using the forging die is used since it uses the number of impacts in the drop forging.

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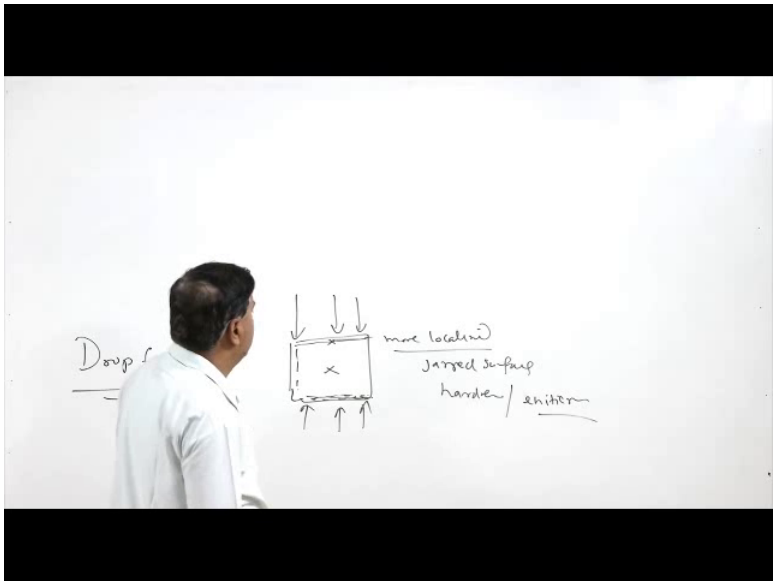

So, whenever the impacts are used in the drop forging the surface layers gets deformed more as compared to the; so, this is the upper surface which will be experiencing the impact of the upper die and the lower surface will also be experiencing the impact of the upper die and because of these impact forces; the metal will be flowing sidewise to occupy the cavity in the die.

So, more localized deformation basically takes place near the surface layers both upper and the lower surfaces and therefore, very jarred surface is produced and surface is much harder than the material in the interior of the job. So, if you measure the hardness at the center and measure the hardness at the top, then more localized deformation will be taking place near the surface layers as compared to the interior portions and that is why there will be heterogeneity on non uniformity in the properties.

So, the deformation actually is not uniform through the depth and through the thickness of the a stock in case of the drop forging now we I will be talking about that if the shape is bit complex like in case of rest with forging where the flat surfaces over there by enlarge. So, manipulation of the metal due to the impacts was more important,, but here since the die is closed.

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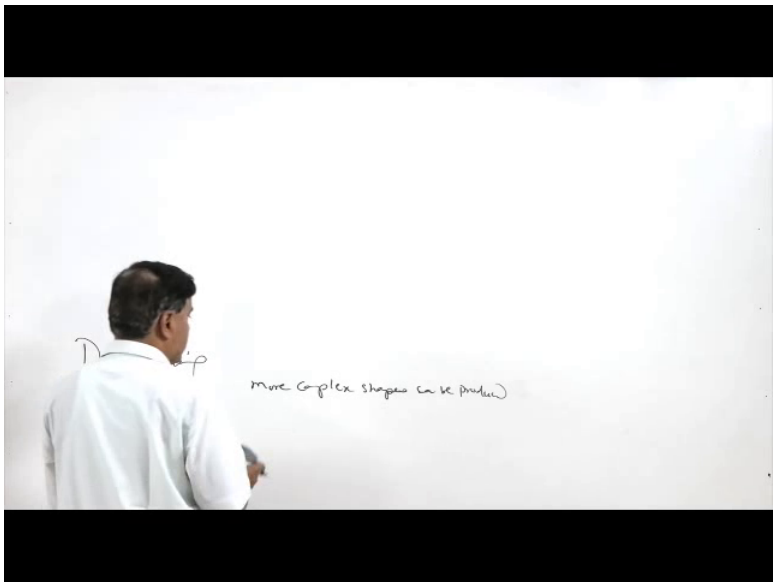

So, more complex shapes can be produced in the by the drop forging process.

But to produce the complex shapes; even one set of the dies may not be enough. So, the number of the set of the dies with the gradually changing shapes are used and for that purpose.

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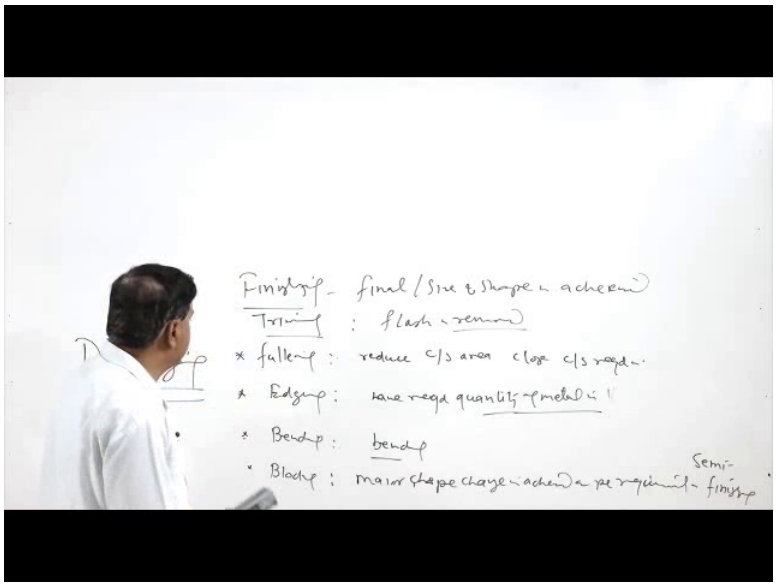

Basically certain steps are used these steps like fullering edging then bending blocking finishing and trimming and trimming. So, purpose of all these steps say for making these somewhat complex shapes we need to follow certain steps depending upon the geometry of the product to be made.

So, fullering actually is used for reducing the cross section cross sectional area close to the cross sectional area required in the job the second is this edging is used to have the required quantity of the metal in the product. So, basically whatever is the amount of the metal desired in the final product that is what is reduced in the edging process and that is what is limited to the requirement in the bending as per the shape of the product here the bending or the bending is a performed. So, that we can reach closer to the with respect to the bending we can reach close to the shape which is desired and in the blocking it is the first major shape change is achieved as per the requirement as per the requirement.

So, this is basically the semi finishing semi finishing step. So, for finishing for finishing purpose after the blocking when the major change in the shape is achieved as per the requirement the final size and the shape is achieved in the finishing stage and then the last one is the trimming if there is in extra material left at the flash. So, the flash is

removed in the trimming steps. So, these are like say 5 six number of these steps which are used in the drop forging for achieving the complex shapes and for each step the separate the die is used. So, that is what; we can you can see with the help of this diagram how it is realized.

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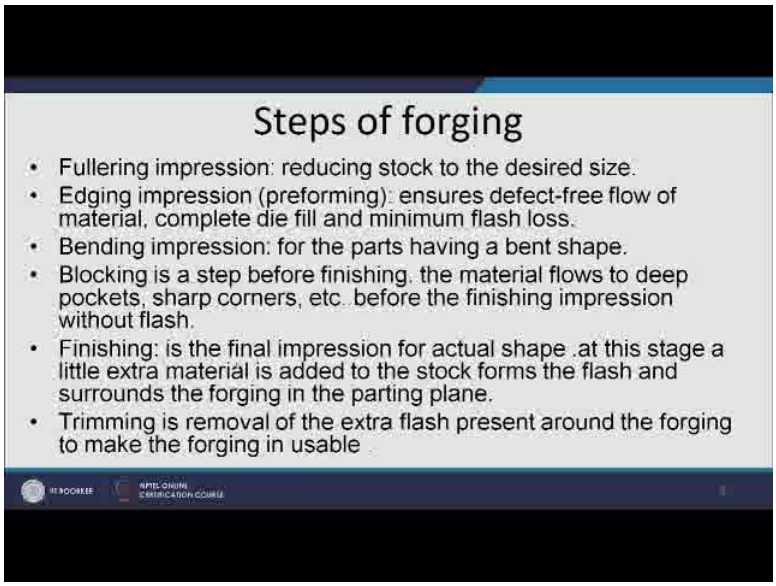

So, if we see here, yeah, these are the steps of the forging like fullering edging bending blocking and the finishing and finally, the trimming.

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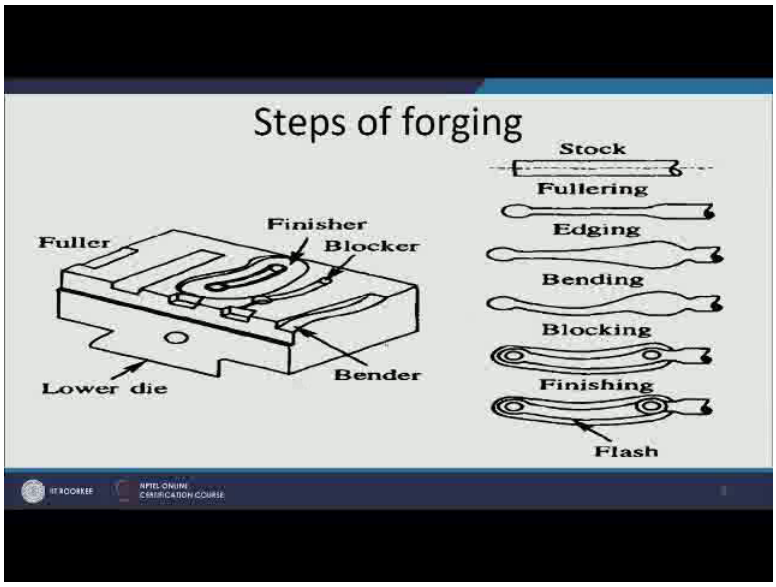

These are the steps which have been shown is schematically here this is the rai stock and the rai stock is first of all brought to the desired cross section by the fullering process and then required volume of the material for the final product is achieved in the edging steps and then as per the shape the bending is carried out and after the bending we do the blocking and blocking helps us to get the shape closer to the shape which is desired and then finishing will help us in getting the final size and shape and once the final size and shape is achieved the extra material which is left can be removed with the help of the trimming.

So, these are the different we can say the steps which have been shown the first one is for fuller then edging and then the blocking finishing bending. So, the different the dies are used for each step.

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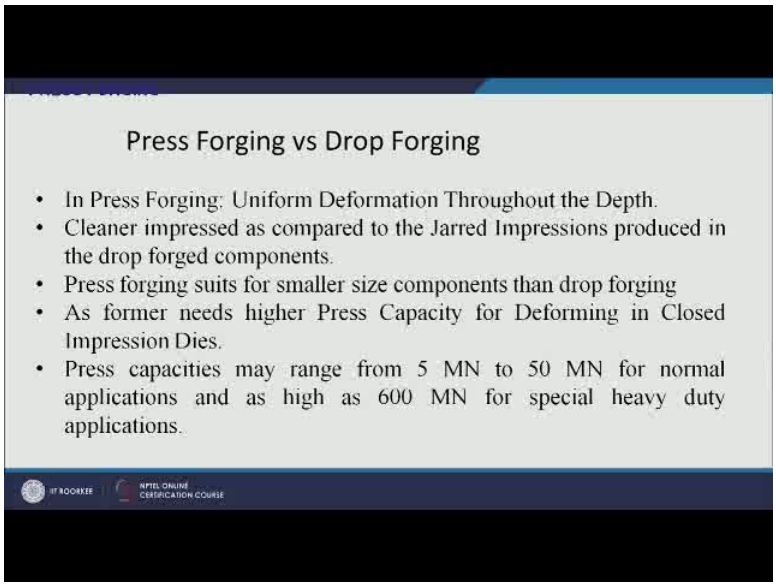

So, that in sequentially the desired shape and the size can be achieved. Now if you have to a compare comparison on the comparison part I will come later because I need to talk right now first about the press forging.

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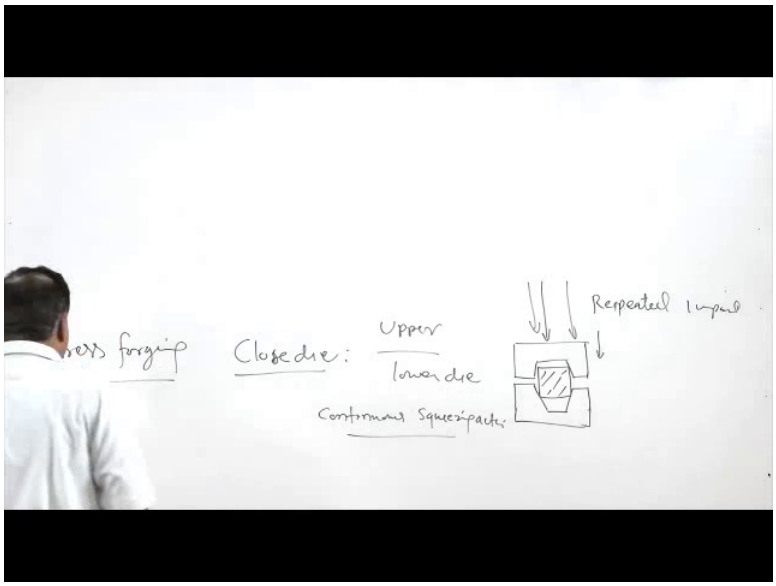

So, now, will take up the press forging press forging also uses the close dies means there is a upper and there is lower die and the metal is placed between the upper and the lower dies.

So, after the application of the pressure; the die is closed and the shape is desired. So, like this is the upper die and this is the lower die and the raw material is placed between the 2 dies like this. So, what we do the in the earlier case, repeated means in the drop forging repeated impacts were applied through the upper die,, but in this case continuous increasing pressure performs the squeezing action.

So, once the pressure starts to build up the upper die is moved continuously until the dies are closed. So, the metal is closed a metal is basically is squeezed between the 2 dies and when it is squeezed it flows within the cavity and follows all the profiles which are there. So, that there is continuous flow of the metal to fill the; to fill of the various cavities and the features which are there in upper and the lower die.

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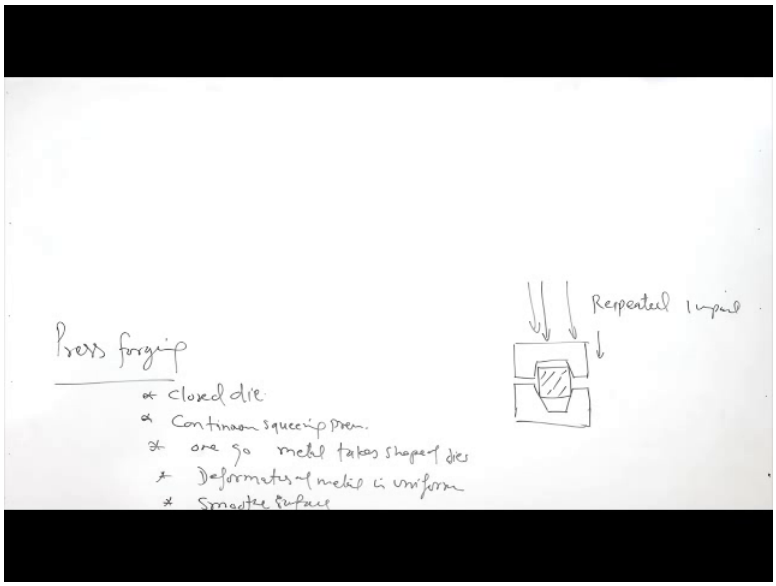

So, here in this case; the important features like closed dies are used uses closed dies and continuous squeezing pressure is used and when the continuous pressure is used in one go in one go the metal takes the shape of the dies on closer and during the squeezing action the deformation of the metal deformation of the metal is uniform through the thickness or throughout the depth.

So, deformation of the metal is uniform through the depth or through the thickness. So, more homogeneous flow an uniform flow of the metal takes place under the pressure conditions and more smoother surface is generated; so, more a smoother surface.

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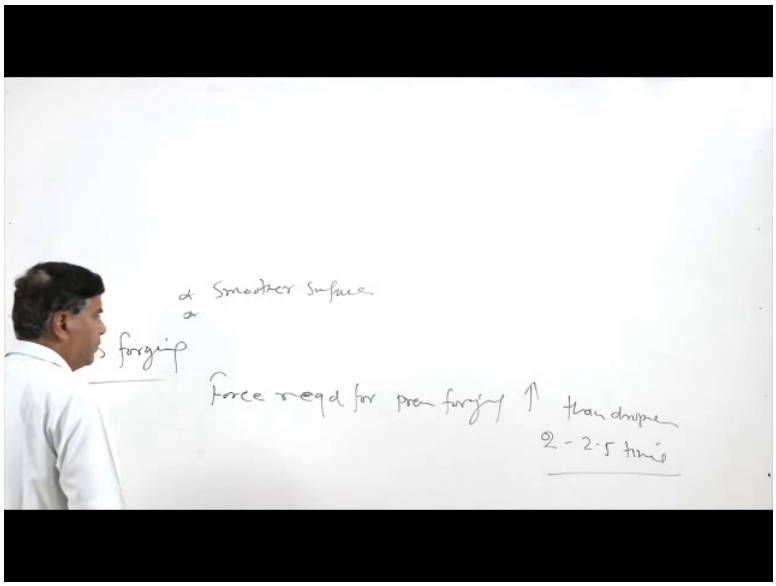

So, here we can say the; is smoother surface is generated in the press forced products as compared to the drop forced products.

Since, it applies the squeezing action by increasing the pressure continuously. So, the kind of pressures which need to be used for the press forging a kind of force which is to be used for press forging is very high. So, the force required for press forging is very high is higher than the drop forging and which is sometimes 2 to 2.5 times of the press capacity then that is needed for the drop forging.

So, now depending upon the kind of the size of the job the press forging is used since the force.

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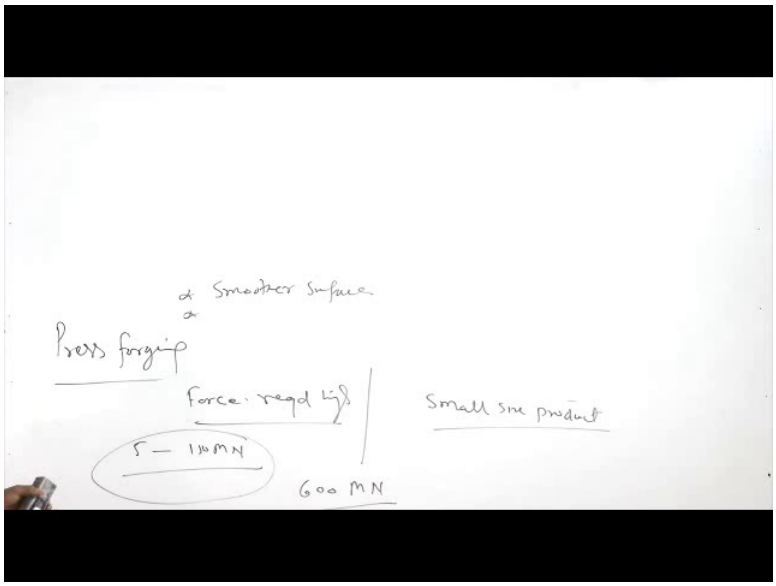

Required is high for the press forging and therefore, it is mostly used for the a small size products because it is difficult to have the presses of the very large capacity. So, if we see here normally the 5 to the 150 million Newton press capacities are normally used, but these can be much larger up to like say the 600 million Newton capacity. So, it is the capacity that limits the size of the job which can be handled by the forging pressure forging press forging because very large capacities of the presses are required for press forging for the large size job.

Therefore the press forging is limited to the; a small size products coming to the machine.

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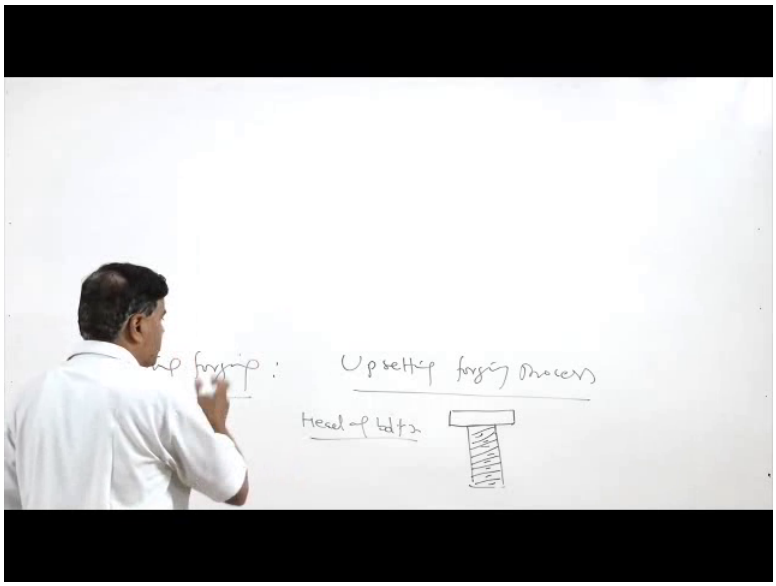

Forging machine forging is basically this has been used for the upset forging processes mainly like in case of the head of the bolts for making the head of the bolts machine forging has been used extensively like we have the bolt having the threads like this. So, at the top if we need bolt we need to upset and make the head like this.

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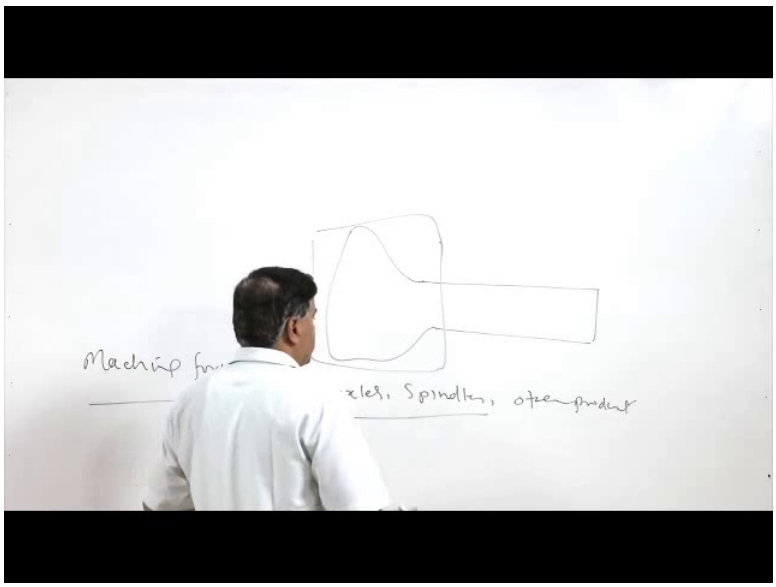

So, for making the heads in case of the bolts this process was initially used and thereafter it has been used for making many other the products of the importance like the axles spindles and a number of the components having the like where is upsetting is needed

and other products which use the one end is a cylindrical or of the particular cross section and other end is of the having the upset section. So, this may be of the different cross sections. So, such kind of cross sections where one end is of this smaller cross section and other end is large. So, the machine forging is normally used for and those purposes and the axles spindles head of the bolts are the common examples of the machine forging products.

So, if we see here the just for the comparison purpose as I have said the press forging and the drop forging in press forging uniform deformation throughout the depth and the surface is more cleaner as compared to the drop forged products because the drop forged products have the jarred impressions and in your press forging suits for the smaller size component than the drop forging because the capacity limits the size of the components which can be made by the press forging because the press forging needs the higher press capacity for deforming in closed impression dies.

So, the press capacities doubly range from say 5 to 50 million Newton for the normal applications, but this can be much higher for especial duty in heavy duty applications like 600 millions.

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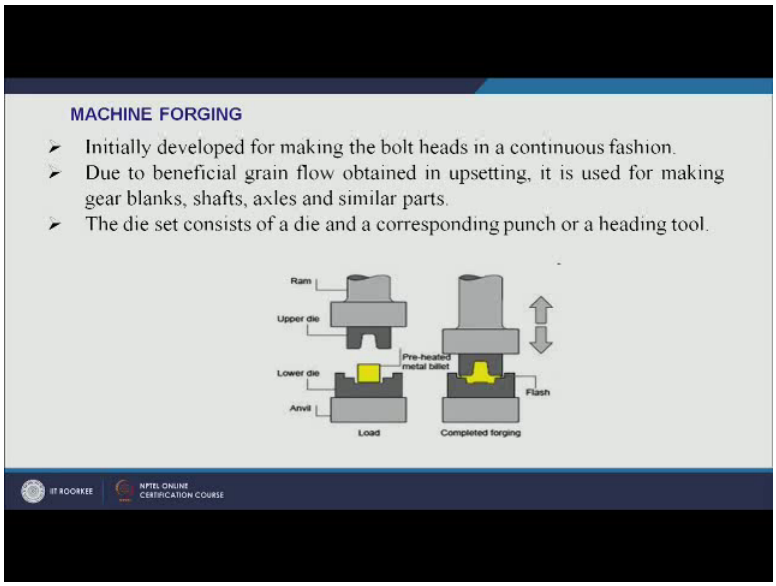

So, as far as machine folding just as I have described; the initially the machine forging has been developed for making the head of the bolts in continuous fashions and advantage of this, it helps to regulate the flow of the grains in such a way that we can

have the grain orientation in favorable manner. So, that desired properties can be achieved. So, gear blanks shafts axles and the similar parts can be made by the machine forging and the die sets which are used for the machine forging which uses die set where there is a die and there is a punch for heading the or you can say heading or punch or the heading tool.

So, if we see here this is the ram this is the upper portion of the die and this is the lower die and this is the anvil and between the 2 the job is placed. So, this is smaller cross sectional area in one end another cross sectional area is increase in cross sectional area is a chip through the upsetting. So, that one end is of the larger cross section, then the another end.

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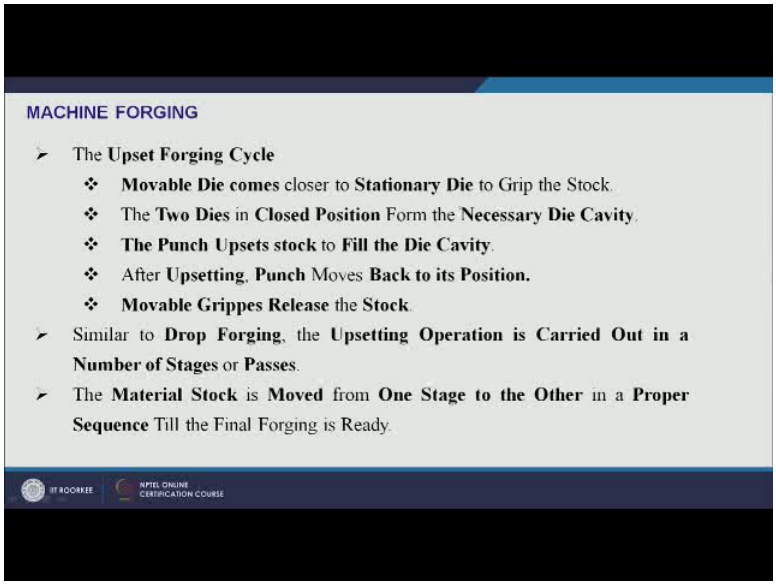

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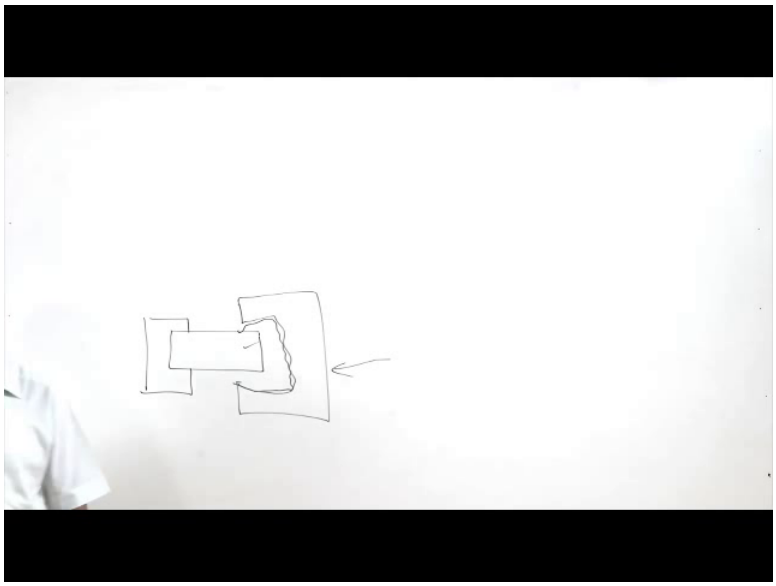

So, these are the steps which are used where upset forging cycle is used where movable die comes close to the a stationary die to grip they stock and so it is; there is the process very simple here like this; there is this is a stock.

So, this is a stationary die and then there is a moveable die. So, moveable die is in this side. So, this will have the complication the shape which is desired it will be move it will be moved coming closer and once the dies are closed the flow of the metal will be taking place. So, as it moves the dies will close gradually in meantime the stock will be upset and the flow of the metal will facilitate will be occupying the; will be following the path of the internal surfaces of the die cavity. So, this is what is achieved movable die comes closer to the stationary die with the grip to the stock and the 2 dies in closed positions form necessary impression in the die cavity necessary die cavity form that necessary die cavity and the punch upsets stock until fill the die cavity and after upsetting punch move is back to its position and movable grippes movable grippes release the stock.

So, this is similar to the drop forging upsetting operation is carried out in the number of a stages as per the required complexity of the shape and the stock material is removed from one stage to the another in proper sequential manner. So, as per the complexity of the shape different kind of the different stages can be followed.

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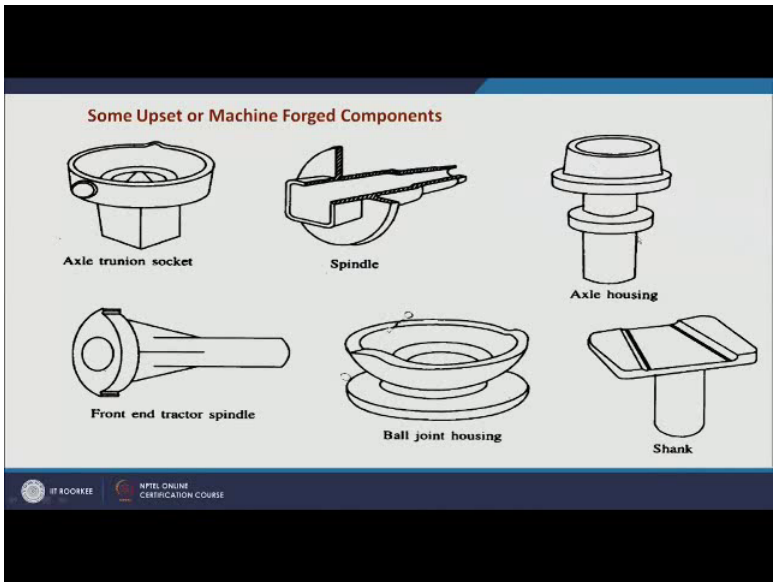

So, these are the different products which can be made having the one end of the smaller cross sectional area, then the other end and these kind of the shapes can be made easily using the machine forging process.

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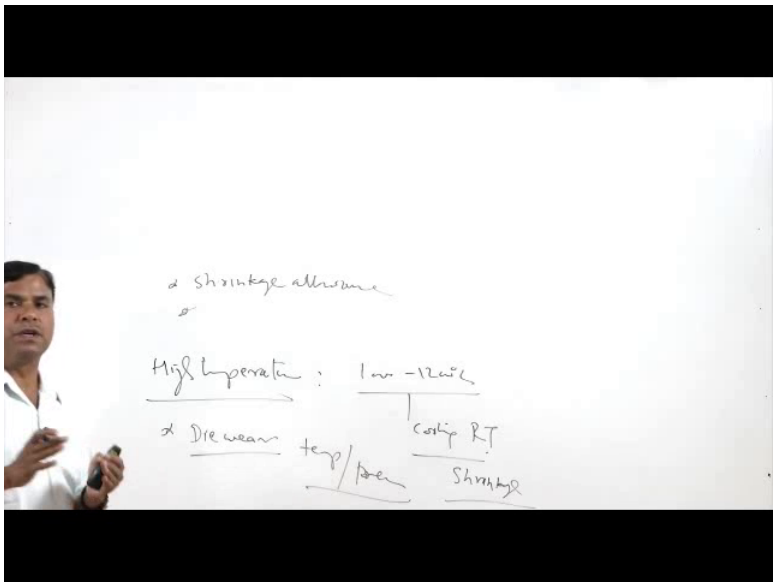

So, now there are few more things related with the forging process since the forging is carried out at the high temperature invariably its hot working. So, high temperature leads to the likes say 1000 to the 1200 degree centigrade at which the deformation is facilitated followed by cooling to the room temperature. So, this involves lot of shrinkage. So, the

shrinkage is kept in mind and for this purpose normally the shrinkage allowance is given the second is the second aspect is the die wear allowance we know that the dies allowed to work at high temperature and under the high pressure conditions.

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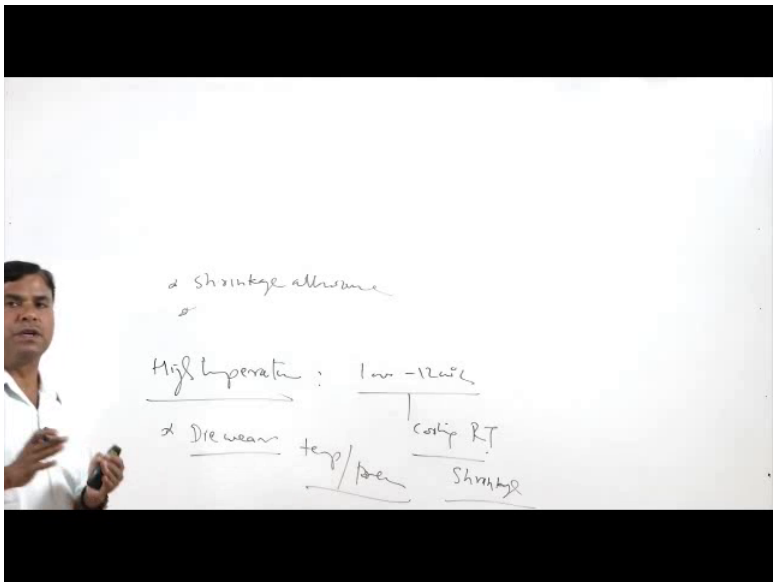

So, the die surface is we are out gradually and the; to take care of that wear of the die surface when the die-surface will be are out there will be increase in the dimensions of the job.

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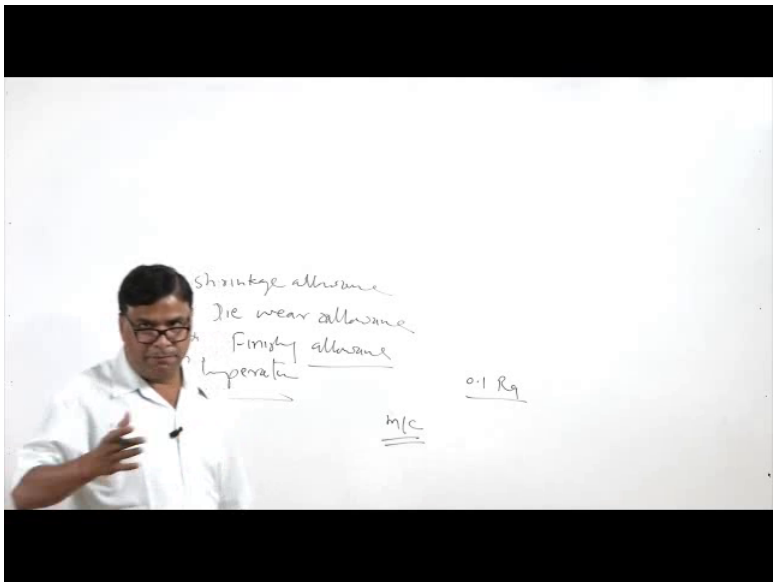

So, that is also taken care of in the die wear allowance die wear allowance and then there is one more thing which is kept in mind that is the finish allowance finish allowance we know that if you have to if you have if you want to have a very good surface finish like 0.1 which of course, cannot be achieved through the metalworking processes.

So, we need to machine the surfaces. So, for machining purpose for machining the components we need to have the material. So, additional material is provided for and the machining purpose. So, that desired finish can be achieved and for that extra material is provided by giving the machining allowance. So, these are the additional features with the forging.

Now I will summarize this presentation. In this presentation, I have talked about the forging process and that there are 2 broad categories one is upset forging and another is drawing out means these are the 2 steps and there are four types of the forging process a smith forging where drop forging press forging and machine forging and the variety of the products can be made with very good mechanical properties for the service of the engineering applications.

Thank you for your attention.