Manufacturing Processes - 1

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Module - 01
Lecture - 05
Forging

I welcome you all to the second session on metal forming processes. We have started this series of lectures, on manufacturing technology with emphasis on powder metallurgy and metal forming processes. Three lectures were delivered on the basic and fundamental aspects of powder metallurgy, after that we shifted our attention from powder metallurgy to another important aspect of manufacturing processes that is metal forming processes. In the first lecture on metal forming processes, we discussed the fundamentals of metal forming, then we discussed regarding the various metal forming processes.

After that we discussed hot, cold and warm working. In different metal forming processes, we have discussed that there are number of processes that fall under the broad category of metal forming. So, these processes basically were forging, rolling, tube drawing, wire drawing, bending, swaging, extrusion and a number of other processes. So, now in the subsequent lectures, we will discuss regarding each one of this process, and in this we will discuss regarding the fundamental of the process with the help of some diagrams. We will try to understand the fundamental of the process; then we will try to look into the some numerical aspects of the process.

We will see what types of materials are required? What type of material can be processed by that process, and all those type of details will be seen. So today, we start our discussion on another important aspect of manufacturing technology that is forging. In this, we will first go towards the review of first lecture that we had on metal forming one, where fundamentals were discussed a brief review will be there, what we have discussed in that lecture.

And then we will discuss, what is forging? What are the different types of forging processes? What is forging load? What are the forces required for forging, a small numerical problem we will discuss in this lecture. Then we will see what are the different types of die materials or what are the properties that are required for a die material, which can be used for forging process.

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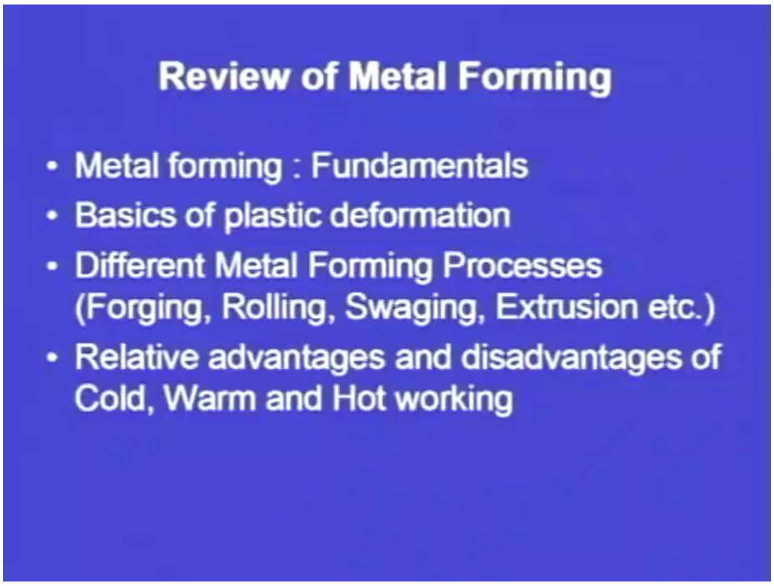

So, a review of metal forming process lecture number 1 we have seen, what is metal forming? Where does it lie in the broad category of manufacturing processes? It was discussed that casting, machining, finishing, metal forming are the different manufacturing processes, where metal forming fit into the broad spectrum of manufacturing technology that was discussed. Then we discussed regarding the basics of plastic deformation, how plastic deformation takes place. Then, we discussed the different metal forming processes, these different metal forming processes were forging, rolling, swaging, extrusion, etcetera.

We have seen with the help of line diagrams, that how these processes work. Then, we discuss the relative advantages and disadvantages of cold, warm and hot working. This is all, what was covered in the first lecture on metal forming. Then, now onwards we will discuss one process in each lecture, today's lecture will be dedicated towards forging process, which is one of the important aspects of metal forming technology. So, what is forging? So, what will first discuss the fundamentals of forging process?

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Forging is not a new process, it has been in use for long, long, long, long time. We have seen certain metal products that have been made out of forging, but when we see a metal product. We are not able to judge that it has been made by forging or it has been made by casting, but forging has been in use for a long, long time, maybe to just give a quantified value, we can say that it has been in use, since 4000 BC. At, that particular moment of time, metal products were made by hammering them with the help of tools that were made of stone. So, stone tools were used to hammer, the metal parts to give them the desired shape.

So that is where the history of forging process lies. Now, what is forging basically, forging is a process, in which material is shaped by the application of localized compressive forces. So, a compressive force is an important point to note here, here we are going to apply the compressive forces to change the shape of the product. So, localized compressive forces exerted manually or with power hammers. So, in the history, I have told that the pressure or the compressive forces were applied manually, but these can be applied with the help of power hammers.

These can be applied with the help of presses, and these can be applied with the help of special forging machine. So, what basically is the forging process, forging is a process in which a material is shaped by the application of localized compressive forces, exerted manually or with power hammers, presses or special forging machine. So basically, we are going to deform a product or deform a raw material to get the final product with the help of compressive forces, these compressive forces can either be applied manually or these can be applied with the help of certain forging machine.

The process may be carried out on materials, either in the cold state or in the hot state. So, in the first lecture we have seen that there are certain advantages and disadvantages in context of, hot forming or cold forming or we can say hot working or cold working. So, if we are going for hot working there are certain advantages and limitations, if we are going for cold working there are certain advantages and limitations. So, this process of forging, this can be carried out in a cold state or it can be carried out in a hot stage. Now, depending upon, the requirements, the specification of the product that we are going to make out of the forging process.

We have to make a decision, whether we are going to use hot forging or we are going to use cold forging, but this process can be used either in the cold state or in the hot state. The process generally used to produce discrete parts, unlike rolling. Now, in rolling process, we can see the different channels, different shapes, different structural components are made on a continuous basis. Now, in rolling we can make tubes or rods, so all these things or wires can also made by rolling. So, wire drying is another process, so here whatever product that we get that is the continuous product.

So, whatever length we want, we can use the shearing machine to cut the desired length, but in case of forging process the product that we will get will not be a continuous product, it will be a discrete product. So, discrete here means that we are going to get a product, that is a individual entity, it will not be a continuous product, it will be a individual entity. For example a bolt head or a bolt, so that will be a individual entity and we will get a number of individual entities after the forging process.

So, continuous products we are not going get here, we are going to get the discrete or the individual entities in case of forging process. Now, the applications of forging what are the different types of forging parts that can be manufactured using the process of forging. Typical forged parts include rivets, bolts, already I have given one example, crane hooks can be forced, connecting rods can be forced, gears can be made by the process of forging, turbine shafts can be made by forging, hand tools, railroads and a variety of structural components used to manufacture machinery. So, different types of machine components can be made using the process of forging.

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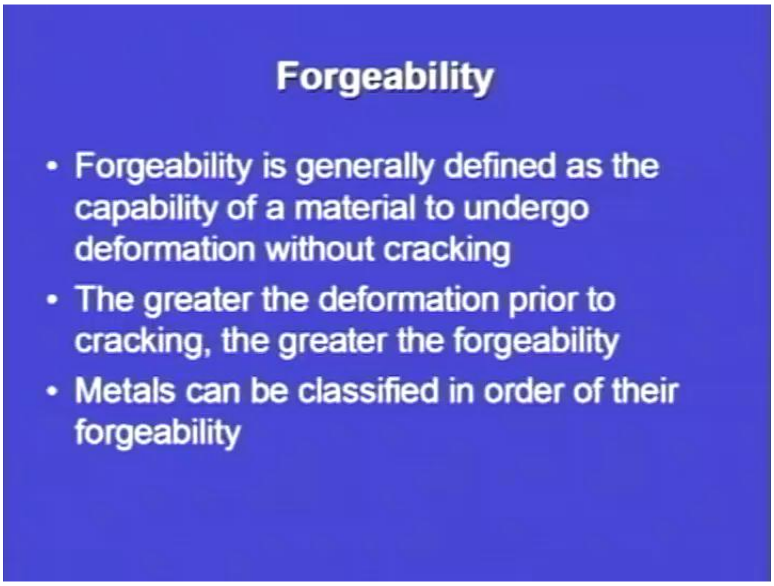

Now, we come onto another important aspect that is forgeability. Now, forgeability what do we understand by forgeability, if we are able to easily machine a product or easily machine a part or easily machine a job. We say that, this particular material of which the job is made up of is easily machinable. If we are able to cast a product very easily, if we are able to cast a material very easily, we say it is easily castable or the castability of this material is very, very good. Similarly, there is the term called forgeability, what do we understand by forgeability?

Now, forgeability is generally defined as the capability of a material to undergo deformation without cracking. So, what is the limitation or the limiting factor, the limiting factor is the cracking, as soon as the crack start to appear on the material. We say that, this is the limit up to which this material can be forced. So, every material will have certain forgeability and certain limits up to which it can be worked using the principle of forging, so the greater the deformation prior to cracking, the greater the forgeability.

So, whatever deformation that we can get before the process of cracking starts or before the limiting factor of cracking is achieved. We say that this particular material is forgeable up to that limit or this can be plastically deformed up to this limit. After, which the cracking will start, and if the cracking will start, then further working or further forging on that particular material is not possible.

Now, metals can be classified in order of their forgeability, all the metals cannot be plastically deformed using the process of forging up to a certain scale. All the metals will have different scales; one particular metal can be work using the principle of forging up to certain limit. The other particular material may be able to sustain the plastic deformation or may be able to undergo the plastic deformation, till a lower limit and another particular material may be able to be forced to a higher limit.

So, each material will have certain limitations on it is forging application. So, depending upon, that what is that limiting factor or where the cracks start to form. We have to decide that we how much plastic deformation, we can give to that particular material, so that it can be easily deformed using the principle of forging. Now, we can say that aluminum and magnesium can be forced easily as compared to some high strength alloys like titanium, etcetera.

So, just to give an example, I have quoted the names or the metals, aluminum and magnesium and titanium. Similarly, any metal that we that is that we see around can be forced works, but it is forgeability is a limiting factor that it should be forgeable up to a desired level. Otherwise, in case of a very brittle material, if we start to hammer it, it may have a brittle failure.

So, each and every material that is present on our earth may not be foregable. So, it depends that, we need to understand the forgeability requirements or the forgeability limits of that particular material. If it has to be worked using the principle of forging. Now, within the broad spectrum of forging, there are other manufacturing processes or subcategories or of the forging process, so what are these subcategories of forging?

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These subcategories are open die hammer forging, impression die drop forging, press forging, upset forging, swaging, rotary forging and roll forging. So, these are some of the processes that fall under the category of forging. Now, as we have seen, if we want to convert a raw material into a final product, we have a number of manufacturing processes or we have a number of manufacturing roots. We can either make a product by casting or we can make a product by machining, we can make a product by metal forming.

We can get the desired product using the principle of powder metallurgy. And there are a number of unconventional manufacturing processes that can be used to convert a raw material into a final product, but the selection of a particular manufacturing process depends upon a number of parameters. Similarly, here also in forging there are number of subcategories, like open die hammer forging, press forging, swaging, roll forging. So, depending upon the specifications of the final product, we have to make a decision that which process out of the available forging operations or the forging processes.

We are going to use to convert a raw material into it is final form, to quote an example, if we want that the product that we are getting should be near net shape or it should be according to the desired shape, and machine accuracy and finishing should be very, very good. We are going to choose precision forcing process, but if we want that whatever shape, we are going to make we can machine it later on, we can go for open die hammer forging.

So, depending upon the requirements, depending upon the facilities that are available, we have to make a decision that which particular manufacturing process or which particular forging operation. We are going to use to convert a raw material into its final part. So, in this particular lecture, we will see or we will try to understand the basic principles of, some of these forging operations.

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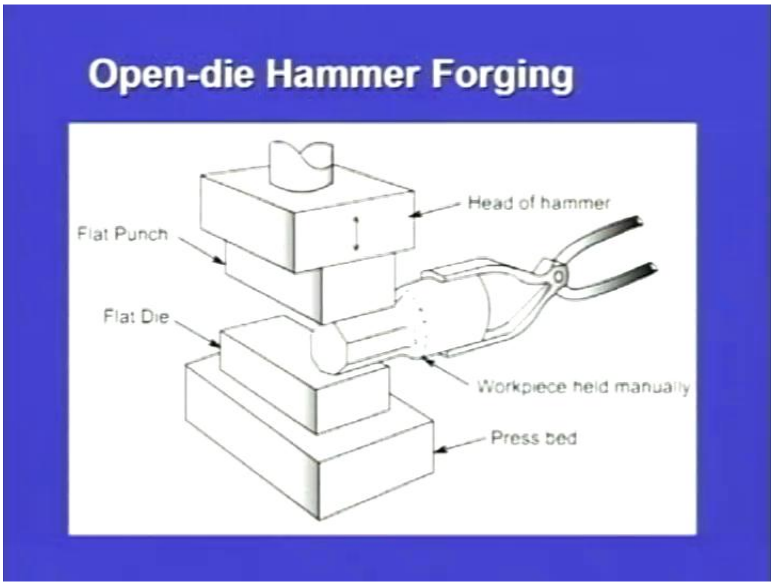

The diagram given here, as you can see is a open die hammer forging operation. The diagram has been labeled as there is a flat punch, which has been shown here, this is the flat punch, there is a head of hammer, this is the head of the hammer. And this arrow shows the movement, this will come down and go up, this will moving this direction. If we call it z axis this will move in the z axis like this. Then there is a flat die, which is shown here, there is a press bed, this is the work piece. We can see, we are giving shape to this work piece with this head of the hammer then this work piece is held manually.

So, this is how the diagram has been labeled, and this is how the basic of open die hammer forging process will work. So, open die means that the die is not enclosed, there is a flat punch and there is flat die. In between the flat punch and the flat die, we will bring the raw material, which has to be forced. And then this is held manually, we can see that tang has been used to hold the work piece. And, we are applying the compressive forces. So, the basic principle of forging operation is that the compressive forces are applied onto the work piece, either manually or with the help of forging machines.

So, here we can see, we are able to change the shape of the product. Now, this raw material, it can either be in the cold state or it can be either in the hot state. Now, depending upon the requirements, we have to make a decision that we are going to use hot working principle or cold working principle, in case of changing the shape. Now, it can be heated in a open hearth or it can be heated in any kind of a furnace, if we want to go for a hot working operation.

In hot working, it has certain advantages and certain limitations, some scale formation may take place the forces that are the required will be comparatively less, the dimensional control may not be that good. Moreover, if we choose cold working operation, the force requirements will be considerably higher, and the surface finish will be considerably better. So, depending upon the final specifications of the product that we are making, we have to make a decision that either to use a hot working operation or to go for a cold working operation.

So, this is the basic principle of open die hammer forging, most of us might have seen blacksmiths working in the markets or working in the small workshops, where they hold the work piece in the tang. And it is manually changed into shape or manually hammered with the help of a hammer, manually to change the shape into the desired products. Crane hooks sometimes are made manually by changing the shape of a rod into the desired product.

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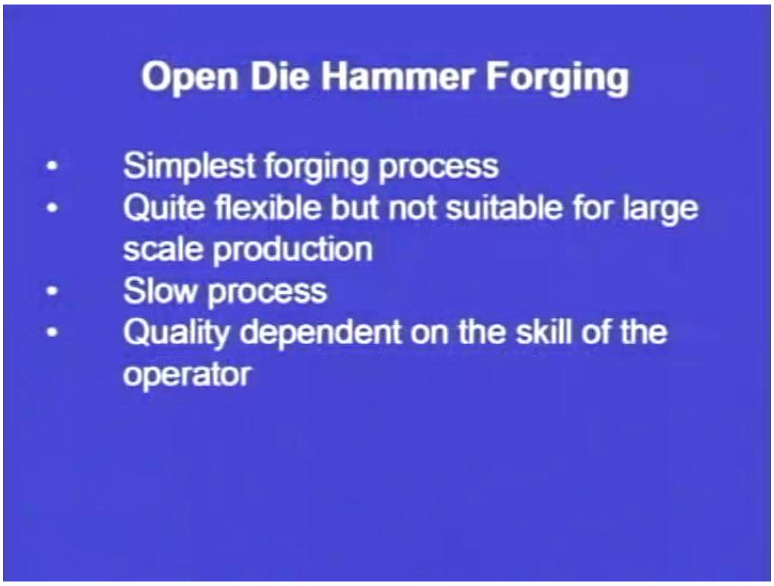

Now, open-die hammer forging, what are the basic fundamentals of open die hammer forging? It is the simplest forging process, very simple not much of control is possible. We take at all rod and change the shape of the rod or change any shape of a raw material into the final product with the help of hammering process, which is done manually. It is quite flexible, but not suitable for large scale production. As the operation is manual, we are not able to make too many products per hour or the volume of production of this process is not as desirable in the industry.

If we say in industry we want 1000, 1500, 2000 products per 2 hours or per 5 hours, this process is not suitable for that type of a operation, this is only suitable where the volume of production is considerably less. The third point is self explanatory, already I have said that it is a slow process, the volume of production is not too much in case of open die hammer forging. Then, the quality is dependent on the skill of the operator, so whatever quality we get by open die hammer forging depends, how skillful our operator is.

Just to quote an example, most of the engineering students go to the engineering college, and they go to the blacksmith's shop, and use the principle of forging to change the shape of a raw material into the final product. As the students go in the first years, the first year they are not that skillful. So, the shapes that they make are not up to the desired level, wherever as they take the help of their instructor, who has a skill set better than the students will be able to make a better job, then the students in the forging or the blacksmith's shop.

So, the quality of the product that we get by open die hammer forging or the simple forging operation is dependent upon the skill of the operator. Then, what is the forging force required to change the shape or the compressive force that we have to exert on the raw material, to change it shape into the desired product. So, there is a analytical model or there is a formula which can be used to calculate the forging force.

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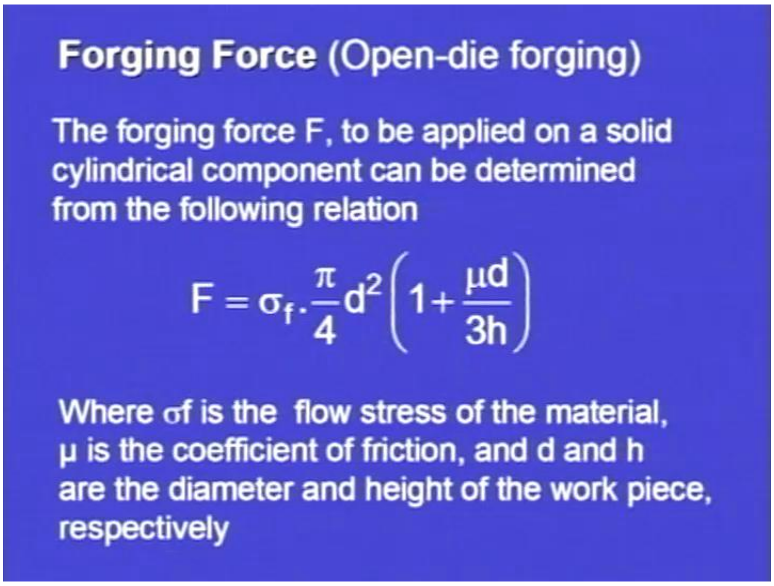

The forging force that has been designated by F, to be applied on a solid cylindrical component can be determined from the following relation, what is the relation? The relation is F is equal to sigma f pi by 4 d squared in bracket 1 plus mu d divided by 3h, it is clearly visible on your screen, you can see the formula for calculating the forging force. Now, what are the various parameters that affect the forging force, these are sigma f is the flow stress of the material, mu is the coefficient of friction, d and h are the diameter and height of the work piece respectively.

So, if we know what is the diameter and the height of the work piece, if we know the coefficient of friction, if we know the flow stress of the material, we can very easily calculate the forging force required to change the shape of the raw material into its final product. Now, we will see, how we can calculate the forging force, we will just see a problem, I will explain that how the problem can be solved, and the students who are attending this lecture can themselves then solve that problem.

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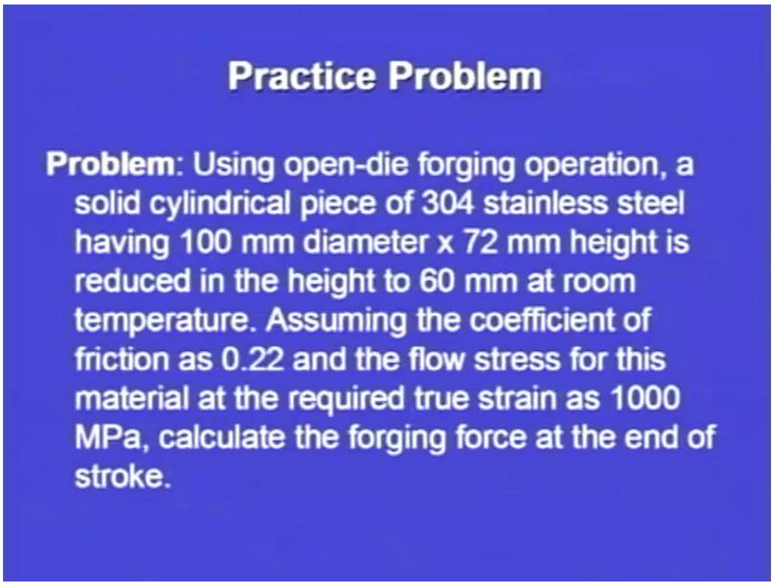

Now, this is the practice problem to calculate the forging force. Now, what is the problem? The problem is that using a open die forging operation, a solid cylindrical piece of 304 stainless steel, this is the material of the job that has to be forced, 304 stainless steel having 100 millimeter diameter, and 72 millimeter height is reduced in height 260 millimeter. So, we can see, initially the height of the work piece is 72 millimeter, which has been reduced to a height of 60 millimeter at room temperature.

So, we are not working at an elevated temperature, we are working at a room temperature only. Now, assuming the coefficient of friction as 0.22 and the flow stress for this material, the material being 304 stainless steel at the required true strain at 1000 mega pascal. So, the flow stress for this material and the required true strain at 1000 mega pascal. Now, calculate the forging force at the end of the stroke.

So, all the parameters that are required to calculate the forging force has been given in this practice problem. As we can see in this equation, sigma f is given that is the flow stress of the material, diameter is given, coefficient of friction is also given, height is also given. So, we can use that has been given in this practice problem, and calculate the forging force at the end of the stroke.

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Now, coming onto the second forging operation, in we can say that impression die drop forging is of step ahead of the manual hammer forging that we have already seen. We have seen that in open die hammer forging, we use a flat punch and we use a flat die surface, and we change the shape of the product. So, it has certain advantages and certain limitation. So, one of the limitations is that it is dependent upon the skill of the operator, in order to counter that limitation. There is another process that is impression die drop forging, where it is not the open flat punch type of arrangements.

It is the closed die that is used to change the shape of the raw material to get the final product. So, as already I have told, this process uses shaped dies to control the flow of metal. In case of open die hammer forging, the flow of metal can be in any direction, maybe we the control over the flow of metal is not too much in our hands, but here in case of impression die drop forging. The processes use the shape dies to control the flow of metal, so the flow of metal is within the shape contours of the die.

The heated metal is positioned in the lower cavity, and on it one or more blows are struck by the upper die. So, the die is made in two parts, there is a lower part of the die and there is a upper part of the die. So, whatever material we want to change in shape, we will put in the lower side or the lower die, and one or more blows are struck by the upper die. This hammering makes the metal to flow and fill the die cavity completely. Now, the shape that we want to make or the shape of the final product has been exactly replicated in the form of the die, the die is made as an exact replica of the final product that we want to make.

So, under the hammering operation between the two dies, upper die and the lower die; the upper die will when it will hammer the lower die, then the metal will flow into the cavity that has been made in the lower die. So, this hammering makes the metal to flow and fill the die cavity completely. So, the material that we want to convert from raw material into the final product will get it is desired shape, in the cavity that will be formed in between the upper die and the lower die.

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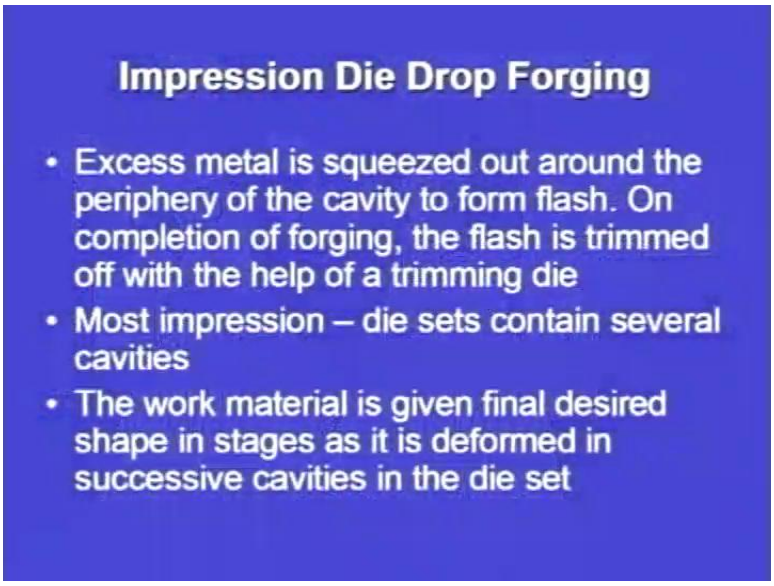

The excess metal that is present, so we know that whatever is the volume of the metal required to convert from a raw material to a final product, but sometimes some excess metal is squeezed out around the periphery of the cavity to form a flash. So, we have we can see here, that they are two die surfaces that are matching together, then these two die surfaces will match together, they will form a thin line and the periphery. So, at this periphery, some of the flash of metal may come out. So, the excess metal is squeezed out around the periphery of the cavity.

Now, cavity has been formed with when a lower die and a upper die, so whatever cavity has been formed it will have some periphery, and the excess metal will come out at this periphery, and it will form a flush. On completion of forging, the flush is trimmed off with the help of a trimming die. So, there is a trimming die, which can be used to scrap off or to trim up this flush that comes out at the periphery of the die cavity. So, in case of impression die drop forging, we sometimes need secondary operation that we can call as the trimming operation.

So once, we are able to make a product, it has to be subsequently subjective to the trimming operation to get the desired shape. Most impression die sets contain several cavities. So, different cavities will be there, it is not that we are going to make one product or one discrete product only, number of products can be made simultaneously. Moreover, it depends that how much deformation we want to give, sometimes we will give the deformation in steps.

So, we will have different types of die cavities, in case of impression die drop forging. The work material is given final desired shape in stages, as it is deformed in the successive cavities in the die set. Already in second point, we have discussed that the shape may not be changed directly from its initial shape to its final shape, it will be done in a number of stages. It will not be that the raw material after one hammering operation will get, we will get the desired product, it will be done in number of stages.

Some of the materials may require four different stages to convert it from raw material to final product, other particular material may require 10 stages to convert from a raw material to a final material or the final product or the final shape. This depends on one of the important aspects that has already been addressed in this lecture, that is the forgeability. Now, depending upon the forgeability, we can decide that how many stages will be used to convert the raw material shape into the final material shape.

So, in this lecture on forging, we have seen the basic fundamentals of forging operation, what is forging? How we change the shape of a material from its raw shape or from its initial shape to its final shape. We have seen there are different types of forging operations like, open die hammer forging, impression die forging, roll forging, upset forging and a number of other operations.

One of the important operations that we have discussed is the precision, forging operation. After that we discussed that die material is an important aspect of forging, and what are the requirements of the die materials, what are the properties that the die material should have in order to make a product of the desired quality. So, in next lecture we will discuss, some other metal forming operation, till then best of wishes.

Thank you.