Manufacturing Processes - 1

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Module - 1
Lecture - 13
Machining Fundamentals

A warm welcome to all of you, in this session on Machining Fundamentals. Before we start our discussion regarding the Machining Fundamentals, we would just like to review that what we have discussed till now in this series of lecture on Manufacturing Processes. We started our discussion with three lectures on powder metallurgy, in which we discussed, what do we understand by powder metallurgy, what are the fundamentals of powder metallurgy, how the different types of powders are produced, what are the different production methodologies for making the different types of powders, what are characteristics of the powders.

Then, we discussed the various stages in the powder metallurgy process, thereby we discussed hot isostatic pressing cold, isostatic pressing. We also discussed what is sintering; what are the different types of mechanisms that are found during the sintering process. Then, we discussed what the finishing operations for powder metallurgy parts are, thereby we discussed infiltration, impregnation to particularly apply this particular powder metallurgy products into specific applications like self lubricating type of bearings.

After completing our discussion on powder metallurgy, we switched over to another important aspect of manufacturing technology that we called as the metal working operations. In metal working operations, we discussed what are the different types of metal working operations like cold working, hot working, warm working.

Then, we discussed what the different types of metal working processes are. In processes, we saw that there are different types of processes like forging, swaging, tube drawing, wire drawing, bending, and a number of other processes.

After that, we discussed certain sheet metal forming operations. In sheet metal forming, we saw that what the various processes are like embossing, twining; we saw what is nibbling, what do we call notching. Then, we saw that there are different types of machines or equipment that are used for the sheet metal operations. Thereby we discussed what are the different types of die punch types of mechanisms. Thereby we discussed different types of dies in which we saw that there is a conventional type of die punch arrangement; then there is an inverted die; then there is a progressive die. So, different types of die punch type of arrangements were seen.

Later on, in one of the lectures, just prior to this particular lecture, we discussed what are the high energy rate forming processes, where high energy is applied for a very small duration of a time. So, the application areas of these processes was seen. So, we ended last lecture with a discussion on electromagnetic forming.

So, today, before starting our discussion regarding the Fundamentals of Machining Operation, we will just complete our lecture on high energy forming processes. So, the fundamentals of high energy rate forming we have discussed.

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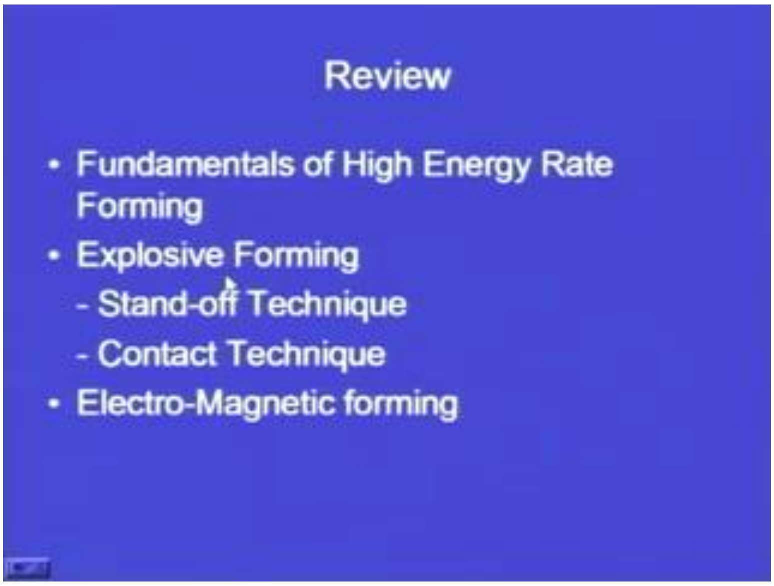

We are just now reviewing that what we have discussed in the previous lecture. We saw what are the fundamentals of high energy rate forming processes. Thereby we discussed that there are three important high energy rate forming processes that will be discussed in the course of this lecture or this series of lectures. We discussed what is explosive forming; where explosive is used; and a pressure pulse is generated and the metal is deformed.

In explosive forming, we have discussed two different types of explosive forming processes - that is, the standoff technique, and the contact type of technique. So, this was discussed in the previous lecture in detail.

Then we discussed what do we understand by electromagnetic forming; how it functions; and what are the different types of shapes that can be produced by electromagnetic forming processes. So, today, the last portion of the last lecture, that was left in the previous lecture, we will be cover today before we switch on to the machining fundamentals. So, another process that was left was the electro hydraulic forming.

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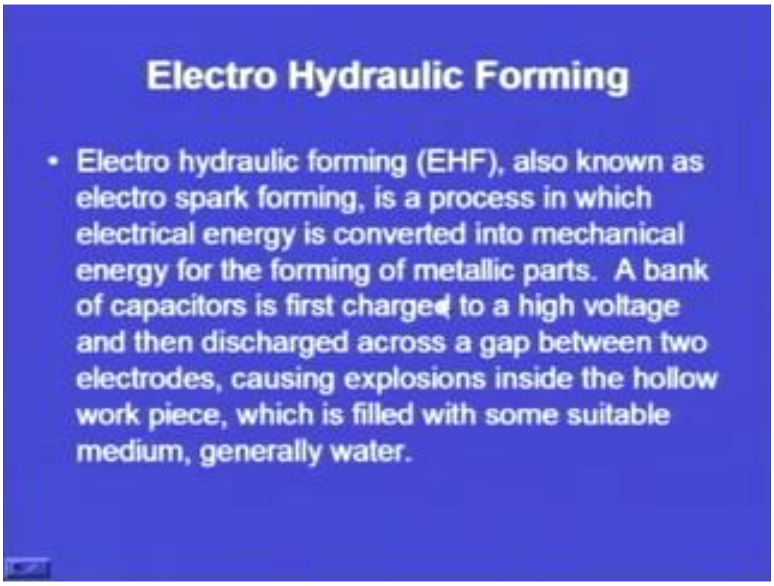

So, electro hydraulic forming or we can call it in brief EHF also known as the electro spark forming - it is also called electro spark forming - is a process in which electrical energy is converted into mechanical energy for the forming of metallic parts. So, here we can convert raw material which is in the metallic form, from its nascent stage to its final stage. A bank of capacitors is first charged to a high voltage and then discharged across a gap.

So, first, a bank of capacitors they are charged to a high voltage, and then they are discharged across a gap between the two electrodes. Now, there is a gap between the two electrodes - in between this bank of capacitors - will be discharged, causing explosions inside the hollow work piece. So, there will be a hollow work piece or we will see with the help of a diagram what type of work pieces can be handled using electro hydraulic forming. So, hollow work piece will be there, and there will be a explosion in between, because of this discharge causing explosions inside the hollow work piece which is filled with some suitable medium - generally water. So, there will be some medium in between the hollow work piece. So, we will be able to deform the hollow work piece according to the desired specification or according to the desired shapes of the final product.

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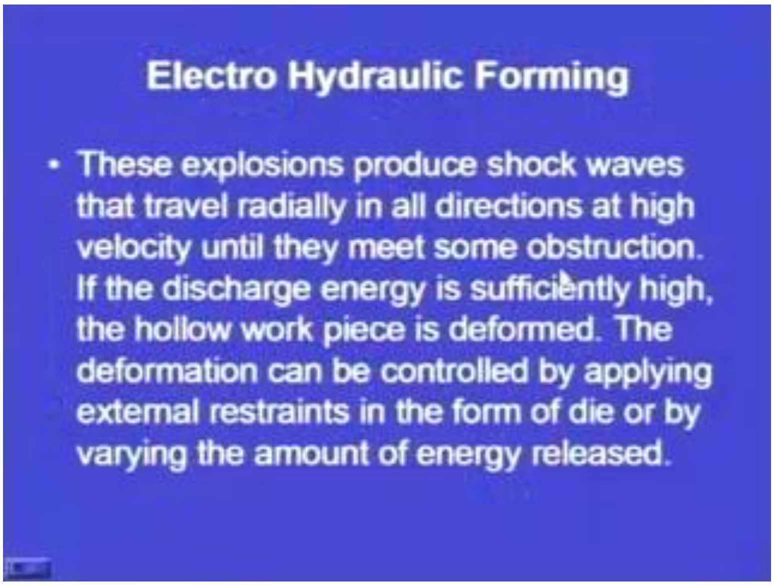

Now, these explosions produce shock waves. So, in pressure pulse it was also generated - in one of the previous processes that we have discussed. Here these explosions, these will produce the shock waves. So, these shock waves that travel radially in all directions at high velocity. So, we can see that the velocity of these shock waves is very, very high. And they will travel in all the directions until they meet some obstructions. So, obstruction - what will be the obstruction? Obstruction may be in the form of the work piece material. So, these explosions which produce shock waves that travel radially in all directions at high velocity until they meet some obstruction. If the discharge energy is sufficiently high - so, if the energy level is high, because these processes come under the broad category of high energy rate forming processes. So, wherever we are discussing such a process, the energy levels will be very, very high. So, then only the deformation in the sheet metal will take place.

If the energy levels are substantially less, then the deformation may not take place. So, if the discharge energy is sufficiently high of these shock waves, the hollow work piece is deformed. So, there is hollow work piece - already we have discussed - it will be deformed. The deformation can be controlled by applying external restraints in the form of die or by varying the amount of energy released. Now, it is in our hand that how much deformation we want.

So, there can be two types of deformation that is taking place. We can categorize it into two different broad categories: First one, is a restrained type of deformation and the second one is unrestraint. So, suppose we take hollow work piece, in between there is a explosion and shock wave is produced, then a deformation will take place.

If we do not want to have any control on the outer shape of the hollow work piece, then we can go for unrestrained type of technique. If we want that the outer shape should be according to some desired level or according to some desired specifications or some desired requirements, then we can use a die arrangement. There can be a hollow work piece like this - this is a hollow work piece - and outside if we want like this kind of a section, we can have a die of this particular shape. So, inside, when the shock wave will be produced, this material will go out, this material will be pushed out, because of this explosion and high energy that is generated.

So, this sheet, if it is this is one end of the sheet, this will get deformed according to the shape of the die. If this die is not there, then if it is an unrestrained type of process that we are using, this is hollow piece and in between the shock wave is produced, it will take any shape according to the shock wave that is generated. So, this we will try to understand with the help of a diagram. Now, this is the diagram you can see on your screens.

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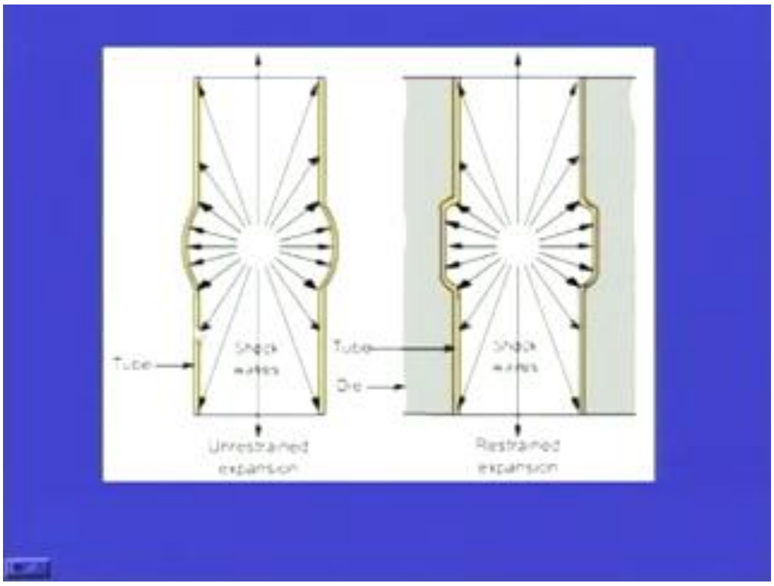

Now, this is the unrestrained expansion. In unrestrained expansion, we can see this is the hollow tube - this color, yellow color, you can see - this is the hollow tube, and this is the shock wave that is generated. You can very easily see that a shock wave will travel in all the different directions; it will travel in all the directions, and then, this is the other portion of the hollow tube. So, this is the hollow tube and this explosion is taking place here, and we can see initially it was straight, now it has been deformed. So, this is the deformation that we have been able to achieve. So, this is how we have achieved it. We have achieved it using the electro hydraulic forming. Now, this is a case of a restrained expansion; here it was free expansion, unrestrained expansion. This is a case of a restrained expansion.

In restrained expansion, we can see, that there is a shock wave - these are the shock waves - and then, this is the work piece - this; and this is one wall, and this is the another wall, and in between it is hollow. Already we have seen that this can be used for hollow work pieces. So, this is a restrained expansion, and this is a tube - the labeled - it has been labeled as tube, and this is the die. So, this gray portion, this is the die. So, in case of a restrained expansion, the outer shape of the tube or the hollow section that we have chosen for processing using electro hydraulic forming will confirm to the cavity of the die. So, this is the cavity of the die, we can see, this is the cavity on one side, and this is the cavity on the other side.

So, depending up on how we want to deform or how we want to get the final shape of the product or what is the final shape of the product, we can either go for a unrestrained expansion or we can go for a restrained expansion. So, depending up on the requirement we can choose any of these two. Now, there has to be certain advantages of any process that has been developed or research efforts have been put and it has been developed. So, it is bound to have certain advantages.

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So, the advantages of electro hydraulic forming are that EHF can form hollow shapes with much ease and at less cost compared to other forming techniques. So, the main point to address here is that it is not difficult to give a particular shape to any hollow cross section or any hollow work piece or any hollow job, but it has to be performed economically. So, electro hydraulic forming process is a economical process to give a particular shape to a hollow work piece. So, when we compare it with the normal or the conventional forming processes that give shapes to a particular hollow component in comparison to the conventional processes, the economical justification or the commercial justification of EHF yields that EHF is advantageous as compared to the conventional forming processes. So, the first advantage, that to just summarize, that EHF is economically better as compared to conventional manufacturing processes or conventional forming processes, in order to give shapes to the hollow components.

Then, coming on to the second point. EHF is more adaptable to automatic production compared to other high energy rate forming processes. Now, first comparison we have done of EHF with the conventional forming processes.

Now, second comparison we are doing among the high energy rate forming processes. We have already seen, that there are different types of high energy rate forming processes. In these series of lectures, we have seen that there is a explosive forming; within explosive forming there are two techniques - standoff technique and contact technique; then, there is electromagnetic forming; there is electro hydraulic forming. So, among different high energy rate forming processes, this EHF or electro hydraulic forming is more adaptable to automatic production. So, if we want to automate our process, we do not want any manual interference within the process, then EHF is more suitable or more susceptible for automation as compared to the other high energy rate forming processes.

Now, coming on to the third point - that is EHF can produce small to intermediate sized parts, that do not have a excessive energy requirements. So, if there are certain parts that do not require too high energy levels, then EHF can be used thereby. So it can be used; it can be used for making parts that are not big in size, those are intermediate or small in size, because the energy requirements are considerably less. So, we have seen that there are certain advantages: it is economical; then, it is adaptable to automation; then, it can be used for small to medium sized parts. So, EHF has certain advantages; that is why it has been used in a number of application areas.

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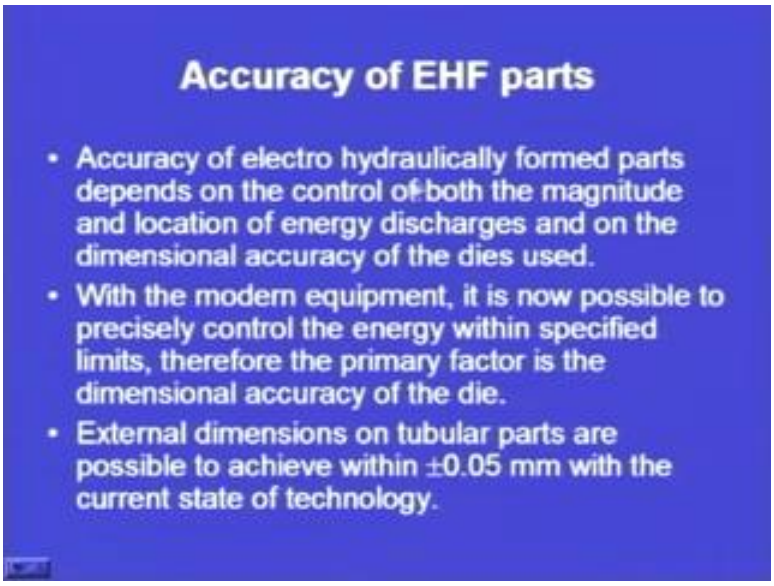

Now, we come on to the accuracy of EHF parts. The first point we will discuss - accuracy of electro hydraulically formed parts, depends on the control of both the magnitude and location of the energy discharges, and on the dimensional accuracy of the dies used. So, this point states that there are two important control parameters in electro hydraulic forming.

First point is the control of the discharges that takes place. So, important point is the control of the magnitude as well as the location. So, we have to control that where the discharge has to take place, because there is a particular hollow cross section; we want to deform it at one particular section. So, we need to control the discharge at a particular place.

Then the magnitude of the discharge also. In the previous slide, we have seen there are certain advantages of electro hydraulic forming. What are these advantages? Like this can be used for deforming or plastically deforming small to medium sized parts. So, the energy level required thereby will considerably less. So, if we want to deform a bigger size parts, the energy levels requirement will be higher. So, we have to control that how much means the magnitude of energy that should be there.

And the second thing that is important to control is the location of the energy, because we have a hollow cross section and at one particular cross section of this hollow component we want to deform it plastically.

So, the location as well as how much energy should be discharged - these two are the important control parameters that we have to take in to account, when we go for electro hydraulic forming operations.

Then another important control parameter for us that will finally identify itself with the final product or the quality of the final product, is the dimensional accuracy of the die. If the die is not of a particular dimensional accuracy or the accuracy that as desired in the final product, we will not get the product according to our desired level.

So, there are three important parameters now I should say. First one is the magnitude of the discharge energy that is it is given, both magnitude and location of the energy discharges. So, first one is the magnitude of the energy discharges; second is the location of the energy discharges; and third is the dimensional accuracy of the dies. So, these three are the important parameters that govern the final accuracy or the final surface finish or the final quality of the final product that we will get with electro hydraulic forming.

Now, with the modern equipment, it is now possible to precisely control the energy within the specified limits. Now, the controls are available, whereas, where by, very precisely, means we are able to control the energy discharges within specified limits. Therefore, the primary factor is the dimensional accuracy of the die. So, it boils down to the dimensional accuracy of the die.

Now, controlling the energy discharge is not a difficult task with the equipment, whatever is available in the present day scenario, whatever technological advancements have been noted, it is not too difficult to control the energy discharges. So, the things now say that we if we are able to control the dimensional accuracy of the die, we will be able to make a product using electro hydraulic forming according to our desired specification levels. Then external dimension on tubular parts are possible to achieve within plus minus 0.05 millimeter with the current state of technology. So, this gives one particular level that is achievable with the current state of technology.

So, when external dimensions of this level means plus minus 0.05 level are achievable with the present technology; may be, this may further be enhanced when newer methods or better control mechanisms are developed. Now, what are the different types of materials that can be formed using electro hydraulic forming?

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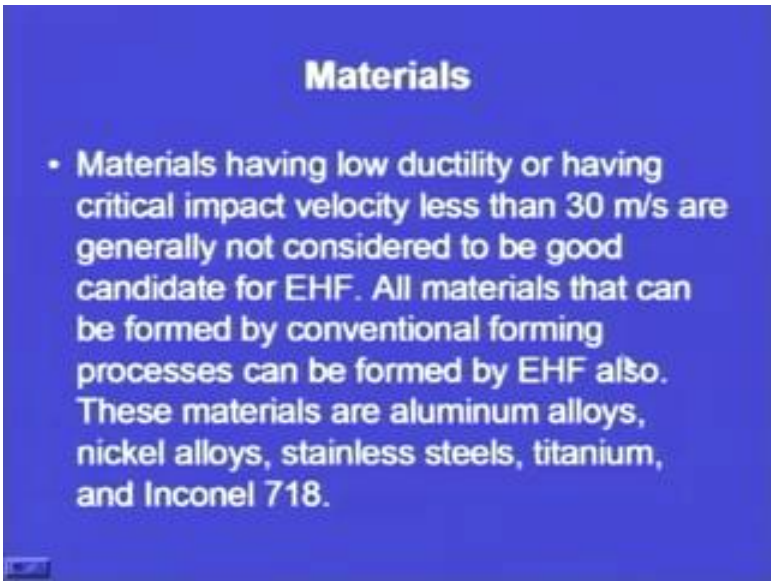

So, materials having low ductility or having critical impact velocity less than 30 meter per second are generally not considered to be good candidate for EHF. So, materials which have low ductility, means that ductility for those materials is less; for those materials, we are not going to use them. They are - these materials - are not generally considered good candidate for electro hydraulic forming.

Another important point is which have or having critical impact energy less than 30 meter per second. So, there are two limitations if the material has ductility which is very less as well as the critical impact velocity which is less than 30 meter per second, then these materials will not be considered for electro hydraulic forming.

All materials that can be formed by conventional forming can be formed by EHF also. So, if there are certain materials which can be formed by conventional forming. If we take an example of very brittle material it cannot be formed. So, if it cannot be formed using conventional processes, it is very difficult to form it using EHF also.

So, all those materials which can be formed using any of the conventional processes, can easily be formed using EHF also. So, these materials are some of the examples; they have been given on the slide. These materials are aluminum alloys, nickel alloys, stainless steels, titanium, and inconel 718.

So, limitations on the materials, we have seen. Now what are the adaptable materials, which materials can be formed using EHF - there are certain examples that have been given; these are aluminum alloys, nickel alloys, stainless steel, titanium, and inconel 718.

So, with this, we come to the end of our discussion on metal working, in which we have discussed a large number of different processes that are there. We started with - what is plastic deformation, how plastic deformation takes place, how it starts, how the plastic deformation starts in case of metals.

Then, we discussed what are the different conditions of metal working in which we saw - what is cold working, what is hot working, what is warm working, what are the relative advantages and disadvantages of these processes. Then, we went on to discuss certain important manufacturing processes that fall under the broad spectrum of metal working processes. We discussed what is forging, we discussed what is swaging, tube drawing, wire drawing.

Then, we discussed different sheet metal forming operations, what are different types of sheet metal forming equipment, die and punch type of arrangement. There by we went on to discuss this last topic on high energy rate forming processes, whereby we discussed three important processes - that was explosive forming, electromagnetic forming, and electro hydraulic forming. So with this we come to the end of metal working processes. Now, we start our discussion on another important aspect of manufacturing processes, that is machining.

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So, we will start the discussion regarding the machining fundamentals. So, we have seen that there are number of processes. Already we have discussed, in course of certain lectures, that there are number of processes, which can be used to convert a raw material from its initial state to its final state.

Now, the process selection, the material selection are some of the important aspects that have to be considered in finalizing or optimizing that which particular process should be used for which particular application. Now, depending up on the size, the shape, the volume requirement, or the intricacy in the product design, we try to optimize that which particular process should be used.

So, there are different processes; already we have discussed, those are used to convert a raw material into its final product. What are those processes? Those processes are to start with it is casting, it can be forging, or it we can say it is casting, or it can be metal working operations, it can be machining, it can be finishing, or it can be any unconventional manufacturing technique.

So, where does machining fall under this broad spectrum of manufacturing processes? Most of the products, they are usually produced using net shape or near net shape manufacturing methods. For example, casting or any metal working process. In casting we make a mold, we pour the molten metal, and we get the desired shape -whatever shape is required; but according to the present requirements, according to the requirements of the present day scenario, the quality as well as the dimensional accuracy, the dimensional tolerances are so stringent, that it is not sometimes possible to directly use a product that has been made using casting into our final application.

We need to perform certain additional operations that we call as the finishing operations or we have to perform certain operations that will bring it to its desired level - the desired tolerance levels - and to the desired dimensional accuracy. So, what are those processes? Those processes basically fall under the category of machining operations.

So, from now onwards we will discuss the different types of machining operations, what are the different types of machining, like orthogonal machining, oblique machining; what are the different types of chips that are produced in machining operation; what are the different types of tool materials that are used; what are the different types of cutting floods that are used. Then, we will see what are the different types of forces that are generated in machining, and then, we will discuss what are the different types of machining operations. For example, it can be drilling; it can be boring; it can be reaming. Then, we can come on to milling operation, shaping operations, turning operations; there are number of operations that fall under the broad category of machining.

Even grinding also comes under the category of machining; that we will see - what is a grinding wheel and how it performs the grinding operation; and how grinding is different from normal machining operations, for example, turning drilling or milling. So, we now initiate our discussion on the fundamentals of machining. We will see what how did machining originate. So, we have already discussed, we have already started our discussion on machining fundamentals.

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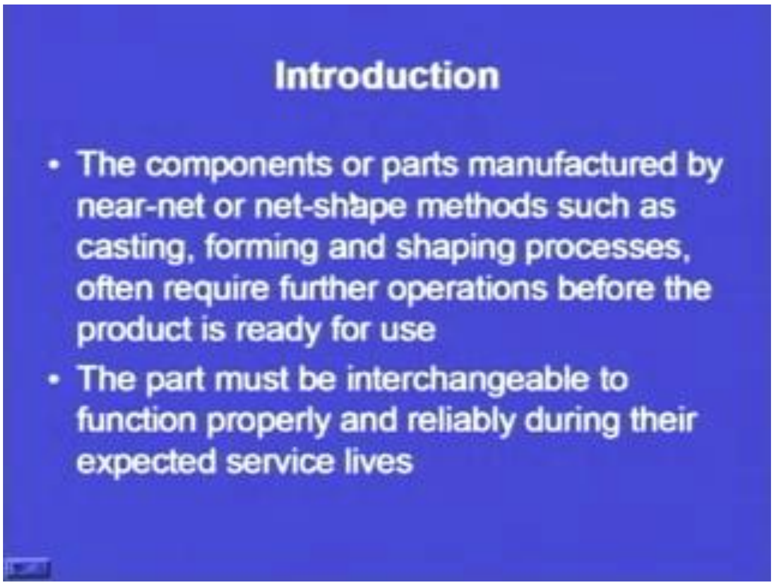

Now, the components or parts manufactured by near net or net shape methods. Already I have told that there are certain manufacturing processes that will directly produce a part according to the final shape that we want,

For example, in the layman's language, we can say if we are using a casting process, we will make a mold of the final shape that we want to make. That mold may be made in sand or if it is a case of a permanent die casting, we will make use of a permanent mold, but the mold will be exactly of the final shape or the replica of the shape that you want to produce. We will melt a molten metal, put it into that mold; the mold may be permanent or it may be temporary - as in the case of sand - and after solidification of the metal we will get the final product. So, that process we call as a near net or net shape manufacturing process.

So, the components are parts manufactured by the near net or net shape methods. For example, casting. Already I have explained what is the basic working principle of casting, forming, and shaping processes. So, these are the near net or net shape manufacturing processes.

Often require further operations before the product is ready for use. Already this point has been addressed. If we take a product, we directly produce it using any net or near net shape process, sometimes it is impossible to use it in it is intended application. So, it requires certain further operations. The part must be interchangeable to function properly and reliably during their expected service lives.

So, the parts must be interchangeable also. So, if the parts have to be interchangeable, then in order to incorporate this concept of interchangeability, the tolerance levels have to be very stringently controlled; the tolerance levels have to be very stringent.

Suppose we want, for example, in order to explain this concept of interchangeability, suppose I manufacture 100 nuts and 100 bolds; and 100 nuts and 100 bolts are lying into two different bins. I take any bolt out of the bin where the bolts have been put, and any nut out of the bin where the nuts have been put. I should be able to assemble the nut and bolt. It means, that whatever nuts have been produced, they are under a particular tolerance levels. Similarly, the bolts also have a particular control that has been put on their quality. So, whenever we assemble any nut and any bolt they should fit in. So, that is the principle of interchangeability. And how we can ascertain it? We have ascertain it if we have a very stringent control over the quality parameters. And, in order to have that stringent control, whatever we are producing using net shape or near net manufacturing processes it is difficult to control. So, in order to have that kind of a control, we go for final finishing operation or final control controlling operations that operations we can call as the machining operations.

So, in order to summarize these two points - this is the basis of machining; why machining is required. The components or parts manufactured by near net or net shape methods such as casting, forming, and shaping processes, often require further operations before the product is ready for use - already explained; the part must be interchangeable to function properly and reliably during their expected service lives. So, the parts must be interchangeable. In order to incorporate that interchangeability, we have to go for subsequent operations.

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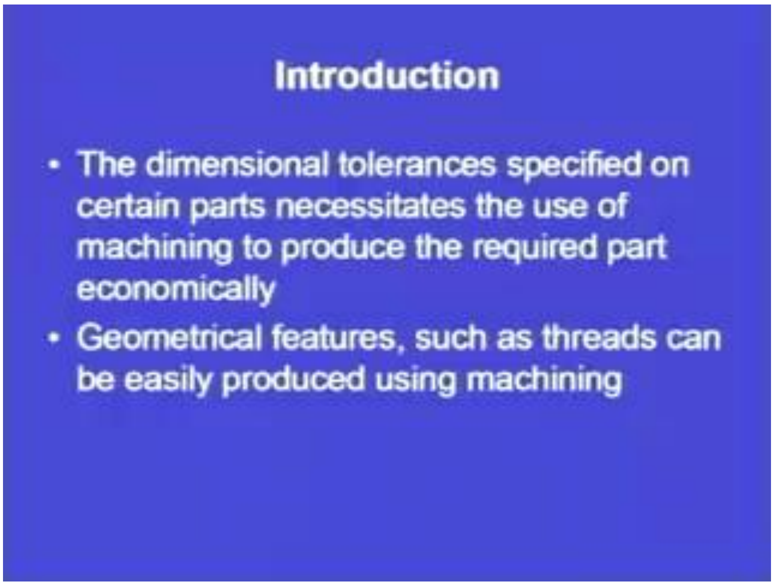

Now, the dimensional tolerances, as I have already told, specified on certain parts - on certain parts, certain dimensional tolerances have been specified - necessitates the use of machining to produce the required part economically. So, the dimensional tolerances that are required on certain products necessitate that they should be machined. So, this point, number one - the dimensional tolerances is specified on certain parts necessitate the use of machining to produce the required part economically. So, that is already explained.

Now, geometrical features such as threads can be easily produced using machining. So, there can be certain geometrical features, which are very difficult or cannot be produced economically using the standard or the near net manufacturing groups. For example, here we have taken an example of a thread. So, if we want to make a thread, and we want to cast it, it will be very, very difficult or certain particular features of the thread may be impossible to incorporate using the casting process or the forming process. So, machining, there by, becomes imperative to ascertain the structural features that we want to make or the geometrical features that we want to make.

So, depending up on the geometrical features that are present in the product, we have to make a decision, that whether machining is required or not; but more often than not, there may be certain cases where there are certain geometrical features, which are difficult to produce economically using any other process. So, we go for machining operation thereby.

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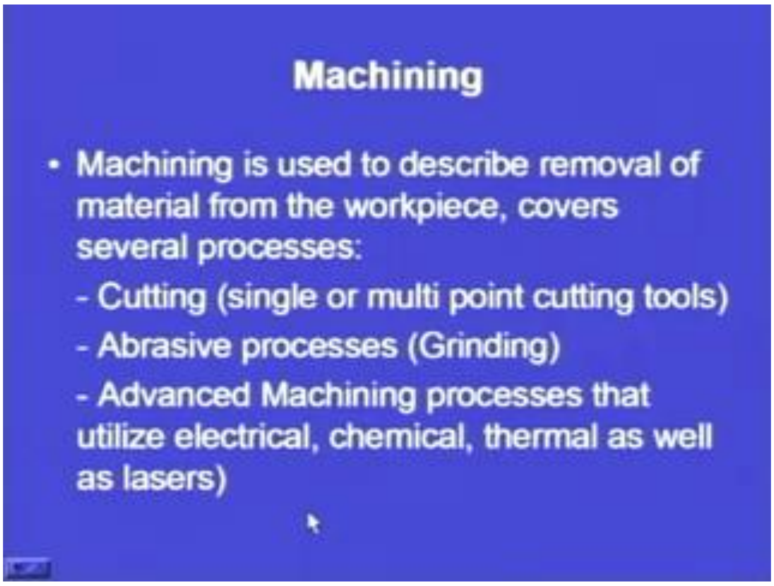

Now, coming on to machining. As all of us may be knowing that machining is used to describe removal of material from the work piece. It covers several processes. So, machining is used to describe removal of material. So, removal of material means that what we have seen in metal forming operations or metal working operations or metal working processes, that there is a particular raw material, we are passing it through the die, we are reducing a cross section. Only we are changing the shape; we are not losing any material. Similarly, we are taking a sheet, we are bending it; in case of bending, we are changing the shape of the sheet, but none of the material is being lost.

Similarly, we can take a bending of a rod. We take a rod; we bend it. In the case of bending, the shape is definitely changing, but we are not losing any material; but here in case of machining - machining is used to describe removal of material from the work piece and it covers several processes.

So, the basic definition of machining is that it results in the removal of the material from the work piece in the form of chips. So, here different types of chips will be produced. In the course of these lectures on machining, we will see what the different types of chips that are produced are; how they curl; what the different shapes of chips are. So, what are the various conditions under which particular category of chips will be formed. So, all that discussion we will take under this series of lectures on machining.

So, basically machining, represents a manufacturing processes, where we remove certain amount of material from the work piece to convert it from a raw material into a final product.

Then, it covers several processes. Now, what are the various processes that are covered under the broad spectrum of machining? So, first one is the cutting operations like single or multi point cutting tools. So, in case of cutting operations, number of operations will come; for example, turning; drilling; boring; reaming; grinding - grinding will certainly as a abrasive processes, but in cutting, grinding may not be considered, but it is also a limiting case of a multi point cutting operation. Then in cutting, we can call different types of operations like turning is a single point cutting operation; and whereas, milling is a multi point cutting operation. That we will see in the subsequent lectures.

So, cutting, we will see, that there are different types of operations that fall under the category of cutting. Then there are abrasive processes; for example, grinding - so, grinding is one example of abrasive processes; there may be other examples of abrasive processes as well.

Then we can have advanced machining processes. In advanced machining processes, they use different types of energy sources, like the some of the processes may use electrical energy, or chemical, thermal as well as lasers can be used in advanced manufacturing processes. So, where do we go for advanced manufacturing processes? That is also an area of study.

Conventional cutting or abrasive processes can be used for cutting different types of materials, but sometimes the properties of the materials are such, that it becomes extremely difficult to machine these materials with the help of conventional processes. For example, if we take a case of a metal matrix composites, which falls under the category of an advanced material, machining it using a standard high speed steel tool, we will see - I am quoting here high speed steel, but in a subsequent lecture, we will see what are the different types of tool materials and under what applications these can be used - but here you can just take it as a tool material; that it is some tool material which is high speed steel.

So, using conventional processes, if we use the tool material, and we want to make a hole in this particular metal - that is, metal matrix composite, a composite material or advanced material - there may be a problem, that the tool may have a extensive or a substantial amount of wear. So, it becomes difficult to conventionally drill a hole in a advanced material using the standard process. Thereby, we have to invent, we have to look beyond the conventional processes towards some unconventional manufacturing processes.

For example, certain advanced machining processes or advanced manufacturing processes that are electro discharge machining, ultra sonic machining, or laser beam machining, electron beam machining; there are number of operations or number of processes that have been developed to machine difficult to machine materials.

So, machining incorporates certain important processes which can be broadly classified as cutting processes - conventional cutting processes - using the single point tool or a multi point tool. Then it incorporates the abrasive processes, which covers the spectrum of processes that are covered under grinding. Then the machining incorporates the advanced machining processes, such as electro discharge machining or ultra sonic machining. So, machining itself covers a large frame work of processes, and we have to see that which particular process should be used, for what particular specific application.

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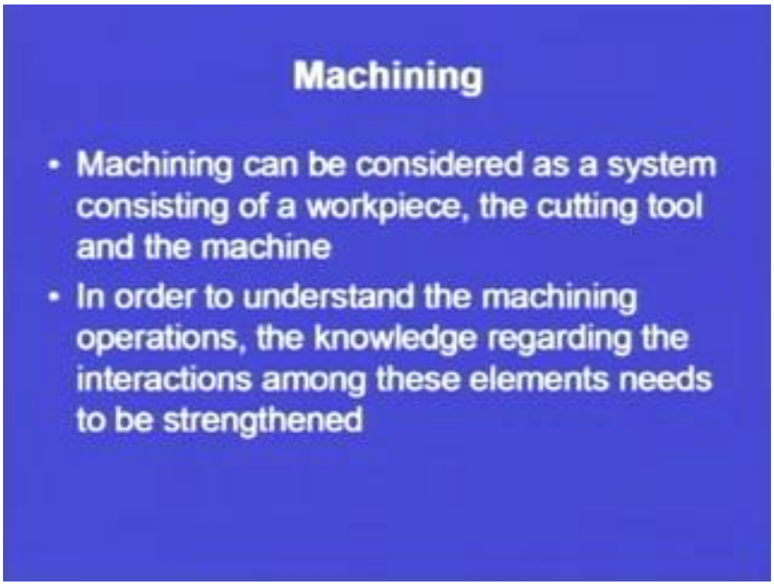

Now, machining can be considered as a system. Now, this system consists of a work piece; there is a work piece; for example, I have taken an example of a metal matrix composite, that is an advanced material. So, it consist of a work piece - the system of machining consists of a work piece. Then the cutting tool - I have told that there is a cutting tool; that is in case of drilling it can be high speed steel tool or it can be made up of any other material; so, a tool will be there; the tool may have a specific geometry; it can be a twist drill.

Now, depending up on the geometry as well as the material, we can classify the tool materials also. So, in machining if we consider it as a system, there will be a work piece; the work piece may be any material - it can be stainless steel, it can be cost iron, it can be metal matrix composite, it can be polymer matrix composite -so, the material can be any. So, there is bound to be a work piece; there is bound to be a tool. Now, the tool can be classified on the basis of the material out of which it has been made; and it can also be classified on the basis of the geometry. For example, it can be single point or multi point, it can be twist drill, or it can be four faced drill, or eight faced drill; depending up on the requirement, there will be a classification of the tool as well as a tool design.

Then, the third important point to be considered in machining is the machine tool or the machine that has to be used for using the tool to make a hole or using the tool to give a surface finish or to give a tool, use a tool to machining in we can say a work piece.

So, basically if we considered machining as a system, the system has three important parts; three important parts being the work piece, the tool, as well as the machine. So, machining can be considered as a system. Then, in order to understand the machining operations, the knowledge regarding the interactions among these elements need to be strengthened.

Now, what are the three elements we have discussed? The three elements are the work piece, the tool, and the machine. And they will interact among themselves in order to perform the machining operation. So, in order to comprehend, in order to understand any machining operation it is important for us to understand the interactions among these three important elements of the system of machining.

So, three important elements - just to summarize I have told: it is a work piece; it is a cutting tool; and it is the machine. So, whatever discussions we will have in these series of lectures on machining, we will be focusing our attention on these three important aspects of the system.

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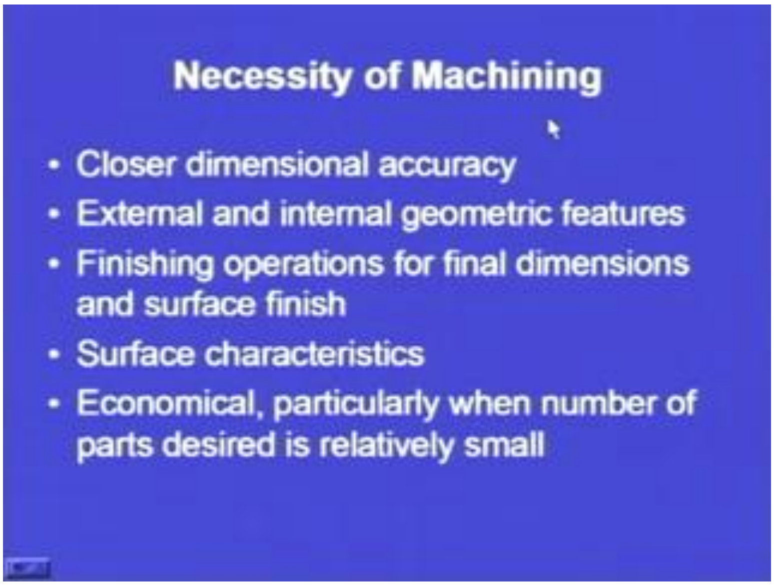

Now, coming on to the necessity of machining. Although in the introduction, we have seen that why machining is important, but here we will try to list the different points, which necessitates the machining as a important manufacturing operation for converting a raw material into a final product.

Now, first point has already been discussed in detail - that is the closer dimensional accuracy. So, if the dimensional accuracy required or there are very sharp edges that are required, which is very difficult to form using any of the normal near net or net shape processes or any of the conventional net or near net shape processes, then we will have to go for machining as the finishing or the final operation in order to have sharp edges. So, if sharp edges are required or closer dimensional accuracy or closer dimensional tolerances are there, we have to go for the machining operation.

Now, the second point is the external and internal geometric features. We have already seen one example of geometric feature, that if we have to make a thread, then it may be difficult to form it economically using any of the conventional processes; we have to go for a machining operation. So, there may be certain external geometrical features or there may be certain internal geometrical features which are very difficult to form using near net or net shape processes. We then have to go to the machining operations, there by converting external feature or the internal feature on to the work piece.

So, if the geometry is very, very intricate, it is not only the external and the internal features, sometimes the geometry of the product that we are going to use or that we have designed is very, very intricate. So, when it is very, very intricate, it is difficult to form it; then we can go for a machining operation.

But machining also has its limitation in forms of the part's shape. It is not that any difficult machine shape is brought, and it will be easily machinable. So, machining also has its limitation; but there are certain shapes, which are difficult to form using conventional manufacturing processes or near net manufacturing processes, then we can use machining to create or to produce those shapes on our final product.

Then finishing operations for final dimensions and surface finish. So, third point says, that sometimes whatever product we have made using casting or forging or forming, where no material removal has taken place, but the surface finish or the final dimensions are not according to our specifications. Why does this happen? This may happen because of certain amount of cooling problems that takes place during the casting operation; or during the forging the die has worn out, it is not giving accurate dimensions that we want; or during the wire drawing or tube drawing operation the dimension that we are getting finally are not according to the desired tolerance levels.

Then whatever dimensions we get or whatever product we get by this particular or the initial processes that have been done, we finally subject that particular job or that particular shape that we have achieved, to the machining operations. So, machining then will result or a machining will act as a finishing operation to give the final dimensions. So, final dimensions may be achieved using the machining operation.

More over, sometimes we need to have a very good surface finish or sometimes there may be a problem of the oxide layer that is forming on the top surface of the work piece. If we need to remove that and we need to have a very good surface finish on our work piece, then also we have to go for a machining. So, machining therefore, will act as a finishing operation in the total product manufacturing cycle.

Then certain surface characteristics are required. Suppose, for example, we need to have a knurled surface. So, knurling is one operation that is carried out or we need to have a particular surface texture on the surface. Then, in order, to have that kind of surface texture or that kind of finish, we need to go for a machining operation.

So, we have seen the different categories of application areas are there where machining is imperative or machining is necessary.

Then the last point here is - it is economical, particularly when number of parts desired is relatively small. So, if the parts desired are in a very large number or the volume of production is very, very large, we may go for a casting operation or sand casting or permanent mold casting, but where the part number or the volume of the parts that have to be produced is considerably less, then in order to economically produce those parts, we may go for a machining operation.

So, we have seen that there are certain advantages or certain necessities that has to be incorporated, like there are certain areas where machining is imperative and machining has to be carried out. If we do not do or if we do not machine that particular part, we will not be able to produce the final part according to our desired quality standards or according to our desired dimensional accuracy. So, there are certain necessities for machining that are there when we choose a manufacturing process.

So, it is not that only machining has one particular necessity; there are number of factors that have to be considered where machining is imperative or we can say machining is inevitable. Now, any process, which has certain advantages or it is necessary it has certain limitations also. So, what are the limitations of machining?

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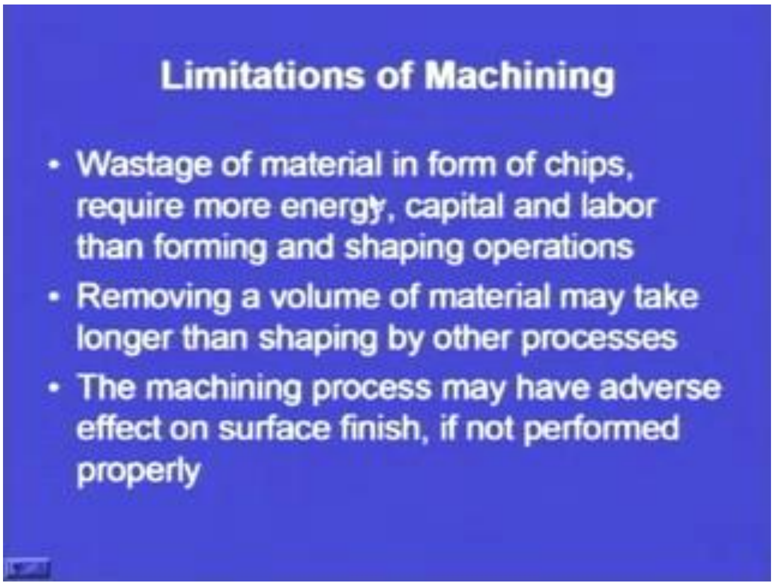

The first point is the wastage of material. So, the wastage of material is in the form of chips. Different types of chips - we will discuss in the subsequent chapter or subsequent lecture. It requires more energy - the energy requirements are more. It is capital and labor than forming and shaping operations.

So, first point here I have addressed this point in detail, that in metal working operations there is no loss of material. When we want to form a particular shape, we are using a initial shape, we are converting it into its final shape by just folding it or just bending it or just letting it pass through a die or just pulling it like in tube drawing. There are different types of mechanisms whereby we convert - we can convert - raw material shape into a final material shape without losing any material; but here in case of the machining operation there is bound to be a wastage of material.

If we are using the machining operation, as a as a cutting operation the wastage of material will be considerably more; but under certain circumstances, we will be using machining as a finishing operation. So, where by the word finishing will come into picture, the loss of material will be substantially less; but any how the loss of material is always going to take place, when we are going to use a machining operation.

So, in the previous slide we have seen that machining is necessary. It is inevitable under certain applications spectrum of products. So, for certain category of products, machining is inevitable; there is a certain necessity for machining operation; but here we are seeing that machining results in the wastage of the material also, in the form of chips. So, this is one big limitation of the machining operation.

Then the second limitation is, that it requires more energy; it requires more capital; and it requires more labor. More over the labor requirements may be skilled labor here; because if our lath machine or a drilling machine or a milling machine has to be operated, then if it is being operated manually or it is a manual machine, then the skill of the operator will directly be transformed into the quality of the final product that we are getting.

If, in the present day scenario, we are using computer numerically controlled machines, then also we have to program, we have to see that what are the G and M codes, and how the programming has to be carried out. So, that is another important skill set that is required for the worker who is working on a CMC machine. So, the skill set involved as compared to normal processes, in case of machining the skill set involved is much wider as compared to the normal operations.

So, the major limitation is in the terms of wastage of material, labor intensive or the skilled labor is required, energy requirements are high, more over the capital requirements are also high.

Then, second point is removing a volume of material may take longer than shaping by other processes. So, the major point here is that it is a time consuming process; wherever we are removing a volume of material, it may take longer time as compared to changing the shape. We can take an example of particular rod, if we need to reduce its size, we can pass it through a die of the required size, and there by we will get the required dimension.

Whereas, if we want to reduce the dimension using the machining operation, we have to perform the machining operation, may be we have to give a number of cuts depending up on the requirement or the depending up on the material of the job or depending up on the tool that we are using, depending up on the machine we are using.

So, that interaction of the three elements, then come into picture - what is the material of the work piece? What is the tool material? What is the machine tool we are using? So, depending up on the interaction, we have to make a decision how many cuts we have to give to that particular rod, of the standard size, to reduce its diameter by a particular level.

Whereas, in case of a drawing operation we may reduce it in a single pass also. There by also a number of passes may be required, as we are talking of number of passes to be given here for reducing the shape by cutting or by turning; but it has been noted, it has been observed, that if we want to remove a volume of material, a time required will be considerably higher as compared to getting the same shape, using any of the metal forming or metal working operations. So, time consuming process. So, machining time consuming - time consumption may be higher as compared to the other processes.

Now, coming on to the third point - the machining process may have adverse effect on the surface finish if not performed properly. Now, we have been discussing, and we can see, that machining is required for improving the surface finish of the part or the component; but sometimes if we are not performing the machining operation properly - properly means that sometimes some kind of chip formation will take place. All the time chip formation will take place, but sometimes it will be a continuous chip formation.

Now, the continuous chips when they will form, they will get entangled with the tool holder, that they may get entangled with the work piece, and hardness may be more for these chips. So, when these will rub against the work piece, the surface finish may be spoiled. So, performing the operation properly, means that we have to ascertain that these chips that are forming or the continuous chips that are forming do not entangle with the work piece. If they entangle with the work piece, the surface finish is bound to be spoilt.

Another important point is, if we do not mount our tool particularly on the tool holder or it has not been clamped properly on the tool holder. Then there may be some chatter that may takes place, and if chattering is there, the tool may rub against the work piece and they may spoil the surface finish of the work piece.

If the work piece has not been clamped properly in the chuck, thereby it will vibrate and certain amount of surface finish will be spoiled. So, depending up on that how we have to perform the operation, if we are not performing the operation properly, then the surface finish is bound to be spoiled or is bound to be affected adversely.

So, it is important that if we are performing a machining operation, we have to take care of all the precautions, we have to take care of all the guidelines, so that the surface finish that we desire we should be able to get that particular surface finish. So, with this we come to the end of this session on machining fundamentals. Although we have discussed the machining fundamentals for half of this lecture only, initially we discussed the left over portion of the last lecture, whereby we were discussing the high energy rate forming processes.

So, we just reviewed what we have discussed in these series of lectures on metal forming or on manufacturing processes, thereby we discussed what are high energy rate forming processes, whatever we have discussed in the last lecture was reviewed, and thereby we switched our attention towards another important aspect of manufacturing technology that is the machining operations. Right now, we are in the middle of discussing the fundamentals of the machining operations. We will continue with the machining fundamentals in our next lecture.

Thank you.