Manufacturing Guidelines of Production Design

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Lecture-24
Design Guidelines for Machining

Namaskar friends, welcome to session 24 of our course on manufacturing guidelines for product design. We are currently in the 5th week of our discussion and just to have a brief review of what we have covered till now. We have already finished discussion for the 4 weeks that is halfway mark we have already achieved. And in the very beginning of the course during the 1st week we discussed about the basic aspects of manufacturing classification of manufacturing processes.

Basic fundamental concept of process capability and we have seen that what are the basic manufacturing processes that are used for making various types of products. In the 2nd week we focused on engineering materials, their classification, their different properties and the selection criteria that is usually employed for selecting an engineering material for a specific application.

And there after we focused our attention on the various tools techniques that are available for the selection of the processes and we have seen that how we can make use of the various charts and diagrams as well as the relationship between the process and the material the process and the shape. And how we can make decisions related to the product design based on the information that is already available in the form of charts and diagram.

Thereafter we shifted our attention on the individual processes which cause that is very very important from the product design point of view. So we have been discussing the processes and we have deliberately followed a proper sequence related to the processes. If you remember we have classified the processes as the primary forming processes, deformative processes then we have seen the material removal processes, joining processes and the finishing processes.

So, if you remember what we have discussed till today or what we have what are the processes which we have already discussed. We have already discussed sand casting, we have discussed die

casting as well as we have discussed compression molding, we have discussed injection molding. So, these are all the primary forming processes in which we give a shape to our product, so sand casting also, so we use metal as the raw material in case of die casting also mostly we use metal as the raw material.

Then in case of injection moulding or compression moulding or extrusion we work with plastics. So, we have seen that whether our product is going to be made by a metal or the product is going to be made by a plastic what are the processes which are generally used. And what are the specific guidelines that we must keep in mind while we are designing our product that is to be manufactured using any of these processes.

So, all these is related to the primary forming that is giving shape to the product, now the second types of processes are the material removal processes which are usually we can say like machining. So, machining is a process in which we remove the material, so we have to have certain guidelines for the parts which are to be made by machining process, what are the specific guidelines that we must keep in mind when we are designing the parts which have to be made by the machining operation.

Subsequently we will focus our attention on the design guidelines or part design guidelines for the joining processes and finally for the finishing processes. So, we have seen that step by step we are trying to learn the design guidelines for various types of manufacturing processes that are usually used for manufacturing of various types of products of different material. So, with this background we have already covered maybe sand casting, die casting, injection moulding, exclusion, compression moulding.

Today our target is machining, that what are the specific product design guidelines related to the machining process. So, but as is the customary we have been following this that we first have a brief discussion about the process and then we go to the guidelines. Because there maybe learners who do not have a background of mechanical engineering, so they may know that what machining actually is and we try to take a very simple example of the process as we have seen.

In case of compression moulding, extrusion, injection moulding and prior to that we have seen for sand casting and die casting, so then to start with let us try to understand machining.

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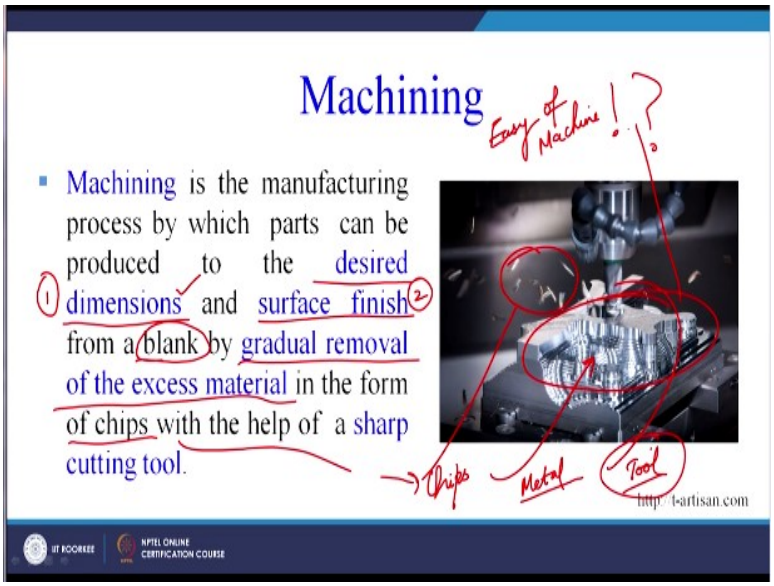

And when diagram is shown here where a metallic piece this is the metallic piece which is being cut and this is basically the tool. So, we make use of a tool and we cut the metal piece and this is what is shown here, the metal flying is these are called as the chips. So, we have chips the material removed in the form of chips in case of metal cutting or machining operation. So, we have a tool, we have a workpiece which is made up of usually metal it is held in a work holding device.

And the tool removes the material in the form of chips, so this is the basic machining process, so machining is the manufacturing process by which parts can be produced to the desired dimensions which is very important. So, if you remember we have use the word machining when we were talking about finishing of the sand castings, we have seen in the data that the surface finish that we get with sand casting process is not very good.

So, therefore in order to bring the product to the exact surface finish we have to machine the material from the sand casting product. So, therefore machining helps us to get the desired dimensions for the product as well as I have already mentioned the desired dimension maybe the

one objective of doing the machining. And surface finish improvement is another maybe objective of doing the machining operation from a blank which is a raw material.

By gradual removal of the excess material, so here we are removing the material with the help of a tool in the form of chips, chips are already shown here. In the form of chips with the help of a sharp cutting tool the tool is also shown here. So, this is the basic machining process where a tool or cutting tool is used to remove the material from the workpiece, why in order to give it the desired shape, in order to get the desired surface finish, in order to get the desired dimensions of the product.

So, that is basically objective of the machining operation, now this is the product which is being made and machining is being done. Now how we must design this product, so that it is easy to machine, so target of our lecture today or target of our discussion is to learn those product design guidelines which will make the product easy to machine. Now we will go to those guidelines now before going to that, so machining is a very versatile process as well as it has got number of variants.

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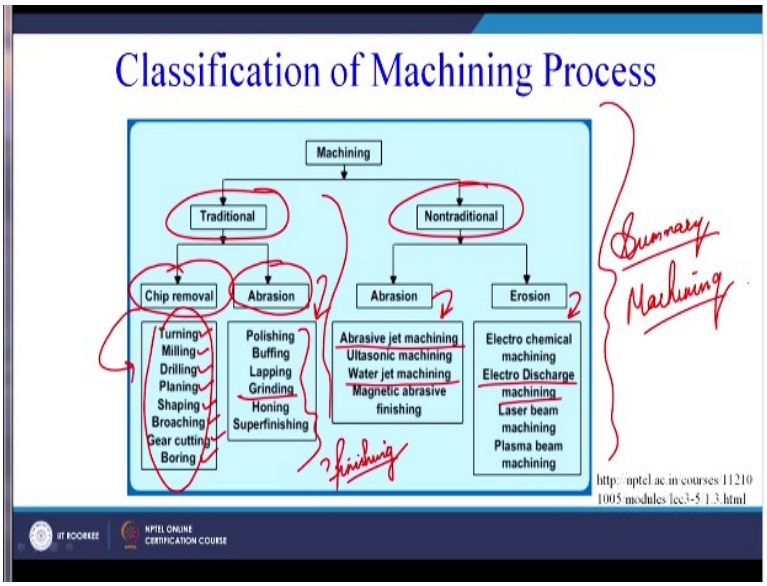

So, we can do traditional machining, we can do nontraditional machining within traditional we can have processes where the materials is removed in the form of chips which was shown in the previous slide. There can be processes in which the material is removed by abrasion process, so

these are all in abrasion, these are all the finishing processes usually called the finishing processes and we will discuss the design guidelines for maybe grinding and some of the other processes as the time allows.

But grinding is a very commonly used finishing process for giving the desired surface finish to our product. So, these are by abrasion where the material is remove mostly the processes are finishing processes, the chip removal processes are basically the major stock removal. For example you have a 10 millimeter thick metallic plate and you want to make a hole of 8 millimeter diameter.

So, in that case how to make the hole you will use a drill and you will remove the material from there. So, lot of material would be cut in order to produce that hole in a 10 millimeter thick sheet or 10 millimeter thick plate. So, therefore in chip removal processes a lot of material will be removed some of the examples are given here turning, milling, drilling, planing, shaping, broaching, gear cutting, boring.

So, all these processes lead to a lot of material removal from the workpiece and then we get the desired shape, desired dimensions of the product. So, these are traditional processes whereas we have non-traditional processes also like where the material is removed by abrasion and where the material is removed by erosion. So, we can have some of the processes which are common electro discharge machining process, EDM is quite common process whereas in abrasion we can say abrasive jet machining is one process and water jet machining is another process.

So, whatever are the design guidelines for the machining, we have to keep in mind while we are designing the product. So, the these processes will remove the material with different mechanisms, in traditional machining the tool will be in direct with the workpieces we have seen in the previous slide. And the material will be removed by different mechanism maybe sharing maybe one mechanism there.

In case of nontraditional machining the tool is not in direct contact with the workpiece in many cases the tool will remove the material by using different forms of energy. The energy can be in

terms of mechanical energy, it can be electrical energy, it can be mechanical energy. So, using different forms of energy the material will be removed from the workpiece it can be by heating and vaporization of the material or it can be by the abrasion of the material or erosion of the material.

Depending upon the process, depending upon the material removal mechanism different processes are there rather I must say vice versa depending upon the process there will be different mechanisms of material removal from the workpiece. So, this is you can say the broad summary of the manufacturing processes which fall under the broad gambit of machining. But since the material has to be removed, so we have to take care that how we must design our product.

So, that it is easy to machine, so wide variety of processes are there but we have to see when the material has to be removed what are the guidelines that must be taken care of.

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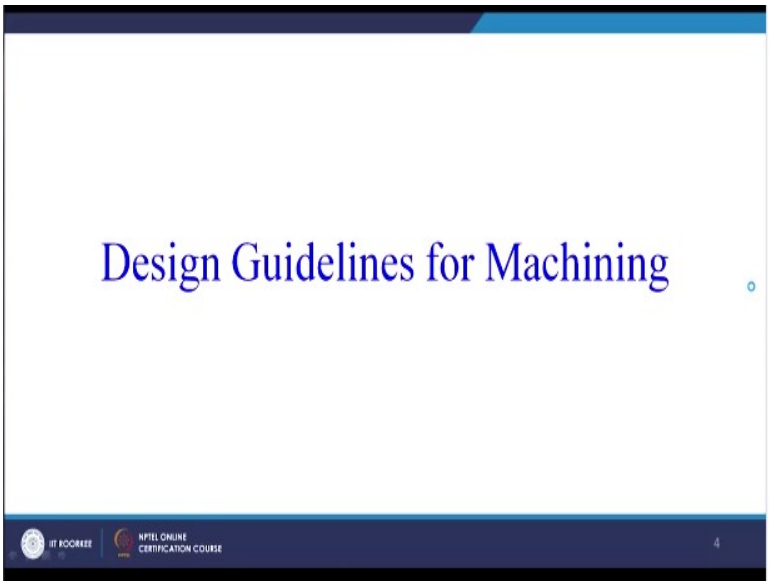

So, now let us see what are the design guidelines for machining operation, now we have designed a product which has to be made by machining or holes are to be made or some surface have to be smoothened or the surface has to be finished or we have a stock of material in which we want to give a desired shape. We will see certain examples with the help of diagrams in the subsequent slides, so we have a raw material we want to remove the material from the workpiece

to give it a desired shape or a specific dimensions or a specific surface finish. We need to think that how the product must be designed, so that it is not difficult to machine, now what are the guidelines let us see quickly.

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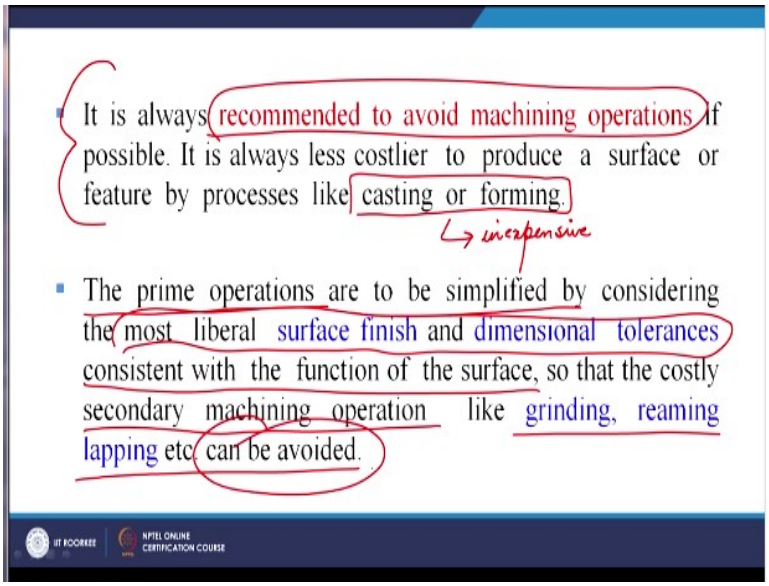

So, the first overall objective while proposing the use of machining process is that it is always recommended to avoid the machining operations. So wherever possible we must should try to avoid the machining operations, why it is always less costlier to produce a surface or feature by processes like casting or forming. So wherever possible we must should try to go for casting or forming because these are inexpensive processes which means they are not very expensive processes whereas our machining process or machining processes are relatively more expensive as compared to casting or forming.

So, the first broad guideline is that if you have a choice you must avoid the use of machining operations. The prime operations are to be simplified by considering, so this is another important guideline that we must simplify our product design why how, why we must simplify because it will become easier to machine. So, why it we need to simplify because we want that the product design maybe made easily how we can do that why we must do it.

Because it will be easier to machine how we can do it, it is also given, so it must be simplified by considering the most liberal surface finish and dimensional tolerances very important. Many

times in the beginning of the this course also I have told the designers maybe over emphasize on the kind of surface finish the customer may not be interested even the customer may not be knowing about the quality that can be achieved with different machining operations.

But as a product designer you always that it must be very smooth the mirror like surface finish must be there but that adds to the cost of the product. So, we can be liberal with our specification related to the surface finish of the product or the surface of the product as well as we must be liberal with the tolerances that we specify for the surface. So, the dimensional tolerances and surface finish, if we choose properly our machining cost will definitely come down.

Maybe a single operation, machining operation may give us the kind of surface finish and dimensional tolerance that we plan to build in our product or that we plan to include in our product design. So, we must not over emphasize the importance of surface finish why because we must be consistent with the function of the surface. If the surface does not require a very high surface finish we must not over emphasize that this is the basic level of surface finish required.

Many time designers tend to produce specifications which becomes difficult to achieve economically. So, as product designer we must first do our basic study that how much surface finish is going to be good. Higher surface finish may make the product look better but may not be consistent with the requirements of the surface. So, that is one thing we must keep in mind, so that the costly secondary machining operations like grinding, reaming, lapping etc. can be avoided.

So, we must try to avoid these secondary operations by specifying the optimal again I am saying the optimal value of the surface finish consistent with the requirements of the surface. So, if the requirements can be met by a lower value of a surface finish we must not over emphasize the value of the surface finish or the dimensional tolerance. Now this is one important slide which is carry forward of the previous slide.

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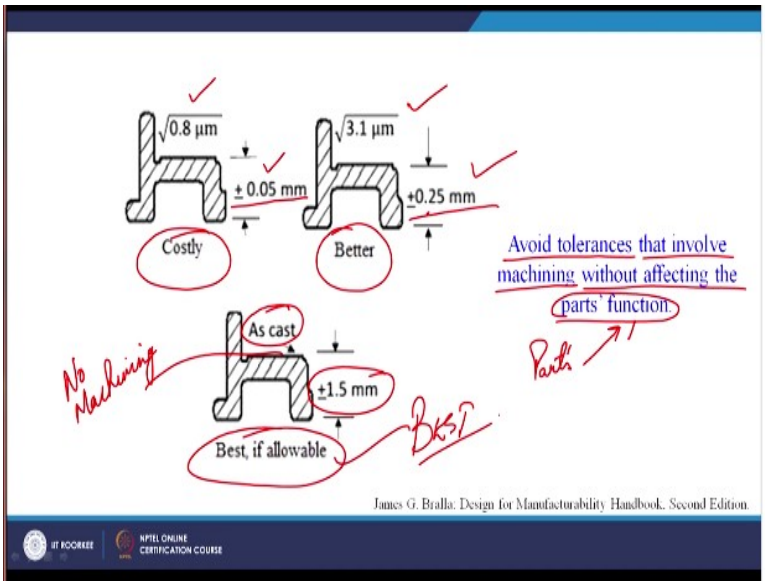

It states avoid the tolerances that involve machining without affecting the parts function. So, it is important parts function is very very important as it is written here. So, the every product is designed for a specific function and we have introduce the concept of function also in value engineering we normally define a function of a product as a verb and a noun. For example we say what is a function of a fan it is to circulate air.

So basically we have to identify the function of the product and once that function has been achieved or function has been defined, how to achieve it is better known to the designer and how to manufacture that product also must know to the designer. So, the designer must feel that this is the function of the product it can be achieved with this much dimensional tolerance, it can be achieved with specifying this much surface finish.

So, it must not be maybe a conflict that the parts function can be achieved with a lower value of the surface finish but the designer in his over enthusiasm maybe specify a higher requirement for surface finish which may lead to secondary operations and may add cost to the product. As it is given in this diagram also, in the figure we see this one is costly and you can see for yourself the requirements which is given here.

And here requirements are slightly relaxed, so it is better both the requirements you can compare the values here and it is best if allowable. So, it is as cast only, so need of machining on this

surface, so as cast if we can use we can completely avoid the machining on this surface. So, one operation has been removed, so it will be best or the cost effective design of this product and the other value also you can compare ±0.05, ±0.25, ±1.5.

So, this is we can say best design by avoiding the machining and by relaxing the tolerances or relaxing the other dimensional tolerances. So, wherever possible we must try to fix up the surface finish requirement and the tolerance values as per the as consistent with the parts function. So the functionality must not be compromised the best possible finish and tolerance must be given or given or maybe specified for the product depending upon the functional requirement of the product, so that is the bottom line.

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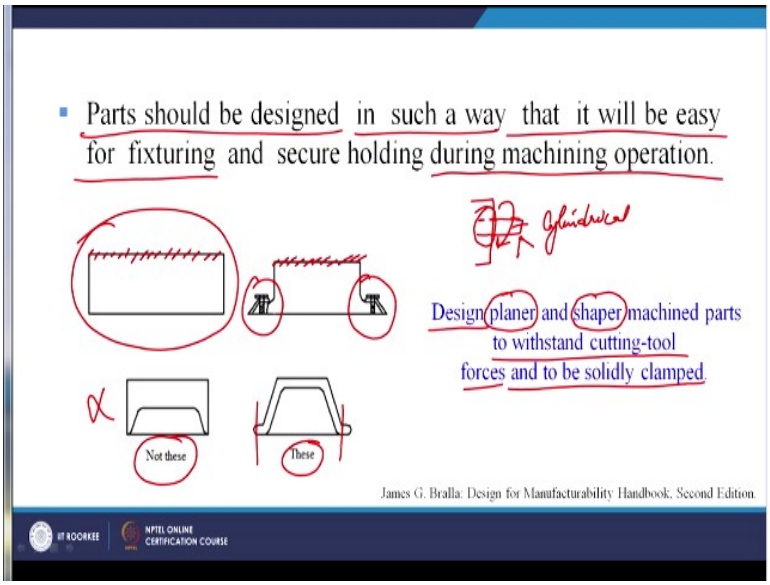

Now we can see parts should be designed in such a way that it will be easy for fixturing and secure holding during the machining operation. Now during the machining operation the part has to be held maybe for example we can say for doing the turning operation the part has to be held in a chuck. So this is the holding mechanism for the cylindrical part, suppose this is a cylindrical part it is held in the chuck it is rotated, so we have a tool here and we remove the material.

So, we need to hold the workpiece in order to remove the material from the workpiece. So, we must design the parts should be designed in such a way that it will be easy for fixturing means it is easy to fix it on the bed of the machine or in the chuck of the machine or in the work holding

device of the machine tool. So, we must ensure that it is easy to fix the job and secure holding during the machining operation.

Now design the planer which is one process and shaper which is another process shaping, so design planer and shaper machined parts. So, the parts which have to be made by planing and shaping operations must be designed in such a way to withstand the cutting tool forces and to be solidly clamped. So, they must be properly clamped, clamped means they must be properly held on the table when the tool is doing the motion on the workpiece to remove the material.

So they must be properly clamped, how that can be done, so this is not a very good design, it will be difficult to clamp but if we can modify the design slightly we provide 2 clamping surfaces here it will become easy to clamp. And suppose this is a surface that we want to machine, so this is otherwise difficult to clamp but once we have clamped it properly it will be easy to do machining on this surface.

Similarly this one is also very difficult to clamp but if we modify the design it will become easier to clamp. So we must design the parts in such a way that they become easy to clamp, easy to hold on the machine table. So, that the tool connect on the material or the workpiece and remove the material as per the desired design of the product. Now this is a third guideline basically that we are seeing, the first one was related to as we have seen related to the clamping.

The two different shapes we have seen for clamping and prior to that we have seen a very important guideline that was related to how much surface finish and dimensional tolerance we must specify for our product it must be consistent with the function of the product. So, the first is surface finish and tolerance guidelines, second are how to design the product, so that it can be easily fixed on the machine table.

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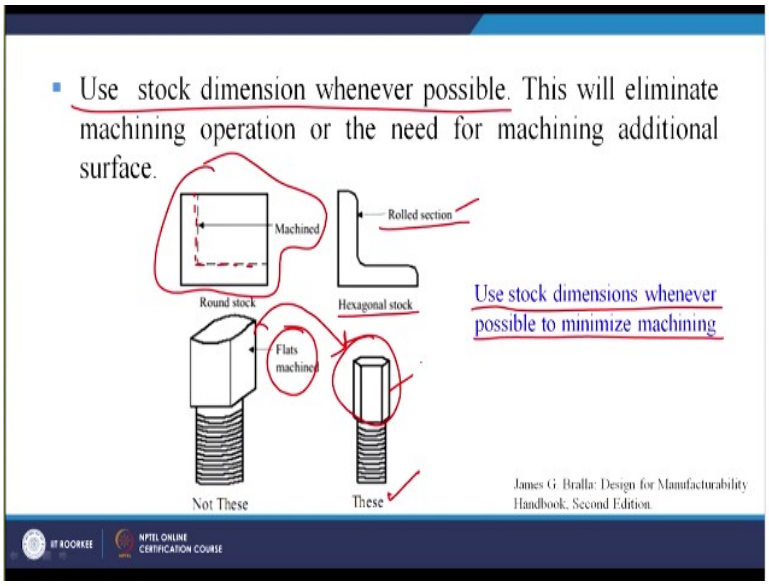

The third guidelines are use the stock dimension whenever possible, so stock dimension whenever possible means that we must be as near to our final product as possible based on the design of the product. Now for example this is our product, this is the final product and some material we want to remove, so we must not take a stock like this and then try to remove the material as specified here.

If possible we must go for the rolled section and if surface finish is required we can do minor or maybe less material removal and we will get our final product. Similarly we can see here this is a flats which are machined here and then we try to make it a hexagonal head like this. but if this is available already then we must choose this material which is use the stock dimension whenever possible, this will eliminate machining operation or the need for machining a additional surfaces.

So wherever possible we must try to look for the similar parts with which we can do minor machining, minor material removal and use it for our product. So, use the stock dimensions whenever possible to minimize the or to minimize the volume that has to be machined in order to get our final product. So, this is you can see in order to generate from go from here to here lot of machining will be required. But many times this type of hexagonal head may directly be available, so we must make use of that.

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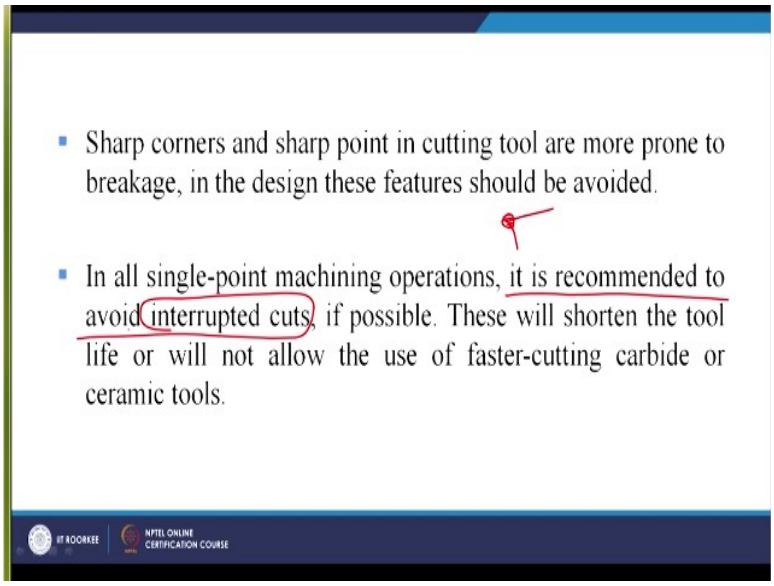

Then the sharp corners are sharp point in cutting tool are more prone to breakage in the design these feature should be avoided. So, sometimes we have very sharp corner in our design, product design, so the tool will need to be sharper enough to reach to that corner. So a very shaper tool may lead to breakage, so we must design the product in such a way that very very sharp tools are not required.

In all single point machining operations it is recommended avoid the interrupted cuts, we must avoid the interrupted cuts, why because these will shorten the tool life or will not allow the use of faster-cutting carbide or ceramic tools. So which may fail under the interrupted cutting, so wherever possible single point cutting tool maybe this is a point of the cutting tool, so in case of single point cutting tool we must avoid the interrupted cuts.

Because that may lead to failure of the tool or it may reduce our choice or limit our choice to the specific tool materials only which we may not be able to use carbide or ceramic tools if there are interrupted cutting has to be done. Because of the forces that will be generated may lead to fracture or failure of the carbide or the ceramic tool. So we must try to avoid the surfaces where interrupted cuts are required during our product design.

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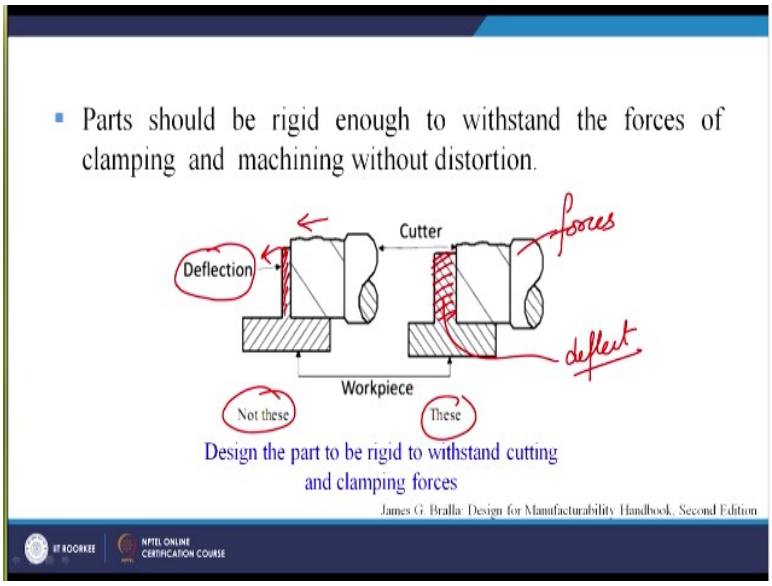

Now part should be rigid enough to withstand the forces of clamping and machining without distortion. So we must design our part in such a way that it can absorb the deformation or it can be rigid enough to resist the deformation or the deflection. So here the deflection will take place, this is a surface, this is the tool. So, when the tool will act in this direction there maybe deflection of this surface in this direction.

So, this can be easily avoided it is not recommended not this design, so this is the design you can see it is a thicker section and the forces of the tool may not be able to deflect this section. So we must design the part in such a way that tool is not able to deflect the section or deform the section. Design the parts to be rigid to withstand the cutting and the clamping forces, so cutting and clamping forces must not be able to deflect or deform the surface which is not desirable.

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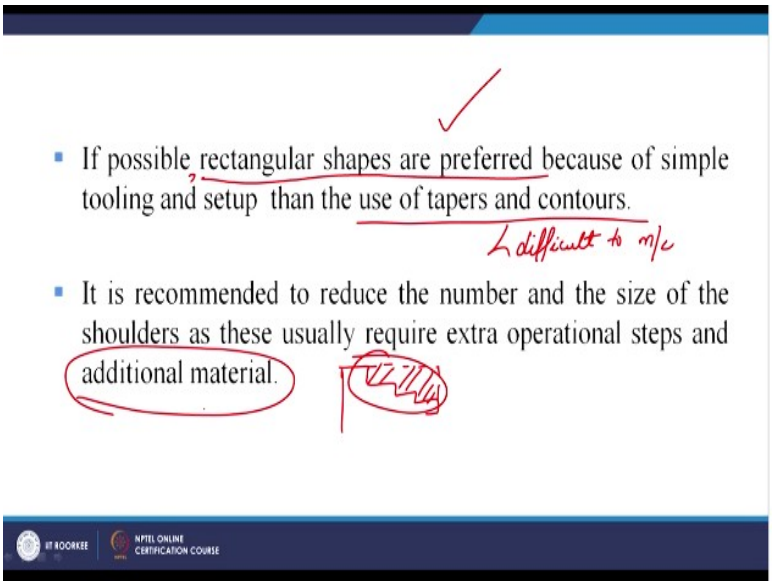

Then if possible rectangular shapes are preferred because of simple tooling and set up then the use of tapers and contours. So, wherever possible sometimes in our product design a tapper or a contour may give a better aesthetic look to the product. But if the product has to be made by machining we must avoid tapers and contours because these are difficult to machine shapes, difficult to machine, so what we must do if possible rectangular shapes are preferred.

So, wherever possible we must and the specifically if the product has to be made by the machining operation. Rectangular shapes are preferred because of the simple tooling and setup requirements rather than going for tapers and contours which are difficult to machine. It is recommended to reduce the number and the size of shoulders as these usually require extra operational steps and additional material.

So maybe shoulders must be as less as possible, so maybe if this type of a product is there number of shoulders are there which creates problem during the machining operation may lead to lot of material wastage also. We can see this much material will have to be removed, operational steps and additional material will be required. So we must design the part keeping in mind these recommendations wherever possible make use of recommendations during the product design stage, so that we are able to make a product which is easy to machine.

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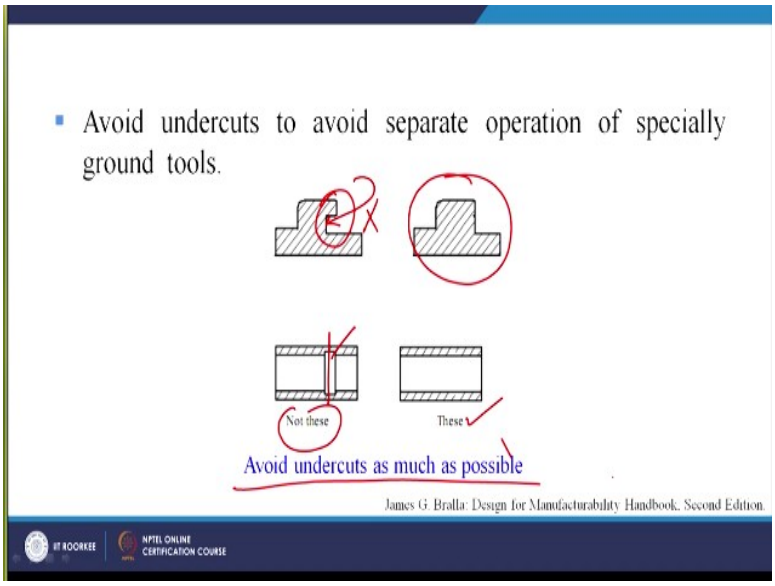

Now avoid the undercuts to avoid separate of specially ground tools, so this is not recommended, this is an undercut here which is not required. So, we can design the part like this, this is also not recommended, this is difficult shape to machine and this is a good shape which can be easily machined. Avoid undercuts as much as possible, sometimes it may be unavoidable, so there we have to go for the undercuts.

But if possible we must try to we must not be fancy our ideas of making a very complicated product and later on we realize it has too difficult to machine. So, if possible try to avoid the use of undercuts in the design.

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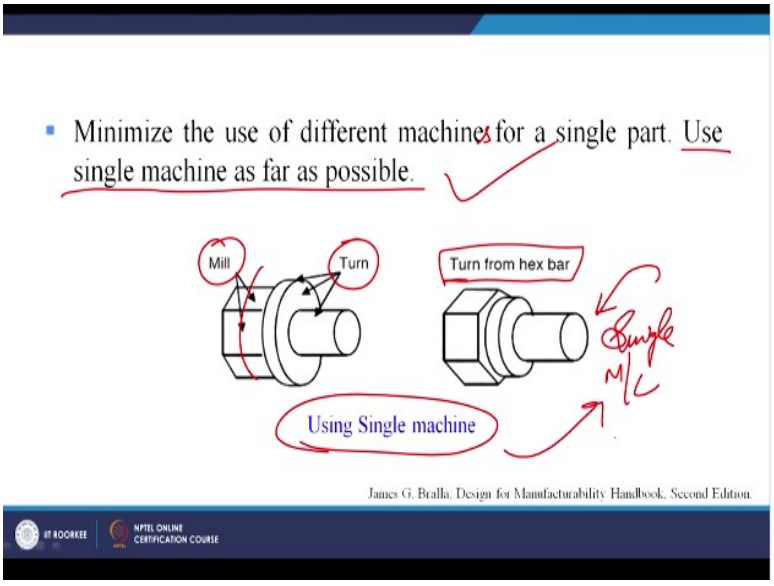

Minimize the use of different machines for a single part, so we can minimize the use, how we can minimize because here you can see here a milling machine is this surface is to be milled. And this is the turning, so we can do we can select a raw material as we have seen in the previous slide also. In this case we must be very judicious when we are selecting a stock of material from which we are going to machine our final product.

So we can choose our stock in such a way here it is being chosen turn from a hexagonal bar. So, if we take the hexagonal bar this can be made on a single machine only, whereas this may require 2 different machine. So, minimize the use of different machines for a single part use single machine very good guideline, use single machine as far as possible. So this will be using a single machine we can very easily make this product.

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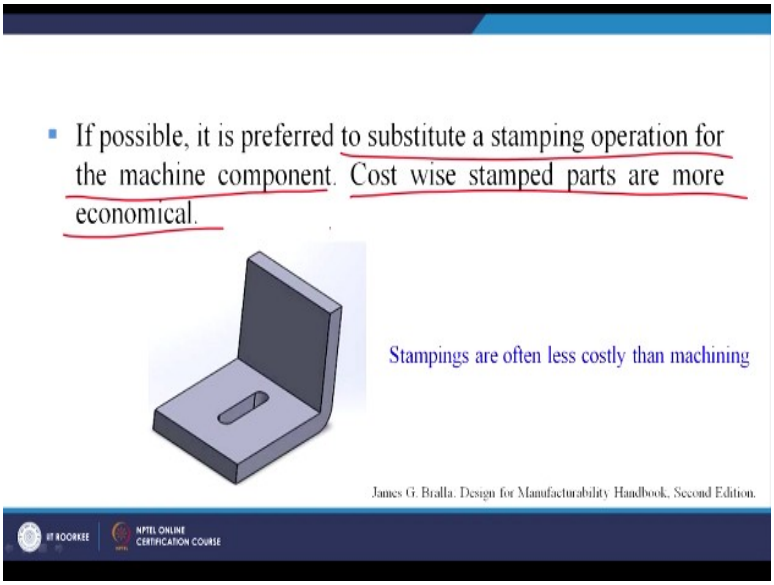

If possible it is preferred to substitute a stamping operation for the machine component, cost wise stamped parts are much more economical. So we can do the stamping operation is the thickness of the plate or the sheet is reasonable we can go for a stamping operation but if it is very very thick then it becomes difficult sometimes to do the stamping operation. But wherever possible instead of trying to remove the material by machining we can easily do it using stamping which will be cost effective.

So if possible it is preferred to substitute a stamping operation for the machine component, cost wise stamped parts are much more economical.

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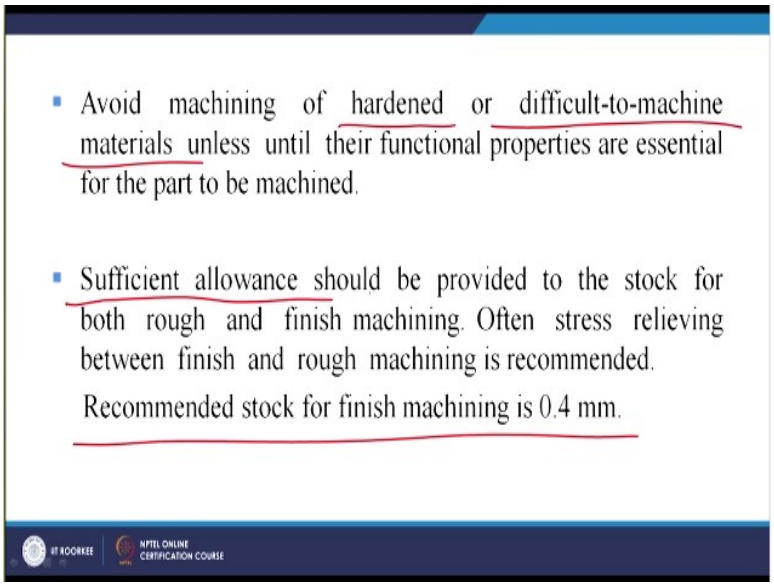

So avoid machining of hardened or difficult to machine material until their functional properties are essential for the part to be machined. So, we must avoid very hard materials or difficult to machine materials because that will affect our performance of the tools also and may not give us the desired results also. Sufficient allowance must be provided to the stock for both rough and finish machining often stress reliving between finish and rough machining is recommended.

Recommended stock for the finish machining is 0.4 millimeter which means that we must leave the sufficient allowance to be provided for the rough and the finish machining which means a simply in 2 sentences we can say. That when we are designing our product and the product has to be made by the machining operation, we must make our product slightly larger than the actual product, we must give some allowance for the machining operation or in order to get the desired dimensional tolerance as well as the required surface finish.

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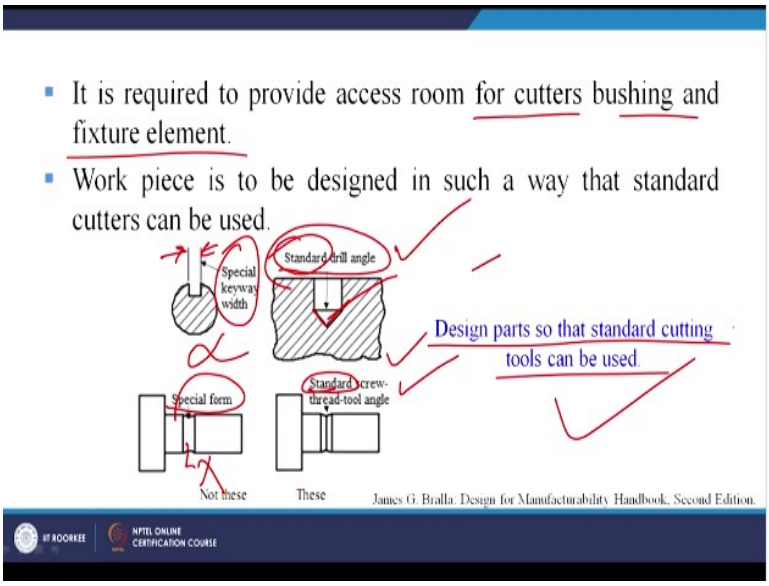

So, it is required to provide excess room for cutters, bushing and the fixture elements. So, we must try to design the part in such a way that the cutters, bushing and fixture element have the excess to the suction or the part of the product. So, it is required to provide excess room for cutters, bushing and fixture element, workpiece is to be designed in such a way the standard cutters can be used.

So, design of the cutting tool will again a challenging task, so we must provide or design the features in the product in such a way that the required tools are already available. And if that is not possible that information is not available to me I must check that what are the standard tools available which can machine different types of features in the product, for example keyways are required.

So, we must see that what are the standard tools which can be use for producing the keyway and then the dimensions of the keyway must be decided based upon the tools that are available or standard tools which are available. Sometimes the designer may not follow this step and may put a keyway as it is the design requirement and then later on it maybe realize that the keyway design is not standard and there is no standard tool available for cutting that keyway.

So, you cannot go and now design a tool or get a special tool fabricated for producing that keyway. So, while designing the keyway we must take into account what are the standard

dimensions or maybe standard diameter or standard length of the tools which can be used for producing the specific geometrical features in the product. So, this is you can see a standard drill angle is there which is given here, many cases we use a twist drill.

So, the point angle is 118 degree which is a common knowledge, so this is a special form which may not be advisable. Similarly a special keyway as I have given the example may not be advisable, the standard keyway width is what is desirable. And standard screw thread tool angle this is standard drill angle, so we must take advantage of the industry standards while designing the special features in our products specially when these parts have to be made by the machining operation. So, design the parts so that the standard cutting tools can be used very very important slide.

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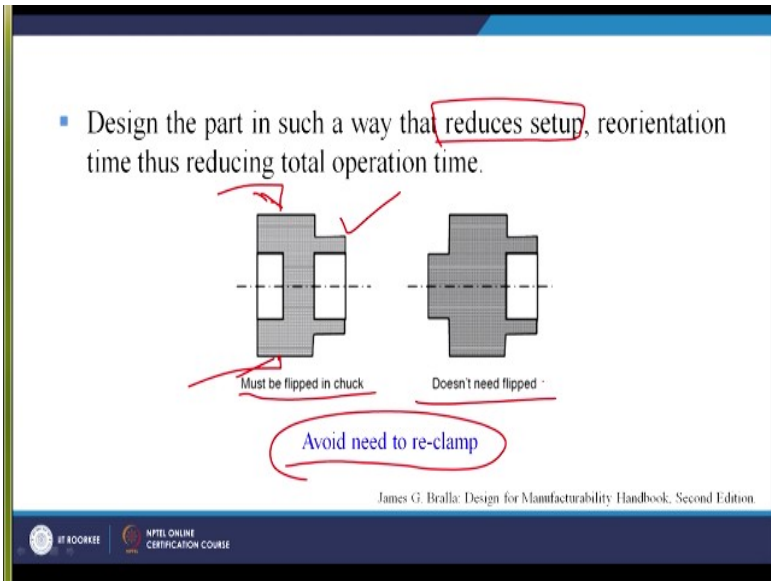

So, the last slide on your screen you can see is the design the parts in such a way that reduces the setup. Here you see it must be flipped in the chuck 2 times. So, must be flipped in the chuck means first you will set the job maybe this is the chuck it is set here, this is the way it is fixed here. And then once you do the machining the other side also we have to do the machining, so we have to take it unclamp it again clamp it from the opposite side, we have to flip it.

But if we change our product design it does not need to be flipped we can fix it here and then directly we can machine it. So, maybe many cases we may not require we must ensure that in

single setup only all the machining operations can be done easily on the design. So, this avoid need to re-clamp the tools as this needs to be flipped, this does not need to be flipped, so this is just one example.

We can look for many such examples where we require the job to be taken out from the work holding fixture and again to be clamped for doing the other operations. So we can modify our design in such a way that we are easily able to do most of the maybe 90%, 95% of the machining operations on a single setup only. So, with this we come to the end although I must admit here that there are large number of guidelines for machining.

But since we have to cover the entire spectrum of our course within a span of 20 hours only, so I think the today's session will give you a brief overview of the kind of guidelines that we must keep in mind when we are the products which have to made by the machining operation, thank you very much.