Manufacturing Guidelines of Production Design

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Lecture-39
Rapid Prototyping

Namaskar friends, welcome to session 39 of our course on manufacturing guidelines for product design. So currently we are in the last week of our discussion and we started this week with the very important concept of design for environment. Now we are to trying to finally achieve the target of prototyping the product, initially we have seen that what are the guidelines that we must keep in mind when we are designing the product which has to be manufactured using any of the standard manufacturing processes.

In the course of our discussion we have discussed the design guidelines for products which are going to be made by casting process. Guidelines for products to be made by die casting process, guidelines for the various manufacturing processes for plastics such as injection moulding, compression moulding. Then we have seen that once the product has been formed if it has to be joined together what are the guidelines?.

We have seen different types of joining processes and if you remember in the last 2 weeks of our discussion that is week number 6 and week number 7 our target was to learn about the various joining strategies that can be use for assembly of the product or for we can say adhesive joining or welding or brazing or soldering or vibration welding or ultrasonic welding or microwave welding or hole making.

So all that was the target of our discussion in week number 6 and week number 7. So in overall summary what we have learnt is that once we are designing a product and we have to decide that which process going to be adopt to manufacture this product. Now different processes are there and the very first week focused on the over view of the manufacturing processes. The second week our focus was on the engineering materials.

So once we have finalized our design we have to finalize the material which is going to be used for making the product as well as we have to finalize the manufacturing process which is going to be used for manufacturing of the product. So once the materials are finalized, the processes are finalized we have to then think that how easily we can manufacture the product and for that all the guidelines that we have discussed in this course are going to help the designers.

I must address that today we are at the fag and of our course, today is the 39th session that we are discussing this topic of rapid prototyping. But there is a lot of information which is available, we have been only able to touch the tip of the iceberg only there is a lot of additional information which is available. There are different books which give additional guidelines related to various processes.

For example we have taken design for machining only 25 minutes of discussion, 5 minutes of revision, 25 minutes of discussion. There are chapters which have been written on the design for machining guidelines that if the product has to be machined or the parts of the products have to be machined or have to be processed using the machining processes what are the various types of guidelines that must be kept in mind.

Similarly when the product has to be joined together using the welding process, what are the various type of guidelines that must be kept in mind. Although we have discussion on joint designs which are going to be used for welding processes and what are the joint design modifications that can be done. All that we have discussed but I must address that there are lot of other information also available which we must look into when we designing our product.

So, that is an important thing that I feel that when we are closing the course now lecture number 39 is today may be we will finalising with our last session that is session number40 where will try to sum up. But we have already covered and establish a sequence of steps that we must follow when we are doing the analysis of our design from the manufacturing point of view because we analyze the design from various perspectives.

So our target during this course was to analyze the design to modify the design modify the design, to redesign the part keeping in mind the manufacturing guideline. So, that our product that we are planning is easy to manufacture, so all those guidelines basically we have try to cover only the summary of the guidelines. Again I am reiterating there other guidelines also, so once the product has been designed.

All guidelines have been taken care of now we are confident that the manufacturing guidelines for the product design have been taken care of we will go to the next stage that is the prototyping. Once our design is ready we know the material that is going to be used, we know the process or the type of processes or the sequence of processes that are to be followed to finalize the design or to manufacture the product.

We will next go to the stage of prototyping, in prototyping we are these days focusing on rapid prototyping may be 25 years, 30 years, 40 years back may be in the 1960s or 70s we were using very traditional methods of prototyping. But today we have a technology called rapid prototyping in which very quickly in the shortest possible time duration. We try to make our prototype, because of the information technology, because of the development of computing machines.

Because of the development of computer aided design we are easily able to covert our design from the system, from the computer into a 3 dimensional model using various strategies and technologies. Now rapid prototyping long time back I have read that there are 70 to 80 different technologies that fall under rapid prototyping domain. But we may not be able to cover all these strategies.

We have already covered 3 to 4 processes when we completed our course on product design and development which has been successfully run twice under the MOOC's platform. So, in that case we have discussed what is rapid prototyping? and what are the various processes that fall under rapid prototyping and then we try to understand the mechanism of working of 2 or 3 processes. But here our target is not that, that what is Rapid prototyping?.

And what are the types of processes that fall under rapid prototyping our target is that once we are prototyping our part what are the things that we must keep in mind while finalising our rapid prototyping process. So with that background we will try to cover the today's session that what are the guidelines that we must keep in mind once we are going to rapid prototype our product.

Or we are going to 3D print our product, or we are trying to make our prototype using the fused deposition modelling or we are going to make our prototyping using a selective laser sintering or we are going to adopt the process of stereo lithography operators. So there are number of processes but there are few general guidelines that we must keep in mind.

Once we are doing the rapid prototyping of our design which we have already finalized. We have taken care of all the manufacturing guidelines if there are holes to be produced in the product. We have taken care of that the adequate centre to centre distance must be there between the hole. We have taken care that the centre of the hole is adequately at a distance from the edge of the plate.

So all those guidelines we have taken care, now we are going to the next stage. We are going to make a prototype a model of our product and see that whether the product as we have deigned it is looking like that or there are some interference problem when we are trying to join the 2 parts together or they are not fitting into each other. So all those things can be checked during the rapid prototyping stage.

So rapid prototyping is a crucial step in any product development cycle and we cannot ignore the importance of rapid prototyping or I must say prototyping. So let us quickly go through the basic steps that we follow in rapid prototyping. And then we will try to go to the guidelines that we have to follow when we are going to prototype our product using any of the standard approaches of rapid prototyping.

And one thing I must address here there is a good article which was presented by Zara, and Hugo on design for rapid prototyping manufacturing and tooling guidelines. So some of the data that we are presenting here it today's session is taken from this very good article which has been published. And they have tried to the authors they have tried to compile the information and produce a standard document which can be used by people worldwide who are using rapid prototyping processes.

But many things maybe with the advent of new and new process is coming into picture some of the things may need certain revision. But these are whether good guideline for the people or for engineers who are working in the area of rapid prototyping.

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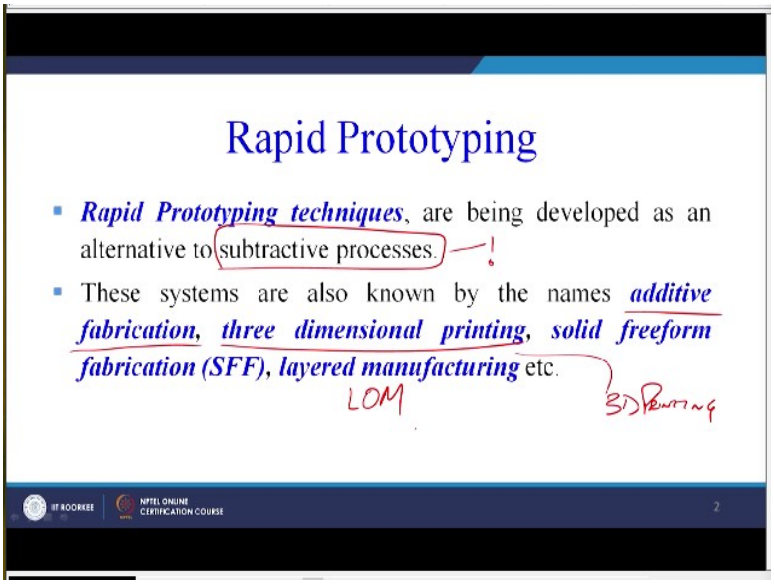

So, let us quickly see what is rapid prototyping?. Just may be very briefly now rapid prototyping techniques are being developed as an alternative to subtractive processes. Now what are the subtractive processes?, all of you may be knowing the subtractive processes are the normally the machining processes where we try to remove the material from the work piece and try to create a model.

So, Rapid prototyping processes are usually additive fabrication processes many times we say additive manufacturing also. We try to produce our prototype layer by layer instead of taking a bigger piece of the raw material. And then cutting the additional parts of the material to create a shape, here we try to create the shape layer by layer thus eliminating the wastage of materials that is usually we can say limitation in case of subjective subtractive processes.

So rapid prototyping techniques are being developed as an alternative to the subtractive processes. This systems are also known by the names of additive fabrication as I have already told additive manufacturing 3dimensional printing very common Rapid prototyping technique, 3D printing. Then solid freeform fabrication, layered manufacturing there is a process called the laminated object manufacturing which is an LOM laminated object manufacturing.

So different strategies, different processes are there that fall on the way broad umbrella of rapid prototyping. Now they can be classified based on the type of raw materials that is being used in a process where we can use a photosensitive liquid polymer. We can call it as stereo lithography operators where photosensitive polymer is used as the raw material. In case of selective laser sintering we use powder as the raw material, in case of laminated object manufacturing.

We use sheets as the raw material, so we can classify the Rapid prototyping processes based on the number of factors, one of the factors we can be the type of raw material that we are using. Now rapid prototyping technology are able to produce physical model.

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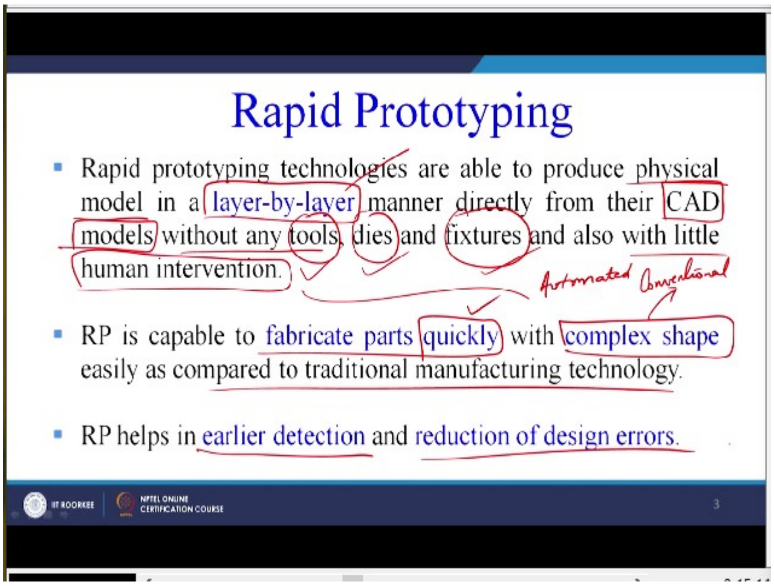

So, this is very important physical model in a layer by layer this is very important and already highlighted. We make a prototype layer by layer, layer on top of the other layer directly from their CAD models, as I have already highlighted with the development in our computational systems. CAD models are being developed for most of the 3 dimensional objects and then these models can easily be used to create a prototype layer by layer.

One layer top of the other without any tools now this is an another advantage without any tools, dies, fixtures. And are also with little human intervention very important advantages of rapid prototyping first thing can be from the name itself rapid and prototyping which means we are saving time quickly we are able to convert our ideas into the prototype we just have to create a CAD model of our idea.

And then using any of the interface between the CAD model and the rapid prototyping strategy number of strategies I have already named such as fused deposition modelling, selective laser sintering, stereo lithography operators. So, different strategies are there using any of the strategies this CAD model can be easily converted into physical prototype of the product. So, that is one advantage is already there that rapid means it is time saving.

Additional advantages are no need of tools dies or fixtures because the product is made layer by layer by layer by layer. And the process is majorly automated, so automatic process is used. So, the human intervention is also minimized, so rapid prototyping is capable to fabricate parts quickly I need not explain it again already I have highlighted the point with complex another advantage of rapid prototyping that very complex shapes which are otherwise not possible with the conventional processes.

If you remember we have seen in most of the conventional processes shape complexity is a major limitation. So, here the shape complexity is not at all a limitation we can create very complicated shapes using the rapid prototyping processes. So, complex shapes easily can be made as computer traditional manufacturing technology, rapid prototyping helps in earlier detection and reduction of the design errors.

As I have highlighted in the beginning of the today's session only that if 3 or 4 parts have to be joined together. We can create these parts from their CAD models easily using any of the rapid prototyping processes and then we can try to assemble them and try to see the kind of interference whether they are looking good or not what kind of joint can be better designed. So, if there is a faulty design of joint it can be improved.

So early detection of errors and remedial measures can be taken accordingly, so this is will reduce the design errors. Now rapid prototyping we are doing after our design has already been finalize, so design is ready now we are trying to prototyping, during the design we have taken care of all the guidelines that we have discussed till today. So, these guidelines we are now trying to check using prototyping.

And if there is a problem they will go back and try to change our design based on the various manufacturing guidelines that are known to us. So, therefore rapid prototyping is giving us or is increasing the timely manner in which we are able to launch our product in the market or are helping us to manage our time more effectively and efficiently. Because quickly we are able to detect the error immediately we take remedial action.

Again we prototype and see whether the product is ready or product is ready to be manufactured or not. So we save time using the rapid prototyping strategies now what is the methodology very common diagram which is given in most of the books.

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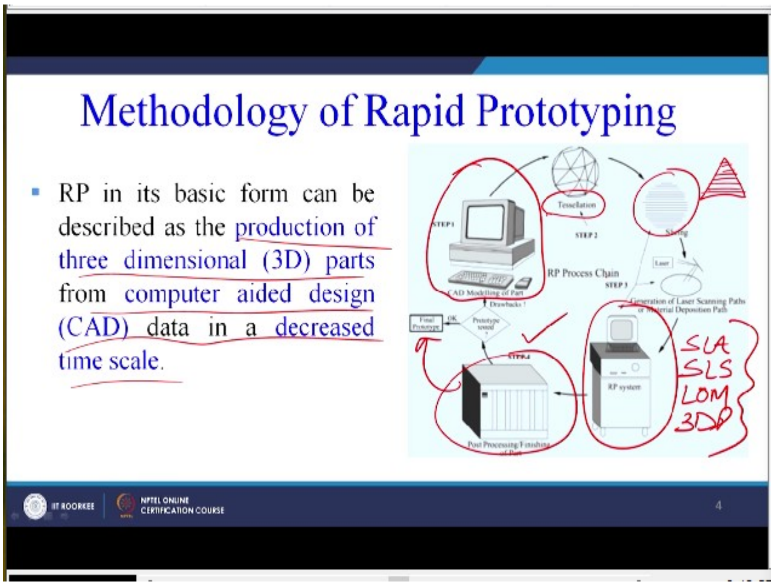

So, the rapid prototyping in its basic form can be described as the production 3 dimensional physical part from computer aided design data in the decreased time scale. So, time is less CAD model is required we have a rapid prototyping system which will create the CAD model into a physical object or 3 dimensional CAD model into a physical object. So, we can see here step by step, first step is a CAD model of the part.

So you have a product you make the on your computer system tessellation is done may be triangulation, then slicing. Because we make the product layer by layer by layer we have to decide how many layers the product will be made up of then we try to use. This is a rapid prototyping system it can be any system it can be SLA it can be selective laser sintering. It can be laminated object manufacturing, it can be 3D printing system.

So we can choose any of the strategy and then the prototype will be ready we will do the post or curing of the prototype. And finally it will be ready for the testing. So this is a standard approach we need a CAD model then we have to do the pre-processing in which we decide the number of layer, the thickness of individual layer. And then we take it this file into our rapid prototyping system where the physical 3 dimensional object is created or the prototype is created.

Then we do the post processing sum additional may be support material if we have used during the creation of our 3D prototype that has to be removed. Sometime additional curing may be required sometimes some surface treatment may be required, surface cleaning may be required. So all that is done during the post processing of the prototypes and finally our prototype is ready to be used or to be checked.

So, for this process there are standard guidelines that have been taken into account. Now what are the design guidelines which are there. Let us try to see those guidelines. First thing is how big prototype we can produce, so the average workspace.

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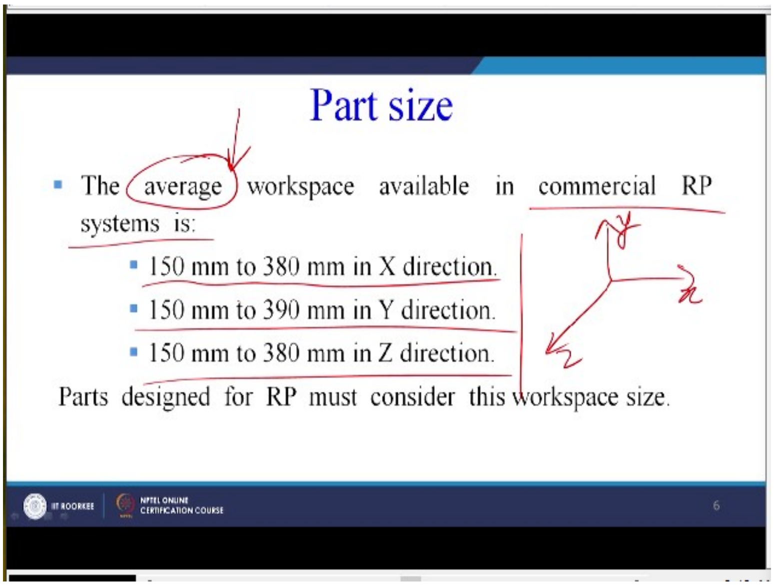

So, I must say the word average here is very very important because as I have already told that 70 to 80 different process is fall under the broad umbrella of rapid prototyping. So, the average work space available in commercial RP system is, so this is generally it is not specific to any one rapid prototyping strategy or process it is the general guideline that we can have 150 millimetre to 380 millimetre in X direction, 150 to 390 Y and 150 to 380 in Z direction.

So, there are 3 directions may be X, Y and Z, so in all the directions the dimensions are given that what can be the maximum size of the prototype that we can produce. Parts designed for RP must consider this work space size, so may be different types of machines will have different types of workspace arrangement or the size of the biggest size of prototype that you can produce.

So, all those things have to be taken into account when you are designing your product many a times it may so happened that our product is much larger in size as compared to the work space available in the rapid prototyping machine. So, what we can do we can scale down our model also, so that the prototype that we are creating is the scaled downed prototype as per the dimensions available in the machine that we are using for creating a physical 3 dimensional objects.

So all those possibilities do exist and we must take care or take advantage of these possibilities wherever possible. So regarding the part size when a part is too large decompose it into smaller sections.

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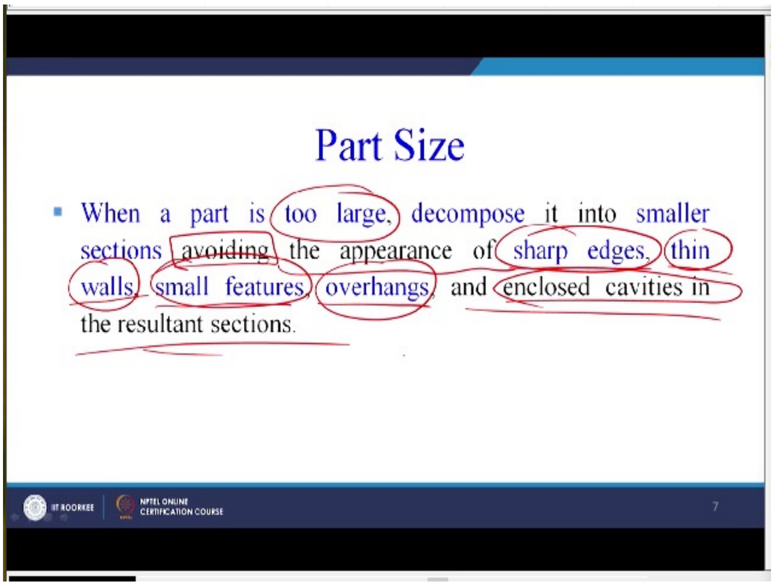

So, we have that can also be done suppose you want to create a model of a very large size torch which is not possible to be created in a single part. So, what we can do we can decompose the complete product into or we can explode the product into individual parts and each part can be created using any of the rapid prototyping machine and then we can assemble the parts.

So, when a part is too large important guidelines decompose it into smaller sections avoiding the appearance of, so we must decompose or divided into smaller substance taking care of sharp edges, thin walls. So, thin walls must not be there otherwise may be there may be deformation or deflection taking place, small features over hangs and enclosed cavity in the resultant sections.

So, we must decompose the bigger product into smaller products taking into account we must into smaller section avoiding. We must avoid what we must avoid sharp edges, thin walls, small features, overhangs and enclosed cavities in the resultant sections. So we can decompose the large parts into smaller parts. But all these guidelines we must keep in mind otherwise even the smaller parts will become difficult to fabricate using the rapid prototyping processes. The use of incorrect layer thickness can cause breakable walls and geometry deformations.

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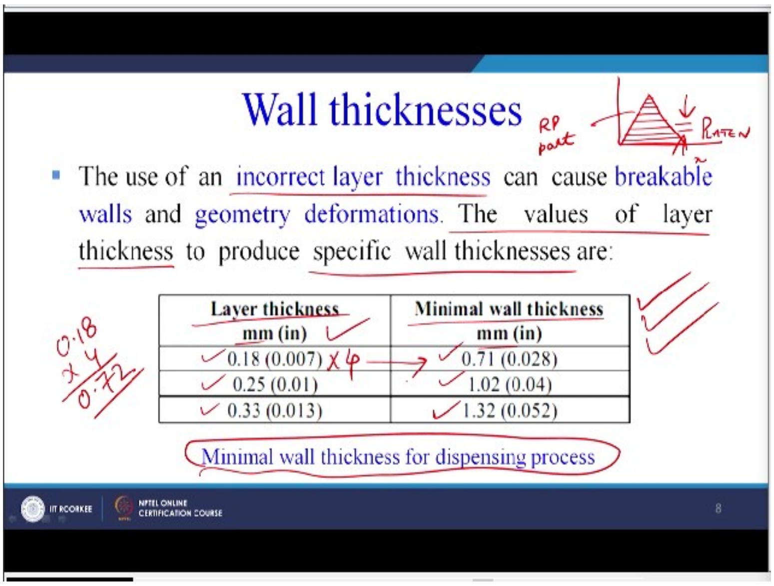

So, layer thickness as I have already told suppose you want to make a product like this a triangular section. So we have to decide that in how many layers this material will be made using the rapid prototyping. So suppose this is the platen, so this will be made on this platen and this is the RP part that we want to produce. Now we want to decide this individual layer thickness suppose X how much be this layer thickness.

So the use of the incorrect layer thickness can cause breakable walls and geometrical deformations. The values of layer thickness to produce specific wall thickness is R now how much with the layer thickness to produce a specific wall thickness that because every product will have some wall thickness. For example in order to make it easy to understand let us take a example of a mineral water bottle or a plastic bottle that we use or a cool drink bottle that we use a plastic bottle.

So, it has got a wall thickness, so that wall thickness is important and the thickness of the individual layers that are getting deposited is in a ratio of the wall thickness of the product.

So, that wall thickness has to be ensured with the help of these individual layers that we are depositing in rapid prototyping. So, we can see this table gives as a very good idea that the layer thickness suppose 0.007 inch.

So the minimum wall thickness that we must get is 0.028 inches or in millimetre if we talk about it is 0.18 millimetre layer thickness minimum wall thickness is 0.71 millimetre. So the values of layer thickness to produce specific wall thickness or so these are the minimum wall thickness for dispensing process. So layer thickness is in relation to the wall thickness of the product that we are going to produce.

So this table must be taken into account, so depending upon the layer thickness we can have our minimum wall thickness. But what I will say is that when we are designing our product we are not bothered about the layer thickness at that point. We design the product the various wall thickness is be decide in our product, so once the wall thickness is known to me I can see that what must be the layer thickness that we must use.

So based on the wall thickness is known to me I can see that what must be the layer thickness that we must use. So based on the wall thickness that is finalized in my product design I can get a guideline that what must be my layer thickness when I am depositing the material to produce the product. Now for dispensing process may be one category of the rapid prototyping processes such as example is given fused deposition modelling.

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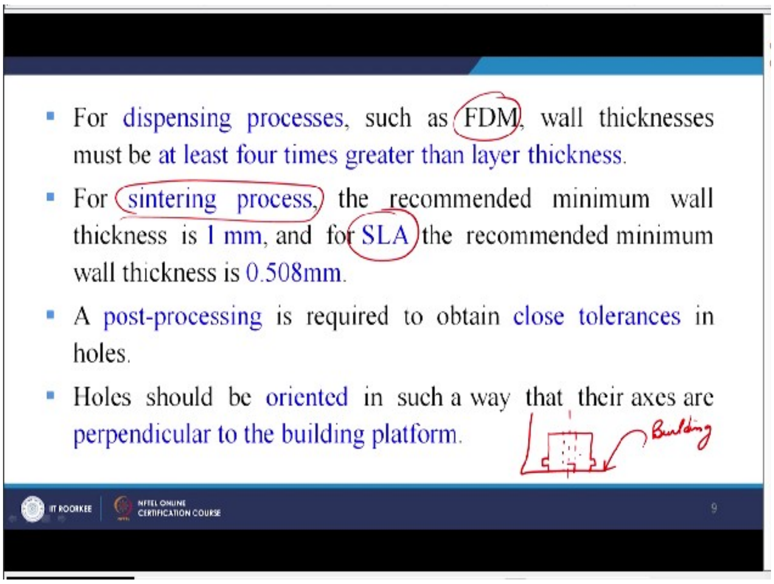

Wall thickness is I have already told must be at least 4 times greater than the layer thickness. So, whatever layer thickness we have decided and if you go back to the previous slide we can see it is already there 0.8 millimetre multiplied by 4 you will somewhere get 0.72 millimetre, so 4 times the wall thickness. So, layer thickness must be 1/4th of the minimum wall thickness or in the next slide we have written that minimum wall thickness must be 4 times the layer thickness.

So, layer thickness is your 0.18, so maybe we will multiplied by 4 we will get 0.72. So, that is we can say that 4 times of the layer thickness. We will get the minimum wall thickness, for sintering process the recommended minimum wall thickness is 1 millimetre and for SLA the recommended minimum wall thickness is 0.508 millimetre. So, these are the other 2 processes sintering process and this is stereo lithography apparatus.

The minimum wall thickness is given, so once we have trying to make a prototype using these two processes the minimum wall thickness is already specified. And this wall thickness is not a new term that we are using in today's session we have use this term in case of injection moulding process also. We have use this term in case of sand casting process also we have use this term in case of die casting process also.

So, for rapid prototyping processes also the minimum wall thickness has been specified. So, when we are designing our part and we know that this part has to be made by the prototyping process maybe SLA. We must take care of the wall thickness requirements, so for sintering process the recommended wall thickness is 1 millimetre. And for a SLA the recommended wall thickness is 0.508 millimetre.

A post processing is required to obtain the close tolerances in the holes. So, this is another guideline as I have already told. Once our physical prototype is ready we have to do the post processing in order to get a final finished prototype. Hole should be oriented in such a way that their axes are perpendicular to the building platform. So as I have already drawn one picture in the previous slide.

So suppose this is a building platform and this is a prototype that we are trying to produce, so what must be the orientation of the hole or the axis of the hole. The hole should be oriented in such a way that their axis are perpendicular to the building platform. So, this is our building platform and we have to see that what must be the axis of the hole. So, we will like to have the hole like this, this is the centre axis.

So, the axis of the hole must be perpendicular to the building platform. So, this is the perpendicularity which is shown here. So, these are the specific guidelines that we must take care of, now if there are fillets and knife edges.

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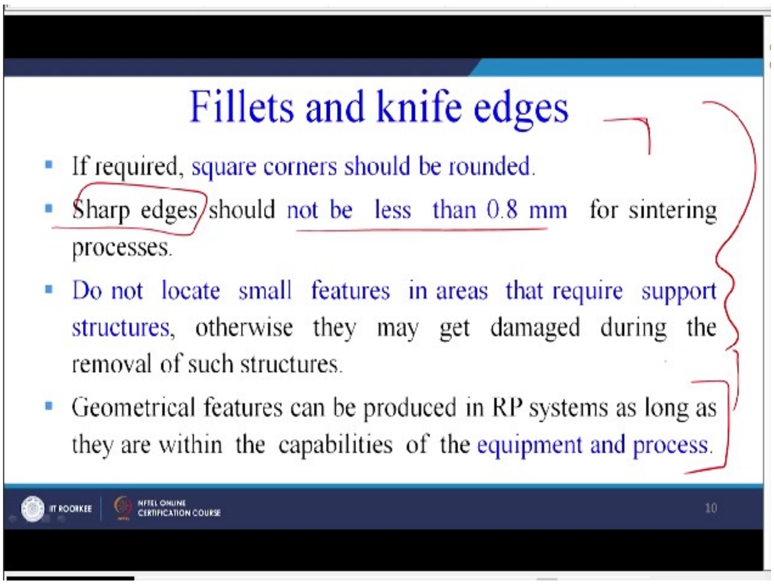

If required square corners should be rounded, so we must avoid the use of square corners and we must try to round them off. Sharp edges should not be less than 0.8 millimetre for sintering processes. So sharp edges must be avoided, range is also given should not be less than 0.8 millimetre do not locate small features in areas that require support structures. Now in many cases I must address this support structure issue here.

That once we are trying to create a 3D model using any of the rapid prototyping processes, usually 2 types of material is used. One is the build material another one is the support material, so the build material will actually create the prototype and the support material will support wherever some overhanging portions are there or wherever some sectional thicknesses are such that there is a tendency of this material or the build material to deform.

So therefore in those cases we will reinforce it with the supporting structure or the supporting materials. So, this is a important guideline here that do not locate small features in areas that require the support structures. So this small features can be deformed during the process, so we must avoid this small features near the support structures. Otherwise they may get damaged during the removal of such structures.

So when you are add the end of your rapid prototyping process we will go for the post processing where in we will be removing all this support structure. So, if we have a very small feature near to the support structure and we are trying to remove the support structure the small feature may also get damaged. So that must be taken into account when we are trying to rapid prototype a part.

Geometrical feature can be produced in RP systems as long as there within the capabilities of the equipment and process. This is the summary of what we discussed here, so whatever is the capability of the process we can make the parts as per the process capability. Now part orientation is also very important.

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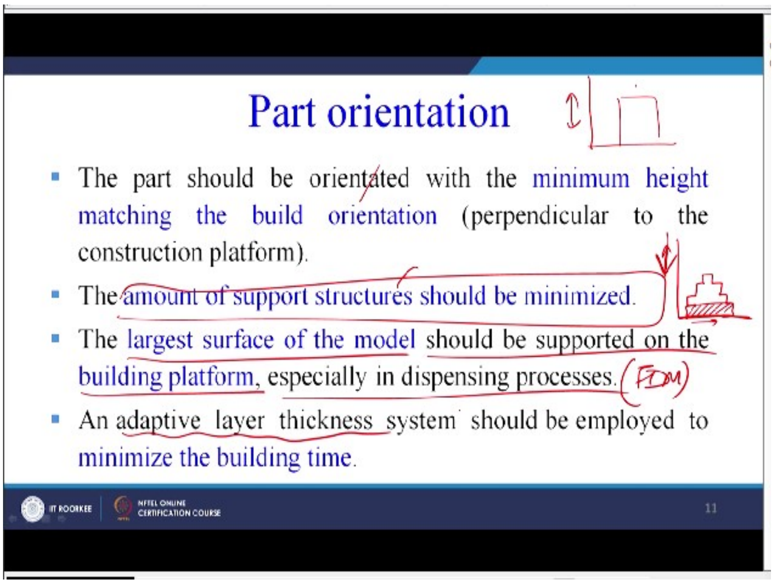

The part should be oriented with the minimum height matching the build orientation perpendicular to the construction platform. So again suppose this is the construction platform which is going to move up and down, so we have to the part should be oriented with the minimum height matching the build orientation. So minimum height we have to see, what is the minimum height and it must match with the build orientation.

The amount of support structure should be minimised, this is very important that we must try to minimise the support structures that are going to be used for making our prototype. The largest surface of the model should be supported on the building platform especially in the dispensing processes. Now suppose our product is let us taken another example this is the platen this is our platen which will move may be suppose it moves down.

So, the product is suppose something like this, so the largest surface must be there on the platen. So, that is the guideline this guideline state that the largest surface of the model should be supported on the building platform especially in the dispensing processes one of the examples of dispensing process is the fused deposition modelling. And adaptive layer thickness should be employed to minimize the building time.

So, that is another may be approach in most of the rapid prototyping systems that is adaptive layer thickness system must be used to employ. So, in next slide we will see that what is a difference between adaptive type of layer thickness system and general layer system.

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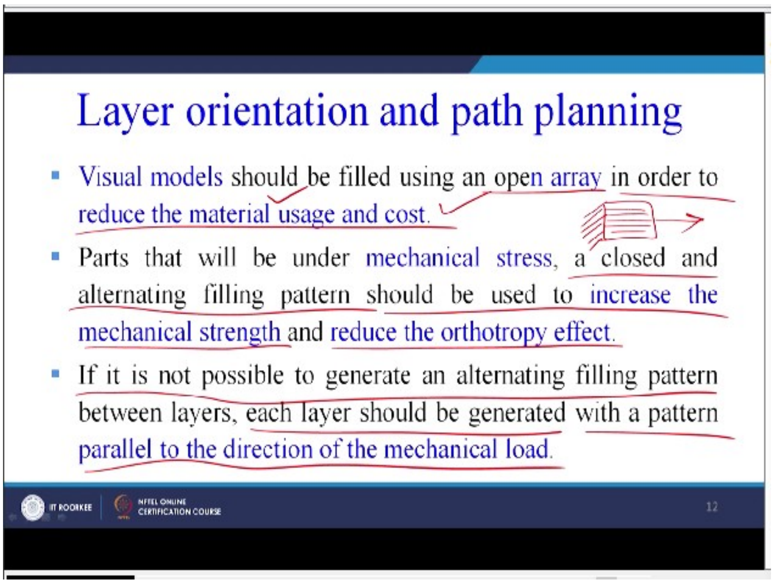

So, layer orientation and path planning visual models should be filled using an open array in order to reduce the material usage and cost. So visual model should be filled using an open array in order to reduce the material usage and cost. Now there are open array we can select the fill density in our model as per our choice. So, may be many cases we just want to see that how the product will look like?.

So, we need not make a very dense rapid prototyped product. Because if we make it very sense may be suppose we select in one of the rapid prototyping system 100% density. So 100% means that it will be fully dense product we just want to see the shape, so there is no need of making it 100% dense. We can make it we can select 50% density also we can select 30% density also.

So the visual models should be filled using an open array in order to reduce the suppose we set 50% density or 30% density different machines will have different levels. But if we select a less denser product we will save the material reduce the material usage as well as the cost will be less. Parts that will be under mechanical stress. Now suppose we have developed a fully functional prototype, so the part is under mechanical stress.

So we are going to test it for some specific requirement, so parts that will be under mechanical stress a closed and alternating filling pattern should be used to increase the mechanical strength and reduce the orthotropy effect. So, what we need to here that we must use a alternating filling pattern. Alternating filling pattern means that suppose this is my head or the gun which is depositing the material.

I must deposit the material in a alternating pattern, so that is an important guideline that we must take into account. We have seen that how much dense part we must make what must be our deposition pattern or the filling pattern. Because that will decide that how much load the prototype can take, so that is also an important guideline that we must have a alternating filling pattern in order to make it a good strength part or a high strength part.

So, that it can withstand the mechanical stress, so but in many cases if it is not possible to generate an alternating feeling pattern means that in both the directions we must fill the material. But if it is not possible to generate an alternating filling pattern what should we do, so in that case each layer should be generated with the pattern parallel to the direction of the mechanical load.

So suppose we have a part like this and it has to be loaded in this direction and fixed in this direction. We must deposit our material in such a way that each layer should be generated with pattern parallel to the direction of the mechanical load. So we can have a pattern which is parallel to the direction of the applied load. So 2 things by now we have been able to understand how much dense our product must be or the prototype must be and what must be the filling pattern of this volume.

So, that we are able to generate a prototype which can be withstand the mechanical stress that is going to be exerted on the prototype for testing purposes. Now there can be chances of distortion, shrinkage and warping because here the shrinkage will take place on solidification.

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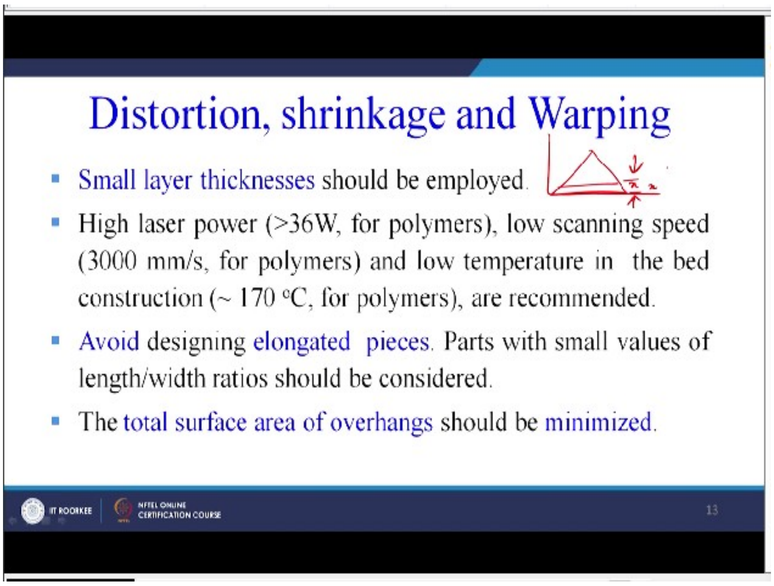

So, how to overcome that small layer thickness is should be employed, so as we have already taken an example again I am making the same part. So this thickness X must be less, so small layer thicknesses should be employed, high laser power maybe greater than 36 watt for polymers low scanning speed 3000 millimetre per second for polymer and low temperature in the bed construction that is approximately equal to 170 degree centigrade of polymers are recommended very good guideline for the polymers.

Specifically for polymers making the prototypes out of the plastics, the laser power is given, the scanning speed is given, the bed temperature is also given or that lower temperature in the bed, so all these parameters if we keep in mind while we are doing the rapid prototyping process we will be able to make good prototypes which will not be prone to failure.

Avoid designing elongated pieces parts with small values of length width ratios should be considered, so long parts are usually not recommended to be made by rapid prototyping, so we must take into account this length to width ratio while we are designing parts which have to be made by the rapid prototyping processes, the total surface area of the overhangs must be minimised because whenever there will be overhang we need to provide the support structure.

And already in one of the guidelines we have to mention that we must try to reduce the use of support structures, so because sports structure later on during the post processing have to be removed and during the removal may lead to failure or damage to the other similar or small cross sectional parts, so therefore support structures we must try to minimize and therefore this is coming from there only that when support structures have to be minimised the overhangs must also be minimized during the designing stage only.

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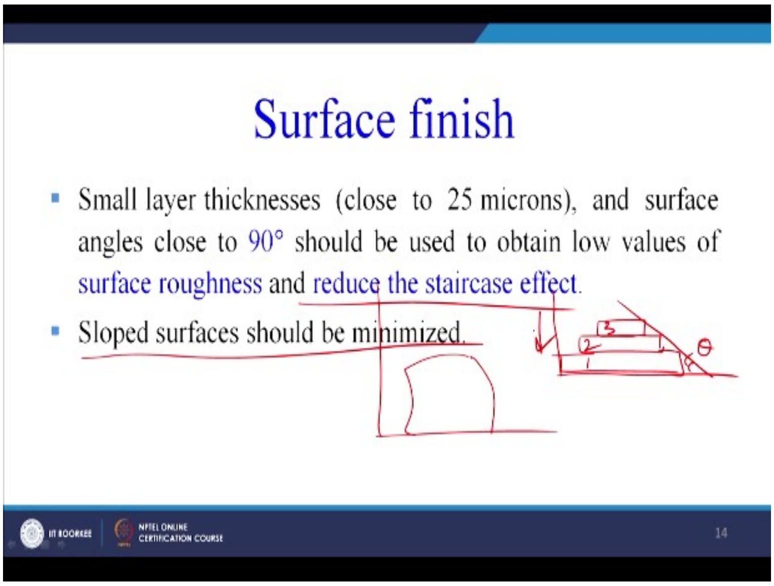

Now what is the surface finish small layer thicknesses and surface angles close to 90 degree should be used to obtain low values of surface roughness and reduce the staircase effect, now what is the staircase effect, now suppose this is one layer, this is on the exaggerated scale only I am saying this is another layer, suppose this is the third layer that we are depositing, now suppose this is our plate end on which we are making this is moving down.

So this is one layer second layer third layer, this is the staircase effect that takes place and may be this is the angle theta which is mentioned here, so we must try to minimise because this will depend upon the layer thickness this is staircase effect can easily be optimised based on the individual layer thickness that we select and based on the angle surface angle theta we can manipulate these 2 we can optimize these 2 to minimize the staircase effect.

So smaller thickness is close to 25 microns and surface angle close to 90 degree should be used to obtain low values of surface roughness and reduced the staircase effect, sloped surfaces should be minimised. So if we have sloped surfaces may be that we are making may be something like this. So these surfaces will definitely have a staircase type of effect. So we must sloped surfaced should be minimized during our designed process.

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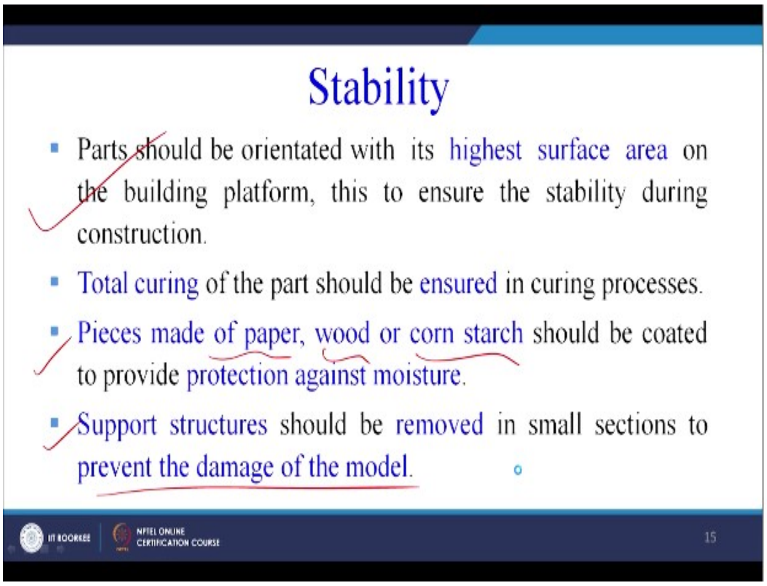

Now stability part should be oriented with higher surface area on the building platform, this is to ensure the stability during construction already discussed I have explained it with the help of a diagram total curing of the part should be ensured in the curing process very important because the parts will polymerise and solidify once the curing is complete, so we must ensure complete curing of our prototyped parts.

Pieces made of paper, wood or corn starch should be coated to provide protection against the moisture, so may be in some of the parts which we are making out of paper or wood or corn starch as the raw material in case as I have already told that rapid prototyping processes can be classified based upon the raw material that we are using. So if the material is made if our prototype is made of paper, wood or corn starch we must try to coat it during our post processing of the prototype in order to avoid the moisture absorption.

Support structure should be removed in small sections to prevent the damage of the model, so if we use the support structure we must remove it so may be chunk by chunk or in smaller sections in order to avoid the damage that may happen to the overall prototype or the built material of the prototype. So with this we can conclude the today's session on rapid prototyping.

So we have seen that once we are trying to make a prototype using any of the rapid prototyping processes we must take into account these guideline related to how much dense our prototype must be, what must be the orientation of the prototype if the holes have to be made, what must be the orientation of the holes, the bigger portion of the prototype must be placed on the platen. So that we can build it in a proper manner.

So all these guidelines we must take into account related to the thickness of the individual layer, layer to the surface angle, so if we follow all these guidelines we will be easily able to produce a prototype which will be which can be a fully functional prototype or can be a just a visual model of our object that we want to be produce. So rapid prototyping is one of the important strategies that must be adopted during our product design process in order to save time.

So we have seen that important parameters like the field density, the deposition, angles of the deposition, directions of the material are definitely going to define the quality of the prototype that we are producing and these must be taken care of and must be selected judiciously in order to make a good prototype. So may be in our last session we will try to sum up the discussion that we have done over the last few weeks and try to see that how these guidelines are going to be useful for the product designers when we are going to design their products.

Thank you.