Operations Management
Dr. Inderdeep Singh
Department of Mechanical & Industrial Engineering
Indian Institute of Technology, Roorkee

Lecture - 10
Rapid Prototyping: Concepts, Advantages

[FL] friends, welcome to session 10 in our course on Operations Management and today we are going to finish the discussion for week 2 in which our focus is on product design and development. So, session 1 or in the first session of this particular week we have seen what is a product life cycle. Then we have seen the concepts of value engineering finally, we have seen design for x where we have seen two examples of design for manufacturing and design for assembly.

In the last session we have seen that how we can design a product by keeping in mind the concept of ergonomics. So, basically we have learnt we have discussed 4 important tools which are very very important in decision making in context of product design and development. We have seen the product life cycle which helps us in decision making, we have seen design for x that is design for manufacturing design for assembly, design for manufacturing and assembly that also helps us to design our product. We have seen the concept of value engineering which also helps us in decision making related to the functions of the product, related to the functional analysis of the product, related to the functional cost evaluation of the product and the last session we have seen ergonomics which also helps us to take judicious decisions in context or in reference to the interaction between the customer and the product, the man and the machine or the interaction between the man and the system as a whole.

So, basically we are not learning the different steps involved in product design process, but we are learning the various tools and techniques which can help us to design a successful product which will help like to improve the economic health of the organization.

So, in that series our focus today would be to discuss the rapid prototyping concept that time is also very very important. We have seen the product should be good, it should be functional, it should satisfy the functions for which the product is being bought by the customer, it should be easy to use it, should be comfortable to use, it should be

ergonomically design, it must be cost effective it must be efficient. So, there we can use n number of objectives to define a successful product, but the time is also very very important. I may have a idea today, I wish that I should make a product out of this idea which is a tangible product which is a commercial product which can be sold in the market.

So, an idea has to be converted from an ideation phase into the actual manufacturing phase and that time is very very important the gap or the time gap once you have an idea and that launch of the product in the market the time gap between this these stages has to be minimized. And as a mechanical engineer usually we feel that the prototyping takes away a lot of time, usually the designs today are made using softwares using CAD. So, we know an auto CAD we have an idea we can directly make that design on our screen we can have 2-D representation of the design, we can have 3-D representation of the design we can look that design from different views. Once that design is ready we want to check the functionality of the product and for that we need to make a prototype and that prototyping will take a lot of time.

Then if you see the conventional manufacturing processes there are a number of courses being offered under MOOCs, on fundamentals of manufacturing processes. So, once you see or understand these processes like casting, welding, forming their other joining techniques like adhesive joining, mechanical fastening. So, number of processes are there which can be used to make a prototype, but all these processes have a time you can second straight or time domain in which they can convert or a raw material into the final product. So, it is always difficult it is not impossible, it is difficult to make the prototype in a very short duration of time or in the shortest possible time, but that is our target.

Today I have a idea any other person may be in any other part of the word may also have the similar idea. Now, the person who is able to the engineer who is able to convert that idea into the tangible product or a commercial product will be the first person to gain advantage and all these study or all these topics that we cover are interrelated. If you remember in product life cycle we have seen that during the growth stage the profits are maximum. So, if the product which has been designed by our competitor or any other person in the other part of the world before we could come we can converge to a product before we could launch the product some other company or an individual has launched that product. That person or that company will definitely gain more advantage will be

profitable as compared to our company why because we are late we are delayed in the launch of our product because we have taken a lot of time in prototyping the product. Therefore, we need to focus on the prototyping technology that how quickly we can convert our idea into the final product or into the prototype.

The prototype can be just it can be a non functional type of prototype we are just looking at it that how the product would look like or it can be a fully functional type of prototype in which suppose 3 parts are made and then we have to check that whether they will assemble properly or not or how they will look after assembly. So, it can be a function, we can even check the functionality of the product of the material for which the product is going to be made up of is similar to the prod material that we have used for making the prototype.

So, we can make both functional and non functional type of prototypes. But the major focus is quick methods of making the prototype and on your screen you see rapid prototyping. Now, rapid prototyping means that we have to quickly convert our idea convert our design into the prototype. So, rapid all of you know means quick and prototyping means we have to make or fabricate or process a prototype.

There are a number of tools and techniques or methodologies which have been invented and commercialized by researchers and scientists number of machines are available based on the different technologies. There may be around 50 to 60 different technologies that fall under the broad umbrella of rapid prototyping. We will not be covering any of these technologies in today's class. Our focus primarily is to focus on this concept that what is rapid prototyping actually and how we can get benefitted by adopting the concept of rapid prototyping. So, we will just be focusing on the concept and we will be focusing on the advantages that we can derive out of these principles of rapid prototyping. Otherwise there are machines available like stereo lithography apparatus SLA, laminated object manufacturing, 3-D printing which is very very common these days, selective laser sintering. So, there are a number of technologies that are available which can be used for converting the raw material directly into the product in the minimum possible time.

And all these technologies may use the raw material which may be in terms of a liquid polymer, it can be particle, it can be sheets of material. So, depending upon the type of

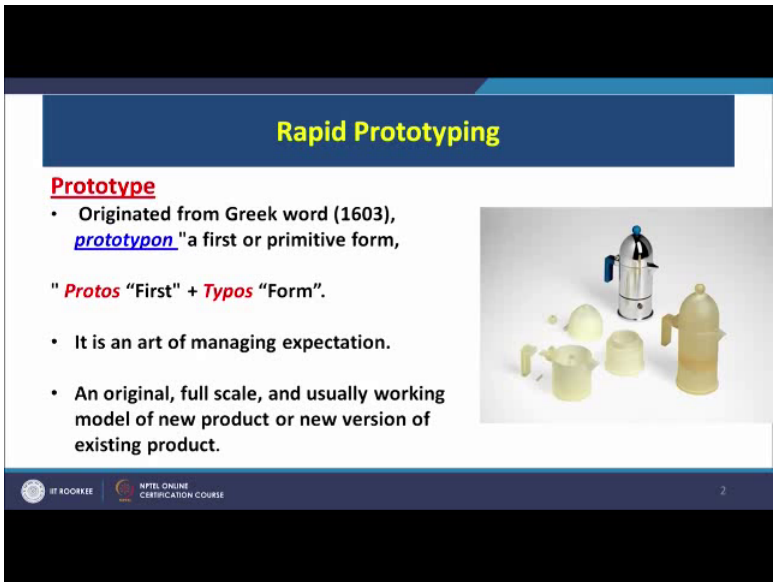
raw material that is being used for converting into the prototype these processes can also be classified that these processes use liquid type of raw material, these processes use solid raw material in the form of particles or there can be a group of processes which makes use of layered sheets for making the prototype layer by layer by layer, consolidating these layers layer by layer. So, depending upon the type of raw material used we can very easily classify these rapid prototyping technologies.

So, I have named a few of them and in our course on product design and development which was a 10 hour course which was offered under MOOCs and I think the videos are now available on YouTube. You can refer to the these technologies also and try to understand the basic concepts we have tried to explain them with the help of images with the help of schematics and you will be able to understand that how a particular tech rapid prototyping technology actually operates and converts a raw material into the final product into the minimum possible time.

But today our focus would primarily be to understand; what is a rapid prototyping I think by the discussion we had today maybe 5 to 7 minutes have already passed. Many of you might have got an idea about rapid prototyping and in the structured lecture that we have today we will further try to cement this concept of rapid prototyping and we will see that what are the various stages involved. Because in different technologies as I have already told you the major steps involved are more or less same the raw material may be different, the process of consolidation may be different, but the basic steps involved in the overall rapid prototyping process are same. We will try to understand what are the steps involved and finally, we will see; what are the advantages that we can derive out of rapid prototyping.

So, let us quickly start our presentation and try to understand the concept and advantages of rapid prototyping process.

(Refer Slide Time: 10:50)



On your screen you have the meaning of prototype, prototype basically originated from the Greek word in 1603 prototypon a first or primitive a first or primitive form. So, prototypon own is a Greek word from there it is a first or the primitive form. So, if for any product you say; what is the prototype of this product it can be the model of that product or the first form of that product. So, protos means first form and typos means form. So, proto plus typos means first form of the product. So, protos means first and typos means form. So, prototype means the first form of the product.

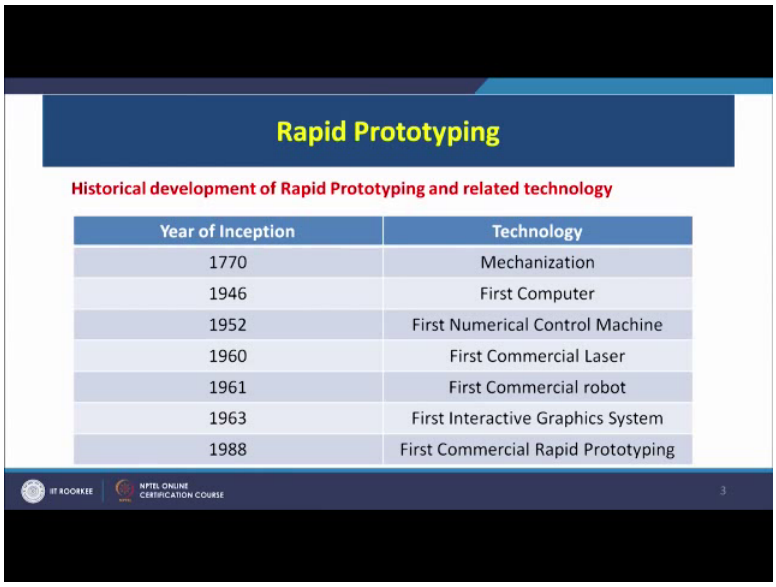
It is an art of managing the expectation. So, it is art of managing means that we have to see, we have imagined a product, we have designed a product on our computer screen using any CAD or designing software. So, once we have designed the product we have imagined the product. So, here what we are doing we are managing that expectation we are producing that expectation in the form of a tangible or a physical product. So, it is an art of managing the expectation.

An original, it will be an original means a new product full scale. So, it can be made up to the scale or we can make a scaled up or scaled down model also, but usually we try to make a full scale model or a full scale prototype and usually working model of a new product or a new version of the existing product. So, we can make a working prototype of a product. So, as I have told you I have used the word functions because we have already discussed the functional analysis or the value engineering. So, it can be a

functional product. For example, suppose we are making outer covering of a mosquito repellent all of us use mosquito repellent devices. So, we are making a outer covering of a mosquito repellent device and it is a completely new design which has different aesthetics involved. So, what we can do we can directly make a CAD file of that particular design and convert it using any machine into a product. So, it is a functional product now what do we can do we can use it as a product also and see how it performs.

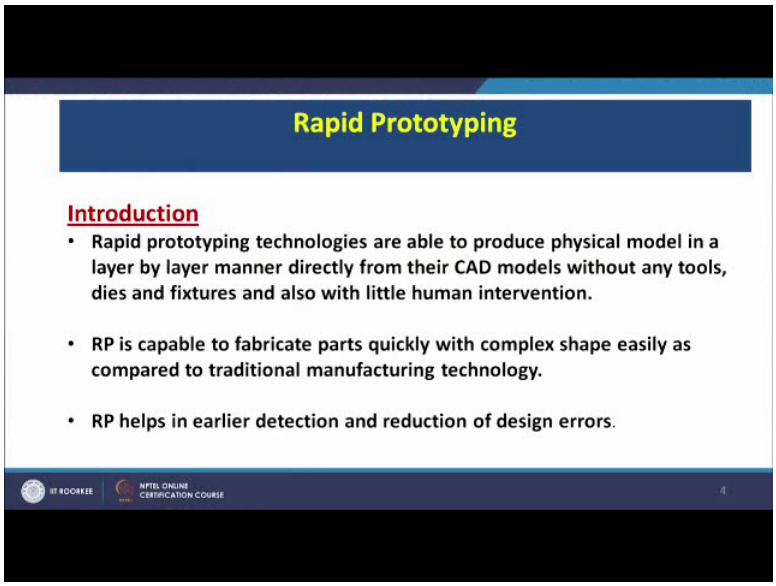
So, usually in rapid prototyping we try to make the functional or the working products only are the working models of the designed product. Many times we may just make product just to see as how aesthetically it will look. So, those may not be the working products, but in many cases our focus would be to make the working products only or the working prototypes similar to the product that we want to design.

(Refer Slide Time: 13:47)



Now, this is the history of rapid prototyping. So, in 1770 the concept of mechanization came into being I will not read I each and every step involved here, but in 1988 the first commercial rapid prototyping mechanism or technology was developed.

(Refer Slide Time: 14:12)



Now, rapid prototyping technologies are able to produce physical model which I have already explained in a layer by layer manner directly from their CAD models. Now, you can see that; what is the output the output is a physical model of the product. How it is made? It is made layer by layer manner. From where do we get the information? From the CAD models; without any tools dyes and fixtures and also with little human intervention, so these processes can be fully automatic, human intervention is minimum.

So, we can say that if we have a CAD file or we can say design file of a product in the form of we can say in a memory stick or we can interface directly the computer where we have designed the product with a rapid prototyping machine. So, the input required is the soft copy or the design in the form of a CAD file. So, that is the pre primary requirement we need to have a CAD file of the design.

In many cases when we do not want to develop the CAD file of the design we have already have a product available with us. We do not have the CAD file of the product, but we have a product a physical product available with us which is slightly damaged. We want to reconstruct that product what we will do there are scanners available in the market. These scanners will construct a three dimensional file for that product just by scanning the product and once we have that file in our system we can use that file from our computer as an input file to a rapid prototyping machine and it can be converted into the physical product using the file that we have created by using the scanner. So, there

are lot of we can say opportunities available with the rapid prototyping technology. So, without use of tools and dyes and fixtures we are able to produce a rapid prototype in a very very time effective manner. So, RP is capable of fabricating parts quickly.

So, as the word rapid, they are able to generate quickly, with complex shape easily as compared to the traditional manufacturing processes. Two advantages are coming here, one is quick another one is complex. So, one thing is that we are able to produce our prototypes quickly I have highlighted that maybe number of times today and the second point which I have not highlighted is that if the product is also very very complex still we are able to make a prototype quickly as compared to the traditional manufacturing technologies.

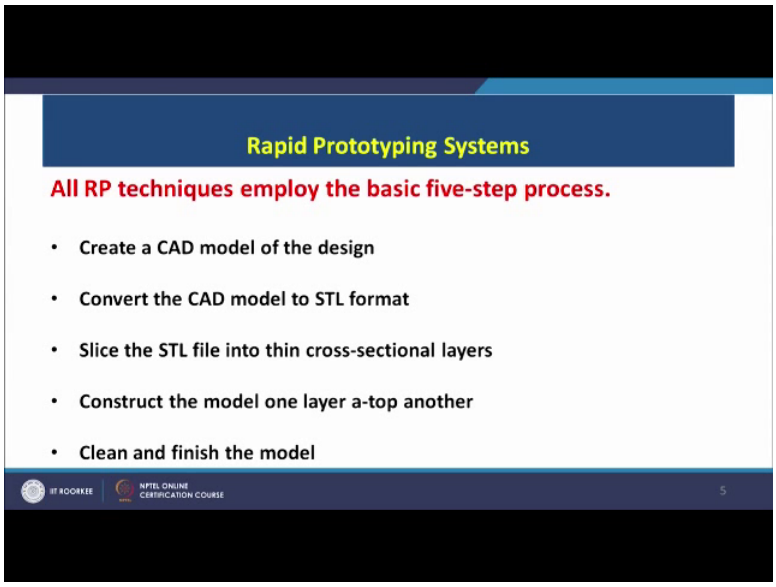
Simple example I would like to take here, that suppose there is a complex product and in earlier days you would like to make a prototype using a casting process how we will make a prototype, it has to be a metallic prototype. So, if it is very very complex it is difficult to machine. So, we have decided let us do the casting, but for making the casting operation or for performing the casting operation we still require a pattern because that will help us to make a mould. So, for making a pattern again we require maybe another technology that how to make a pattern suppose you use a wooden pattern we need to cut the wood into that complex shape. So, traditional manufacturing route of making a pattern making a mould and then making a casting and then finishing the casting may be a longer route of making a prototype.

Whereas, in case of rapid prototyping what do we require? We require only a CAD model of that product and if that model is available to us we can very easily fabricate it using any of the rapid prototyping technologies. So, complex parts are also made easily by the rapid prototyping process as compared to the traditional manufacturing technologies. RP helps in earlier detection and deduction of design errors.

Now, you see if we have designed a product and we have used the conventional route of making a prototype and after making the prototype we do the testing and inspection and find out that these are the design errors again we have to revert back to the design stage. But here since the time required for making the prototype is shortened it is less, so quickly we will be able to identify that these are the errors that are happening. So, we will just revert back and modify and then again come back and make the prototype.

Now, this since the input here also is a CAD model it is very easy to make the changes. So, it is easy for design modification concept point of view or design modification point of view again the rapid prototyping technology is much better as you can where as compared to the conventional method of design as well as to prototyping or manufacturing of a prototype. So, we can see that there are a number of advantages if we adopt the concept of rapid prototyping.

(Refer Slide Time: 19:39)



Now, all RP techniques employ the 5 step process. So, basically there are 5 steps or 5 stages in which we can make a prototype. So, first of all what we have to do? We have to create a CAD model of the design. So, CAD is computer aided design. So, we have to use any software and make a 3-D model of the design.

In second stage convert the CAD model to STL format. So, we have to because these machines understand a specific language only therefore, whatever CAD software we have used to design the product we have to convert it into a language which the machine can understand. So, we have to convert that model to the STL format. Now, we have to slice that STL file into thin cross sectional layers. Now, suppose I make I can take an example of this pointer I want to make a prototype of this pointer, I have to first make a CAD file which is as per the dimensions this is the length, this is the width, this is the thickness, thickness is varying across the length. So, we will see up to this particular

length this is the thickness and after that this is the thickness. So, we will make exact dimensions a CAD file three dimensional file of this particular product.

Now, once we have to make a prototype because we have seen that most of the rapid prototyping processes produce the prototype layer by layer, we have to see that in how many layers this product would be made because you see here the thickness is more and here the thickness is less. So, we have to slice this product into number of layers and that number of layers will be deposited one after the other and this 3 dimensional physical product or the prototype will be created.

So, the third stage is the decision regarding the number of layers. Now, we can use more number of layers thickness will be less we will go for less number of layers thickness of individual layer will be more. Now, depending upon the technology that we are adopting we have to do the slicing of the product into number of layers. So, that is done in the third stage.

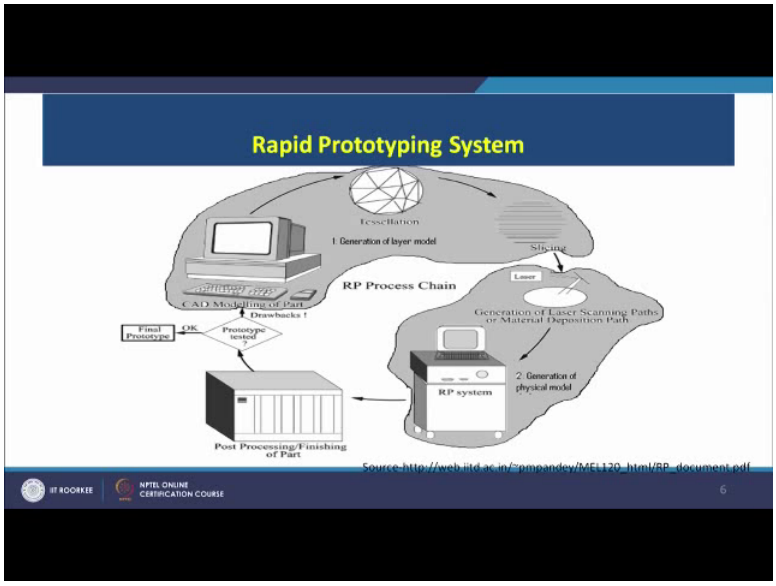
What we have done till now, we have used any CAD software to make a model a CAD model. Now, this CAD model has been converted into the STL file and this STL file has now been sliced into individual layers. Now, construct the model one layer atop another once this product this is we can say the planning process the first three stages and now we are going into the execution of the program. So, first we have a CAD model which is all now available we have converted into a steel file we have sliced the STL file input number of layers and now this is the input to a rapid prototyping machine and once this input is given to the rapid prototyping machine it starts to produce a fabricate or manufacture the product layer by layer or manufacture the prototype layer by layer.

So, first layer will be deposited as per that design, then the second layer will be deposited on top of the first layer, then a third layer on top of the second layer, then fourth layer on top of the third layer. So, layer by layer the material will be deposited and the physical three dimensional prototype would be produced.

Then the last is clean and finish once this layer by layer you have created your prototype you have manufactured your prototype, you have produced your prototype, we will take it out and because it has been done layer by layer by layer it will require a finishing operation in order to have a smooth surface that is the we can say requirement of the design. So, last stage is cleaning and finishing of the model.

In case of a very very complex shape sometimes we use supports also during the fabrication and during the last stage we have to remove these support system in order to get the product or the prototype only. So, this supporting system which has been used to create the prototype will be of a different material may be for example, vex and later on we can heat our prototype slightly. So, that vex can melt and go away and we get our final prototype. So, sometimes supporting structures are also used during the fabrication of the prototype. But still compared to the traditional method compared to the conventional method of making the prototype rapid prototyping technologies are much superior in terms of quality produced, much superior in terms of type required maybe less time is required for making a prototype using the rapid prototyping technologies. So, these are the 5 steps that are followed.

(Refer Slide Time: 24:42)

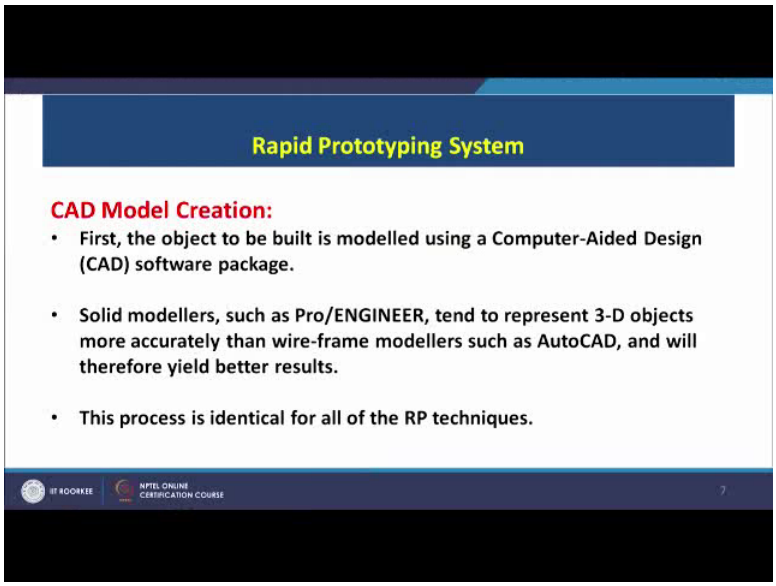


Now, quickly let us see the rapid prototyping system. The source is given here i i t d dot a c dot in. So, this is we can say there is a CAD model of the part, then converting to STL format converts slicing, converting into layer then there is a rapid prototyping machine through which we are creating the prototype and finally, in post processing or finishing of the part. So, here you can see CAD model converts conversion to its STL format layer by layer slicing of the model and then finally, the creation of the model here, generation of the physical model and finally, in here the creation may be the generation of laser scanning paths or material deposition paths.

So, we know now for making the product this is a path in which the material or this is the area in which the material has to be deposited, how our head will move in order to deposit the material at the respective places that decision is also taken. And finally, if you if you can read on your screen this is the this box type of arrangement here is a rapid prototyping system it can be any machine it can be a 3-D pen printing machine, it can be a stereo lithography upright as it can be a selective laser sintering setup it can be a laminated object manufacturing machine this is the RP system.

So, before entering into the RP system or before using the RP system we have to do all these calculations, we have to see we need we do we have a CAD model, have we done that we, have we converted it into the steel format, have we sliced the model properly decided on the number of layers have we generated the path to be followed by the head. Once all this input is ready we give this input to the rapid prototyping machine and then it will create up prototype and finally, we will do the post processing and finishing of the part.

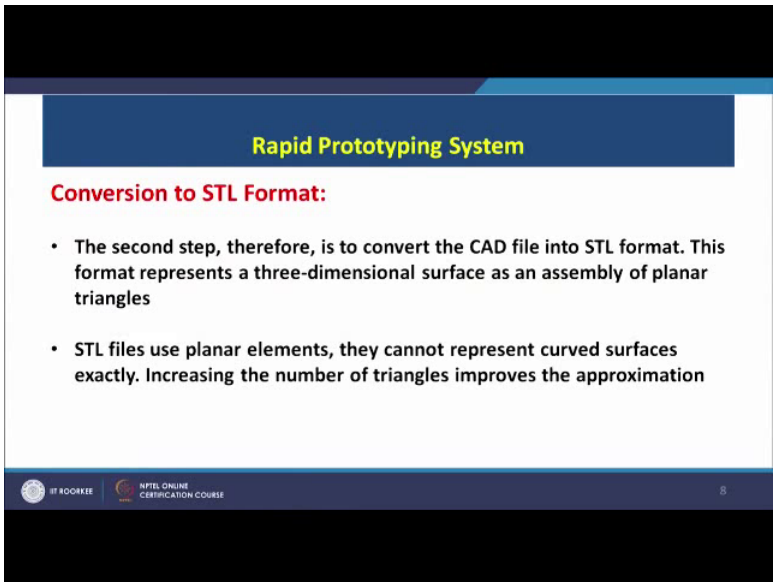
(Refer Slide Time: 26:44)



Now, CAD model creation first the object to be built is modelled using computer aided design I have highlighted already. Solid modular such as pro engineer tend to represent 3-D objects more accurately then wireframe modular such as auto CAD and will therefore, yield better results. Now, that is from the CAD point of view that once you are making a CAD model of your product you need to make a judicious decision that which

software is going to help us to make your model better. This process is identical for all the rapid prototyping techniques. The steps that we have followed are more or less identical for all rapid prototyping technologies.

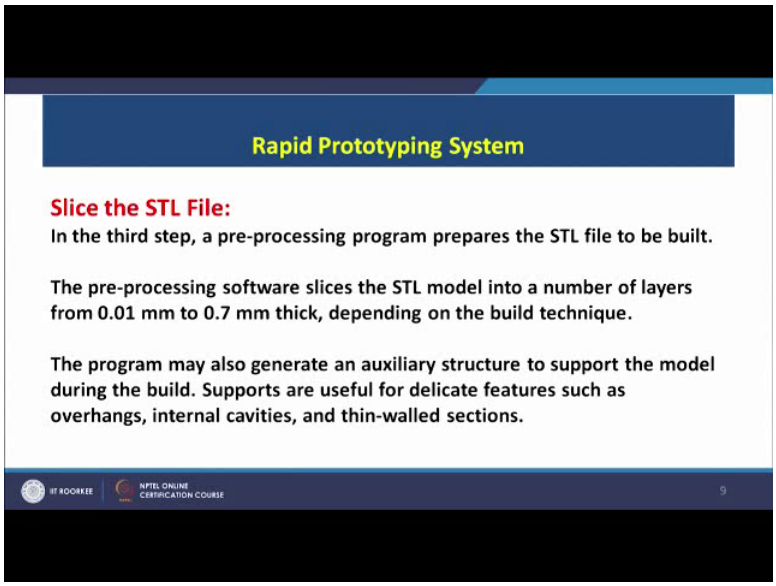
(Refer Slide Time: 27:23)



Conversion to STL format, but maybe the previous was that the CAD model is required for almost all rapid prototyping technologies. Conversion to a STL format the second step therefore, is to convert a CAD file into that steel format this format represents a three dimensional surface as an assembly of planar triangles. So, we have to convert it into this format that CAD file into STL format.

STL files use planar elements, they cannot represent curved surfaces exactly. Increasing the number of triangles improves the approximation. So, we have to convert our CAD file into the STL format which will represent the planar surface in the form of small triangles.

(Refer Slide Time: 28:10)



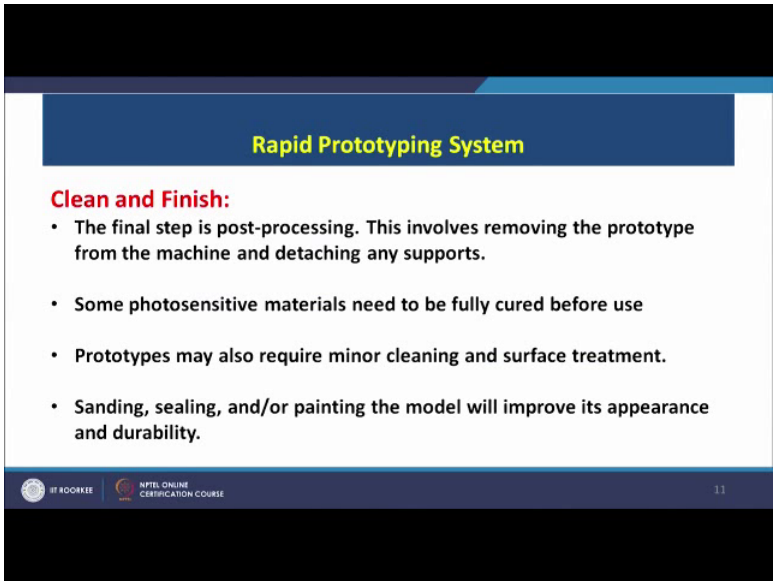
Slice the STL file, in the third step pre processing program prepares the STL file to be built. In a pre processing software slices the STL model to number of layers you know what can be the thickness of layer it can be 0.01 millimeter to 0.7 millimeter thick depending upon the rapid prototyping technique that you are going to use. So, you can see are lot of range is there that what can be the number of layers, that we are slicing, that will be used for fabricating the part or the fabricating the prototype.

The program may also generate an auxiliary structure as I have told earlier a support structure to support the model during the build, you know during the building process or during the fabrication process. Supports are useful for delicate features such as overhangs, internal cavities and thin walled sections. So, once your product or fabric your prototype is being fabricated there may be certain sections which may require some additional support during fabrication and this support is provided by the auxiliary material which I have told you earlier can be vex which later on can be removed and then you get your actual prototype. So, this is the third stage.

And then we do layer by layer construction, the fourth step is the actual construction actual fabrication of the product or the prototype. RP machines build one layer at a time from polymers papers or powdered material I have already highlighted in the beginning of today's session. Most machines are fairly autonomous needing little human

intervention. So, these are more or less automatic machines which help us to create our prototypes.

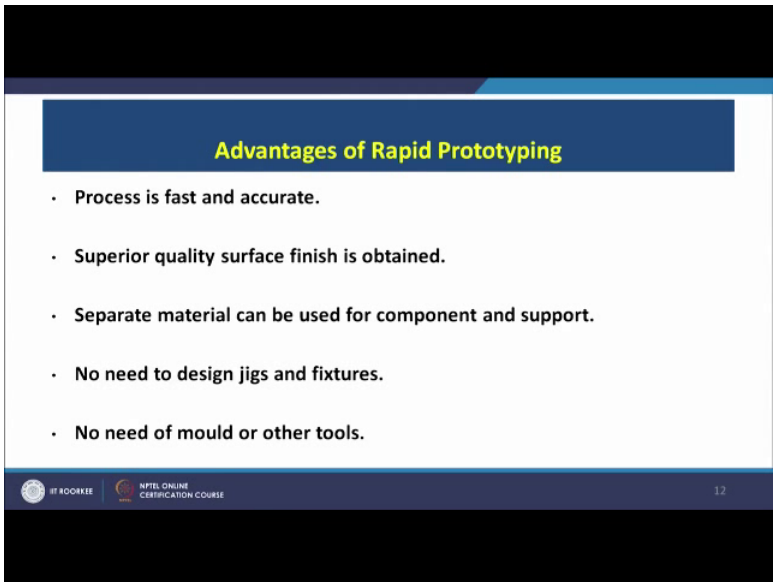
(Refer Slide Time: 29:50)



Clean and finish, the final step is post processing this involves removing the prototype from the machine and detaching any supporting structures. Some photosensitive materials need to be fully cured before they are used. So, we have to use additional maybe heating mechanism or additional furnaces to fully cure these resins before making them fully functional prototypes.

Prototypes may also require minor cleaning and surface treatment. Sending ceiling under painting the model will improve its appearance and durability.

(Refer Slide Time: 30:27)



Now, what can be the advantages? I think I can ask this question to all of you I have tried to explain it in the most simplistic manner. Everybody must be able to answer now that what are the advantages of rapid prototyping. Simply it is process is fast and accurate, superior quality surface finish is obtained, separate material can be used for component and support, no need to design jigs and fixtures because we are not using the conventional methods of producing or fabricating the prototype. We are using a completely advanced technology for creating a prototype and therefore, there is no need of jigs and fixtures and no need of a mould or other tools. Only requirement is the CAD file of the product. Once we have the CAD file we can convert it to STL file from there we can slice it, we can create the tool path and finally, use any rapid prototyping technology to convert that product into its prototype.

So, with this we come to the end of today is session on prototyping concept and advantages. In our next week we will start a discussion on a completely new topic, but just to summarize what we have covered.

Till today we have finished two weeks of discussion: week 1, was on fundamentals of operations management we have seen their objectives, scopes, functions as well as operation strategy. In second week we are focused on that once you are managing the operations you must know that what the company must produce in order to be successful. And there we have seen different tools techniques which can help a designer to develop

or design a product which is much more you can say competitive and successful in the market. We have seen, we have seen product lifecycle, we have seen value engineering, we have seen design for x, we have seen ergonomically, we have seen rapid prototyping. So, all these tools are helpful for designers for designing a successful product. With this we close today is session.

Thank you.