Product Design and Development
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Lecture - 19
Rapid prototyping: Concept, Advantages

[FL] friends, welcome to this last but one lecture on our discussion on Product Design and Development. As you are well aware the overall course was divided into 4 weeks and right now we are discussion discussing or we are into the discussion for the fourth week. And in fourth week we have already discussed three sessions or we have already completed three sessions in which we have seen that what are the DFMA guidelines we have seen that what are the differences between DFA and DFM what are the similarities between DFM and DFA.

Then we have seen that if the product has to be assembled together manually. As I have told that product may be designed in such a way that it may facilitate automatic assembly as well as it may be designed in a way that it may require manual assembly. Now suppose that the product that we are designing requires manual assembly that what are the various guidelines that we should take into account.

So, the manual assembly operation can be divided into 2 broad operations that is handling as well as fastening and insertion. So, from both points of view how the product should be designed that it is easy to handle as well as it is easy to do the fastening operation, insertion followed by the fastening operation. So, we have seen what are the different types of layout for manual assembly in session 2.

In session 3 we have seen that what are the various guidelines for product design, when the product has to be manufactured by the various manufacturing processes. So, we have seen that if we use these guidelines during our design process or we check our design as per the guidelines which are specified for the various manufacturing processes we will be able to come up with the design which is easy to fabricate as well as it is economical to fabricate also. So, both our objectives are met. It is easy to fabricate as well as it is cost savings to fabricate it because we have followed all the guidelines that are there to ensure good quality assembly or easy assembly as well as easy manufacturing.

Now, we have come to the end of our discussion and we are going to discuss that once our design is ready we have a concept we have done the conceptual design, we have done the detailed design, we have taken care of all the guidelines that need to be followed from the assembly point of view from the manufacturing point of view.

Now, we wish that we should prototype our product that we should prepare our manufacture or model our prototype and check the functionality for which we have designed the product. So, prototyping is a last stage before the full fledged manufacturing of the product. So, we will now based on the design that we have generated during this course we would like to now fabricate it using a prototyping technique. So, we will like to prototype or the first of its kind product we would like to prepare and we would like to go for making a prototype, but as the name suggests rapid, so our focus now would be to quickly make the prototype rather than spending lot of time only for the prototyping process. So, our target now is rapid prototyping.

So, we will try to understand in the last two session that what are the latest tools and technologies for making our prototype quickly because we may have completed the design if we spend lot of time in only prototype, on only prototyping the technology may be developed by other competitors also and we may lose that advantage of being the first company to launch the product. So, it is always important to shorten the or reduce the to bridge the product development cycle time and rapid prototyping is one such step which helps us to reduce this launch time for any company.

So, as engineers, as learners, as students we should have the fundamental idea about what rapid prototyping is why do we do rapid prototyping what are the steps general steps involved in rapid prototyping and at least try to understand 2 or 3 process mechanisms of the processes which are most commonly used using the concept of rapid prototyping or the most commonly used rapid prototyping processes.

So, first thing first we should know that why rapid prototyping is required must I tell you that rapid prototyping is a concept, there are number of technologies that fall under the broad umbrella of rapid prototyping and to my knowledge maybe there can be more there are around 40 to 50 processes which fall under the rapid prototyping technology. So, these are the processes which help to produce the prototype as quickly as possible.

Now, let us try to see the basic concept of rapid prototyping. First we will have a historical perspective of rapid prototyping. We can see there are two words here rapid and prototyping, all of you know the literal or the dictionary meaning of rapid, which means quick time saving.

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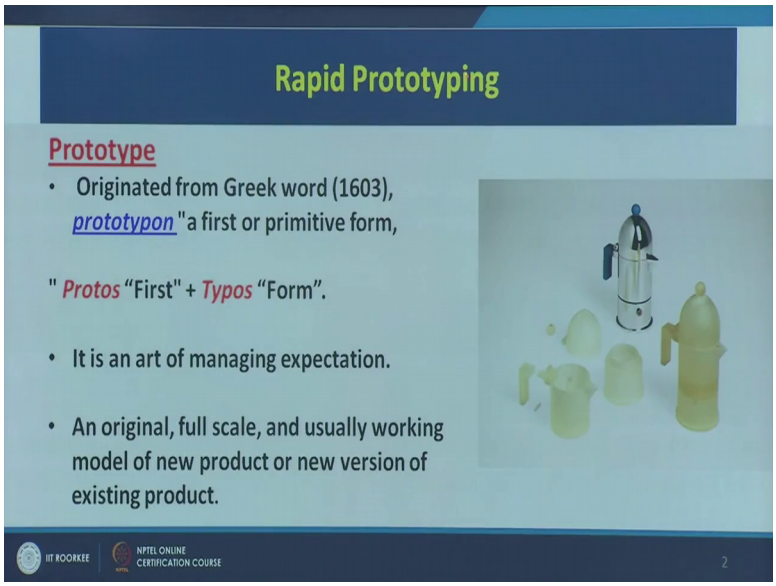

Prototyping we can try to understand it originated from the Greek word prototypon a first or a primitive form. So, prototypon means a first or a primitive form if we break this word into its individual components or elements protos means first and typos means form. So, it is a first form of the design that we have conceptualized and designed. So, for any design whenever we bring it into its actual shape that is called as the prototype. So, it is a first form of the design that we have done taking into account all the steps, all the stages, all the guidelines whatever we can say file we have generated it can be a CAD file or it can be a engineering drawing whatever designed we have done prototype is the first form first actual physical form of that design. So, it is a first form. So, that is required why do we require a prototype in order to check for number of parameters that we will come in it come to see the subsequent slides. So, it is an art of managing the expectation.

Now, customer has certain expectations and we will see that rather the prototype is meeting those expectations or not. If the prototype needs all those expectations we will see we can say with full confidence that the product is also going to meet all those

expectations then an original it is going to be full scale, original full scale and usually working model. So, usually working means in some cases we may make a prototype is which is not actually working we would just like to see that how the product would look like and the prototype may not be a fully functional prototype, it may be adjusted depiction of a product that how it would look like. But in many cases it can be a fully functional prototype also or a working prototype also.

So, in a regional full scale and usually working model of a new product or a new version of the existing product, so it is maybe a full scale model of the product that we have designed and we just want to see that whether it will be able to perform the desired function for which the product has been designed.

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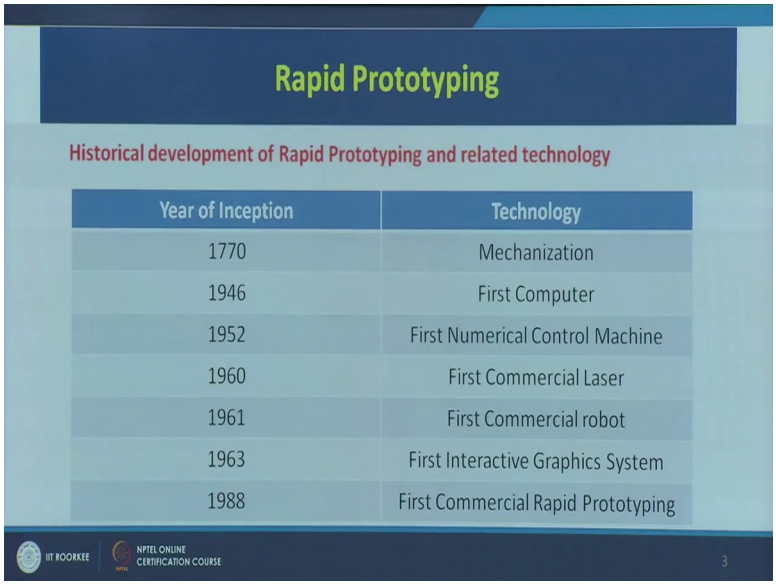

Now, this is rapid prototyping historical development and the related technology because prototype means actually you are going to produce a functional model of the design or the product that we have designed. So, all these techniques have been used for developing these prototypes.

In 1770 it was mechanization came into picture maybe then over a period of time the first commercial rapid prototyping system was developed in the year 1988 and then there were invention of laser invention of numerical control machine graphic user interface. But the first actual working rapid prototyping system which could actually be called as the rapid system was in 1988 and after 1988 a number of techniques that fall under the

category of rapid prototyping have been developed as well as commercialized successfully.

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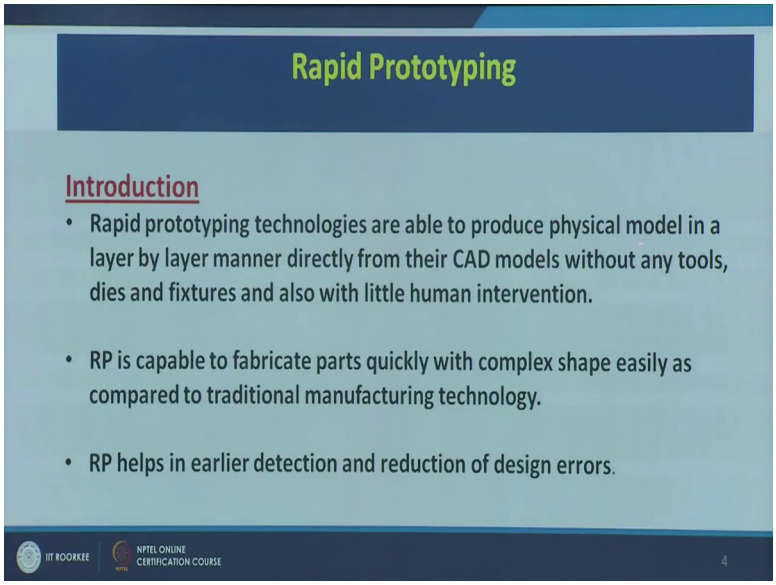

Now, let us have a introductory discussion on this thing that how were rapid prototyping system would work, maybe what is rapid prototyping all of you can search and have information about that, but we should try in our brief time domain that we have that how a rapid proto typing system actually works. And if you are you can say listening to this particular session you will at least have an idea that how a problem will be solved or how a product will be made or a prototype will be made using the rapid prototyping technique a standard rapid prototyping technique. Because in rapid prototyping you will see there are number of techniques and each technique will have its own process mechanism, but the standard method or the steps will remain same.

So, we are going to focus today on the standard steps available or standard steps which are used for converting the design into a prototype. Then maybe in the last session we will see at least one or two techniques with their process mechanism that how actually the design is converted into a prototype what are the steps involved and what is the process mechanism involved.

Today our discussion will focus more on the standard approach of converting a product design into the first prototype or maybe into the model. So, rapid prototyping technologies as I have already explained that it is not a single technology maybe there

are number of techniques that fall under the rapid prototyping technology. So, rapid prototyping technologies are able to produce let us see physical model, I have already told it would be a physical model actual product that that we have designed physical model in a layer by layer manner which is important we will see that why layer by layer directly from the CAD models.

Therefore in one of our sessions we have discussed the fundamentals of CAD also because whatever we will design will be used as a input in the rapid prototyping system. So, therefore, as a product designer I should have a basic understanding of any CAD software, Wipro engineer or auto CAD or there are other criteria there are number of softwares which help us for the doing the card process for any product.

So, we need to have a CAD model without any tools. So, this is the advantage also of rapid prototyping that it works without any tools dies fixtures and also with little human intervention. So, most of the rapid prototyping techniques are fully automatic in nature. So, without much human intervention required.

So, again let us try to understand this definition what are the important elements of rapid prototyping. First is it will generate quickly a physical model of our design, second is it will do it layer by layer and third is that we need to have a CAD model or a CAD drawing of our design and finally, it will not require any dies and fixtures as well as any tools as well as any human intervention.

So, basically if you see as per this definition we need to have we need what is our final output it is going to be a model. So, maybe it can be a model of a pulley, suppose we want to generate a modified design of a pulley mechanical pulley. So, what we will do we will model it we need to have a CAD file of that pulley three dimensional CAD file of that pulley that will be a input. Then we need to have we will slice it into different layers we need to have a system which will convert this CAD file into a physical model of the product. So, the output would be a physical model of the product. We will not require any tools dies fixtures and it can be automatic system once the drying is fed to the system we will see with the help of diagram we will try to understand it with the help of diagram.

Once the CAD file is input into the system the system will may use either a powder or a polymer or a viscous fluid and it will convert it into the physical model and that model

can be used as a functional model or it can be just to see that how the product would actually look like. Even sometimes from mechanical engineering point of view if you generate your physical models like this they can be used as a pattern during the casting process. So, we can make generate our patterns quickly using the rapid prototyping technique. So, the first point I think is absolutely clear and it will become even more clearer when we try to understand the sequence of steps to be followed in the rapid prototyping system. RP that is rapid prototyping is capable to fabricate parts quickly; therefore the name rapid, with complex shape easily as compared to the traditional manufacturing technology.

Just now I have given an example of casting process now suppose we do not have a rapid prototyping technology we want to use the conventional methods of model making. So, what we will do? Suppose we want to make that product by caste or model or the prototype by casting first we will need a pattern for that then for with that pattern we will go for mold making we will make a mold and then we will melt the metal pour that metal into the mold and finally, we will get the shape that we require sometimes we may be requiring to machine that or cut the risers and the runner. So, you can see that it is a long process so many steps are involved only to produce a model or a prototype using the conventional or the traditional manufacturing technology.

Whereas in rapid prototyping only we require the CAD file or the drawing of that particular product and then with that drawing we just give it as a input to rapid prototyping system and it will use the technology any technology it can be stereo lithography apparatus it can be selective laser sintering, it can be laminated object manufacturing, it can be 3D printing which is becoming more and more popular among students these days. So, any of these technologies you get a input in the form of CAD file this technology will convert that CAD file into the STL format and finally, it will help to produce the shape it may require maybe 5 to 7 minutes for generating the model or the prototype of the same product which may require at least a week’s time using the traditional manufacturing technology. So, rapid prototyping has got lot of advantages as compared to the traditional methods of making models of prototype.

RP helps in earlier detection and reduction of design errors. So, prototype means we want to check that if there are any problems with our design therefore, only we are

making a prototype. So, it will help us to find out the problems or the errors in our design process.

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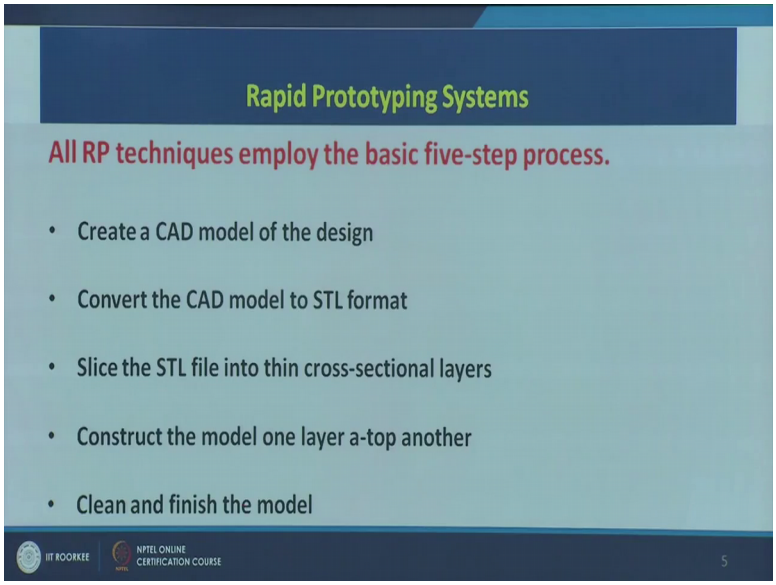

Now, these are the for any rapid prototyping system we have all these common steps in most of the technologies or techniques or systems we will have these 5 steps only. So, all RP techniques employee the basic 5 step process now let us see what are these 5 steps first one is create a CAD model of the design. So, we have already discussed what is CAD and how we can use CAD to make our life simpler and easier. So, we need to use any software which can be pro engineer catia number of modelling softwares are there. So, we can use that software and generate a CAD model convert the CAD model to STL format that is format which is compatible with almost all rapid prototyping systems.

Then slice the STL file into thin cross sectional layers. So, as we have seen rapid prototyping is a technology which produces the prototype layer by layer by layer by layer. So, it is a build up technique build from layer to layer to layer to layer. So, therefore, we need to slice our 3D model into its thin layers maybe it can be 10 layers, 20 layers, 30 layers that will depend upon the technology that we are using for converting the file into the final prototype.

Construct the model one layer a top another layer. So, it will be layer by layer construction and here our physical model will be generated. All these three things will be done in our software only this is a step where actual fabrication will take place and then

clean and finish the model last two steps are related to the actual fabrication of the prototype and first three steps are our proprietary steps which will help us to generate the prototype.

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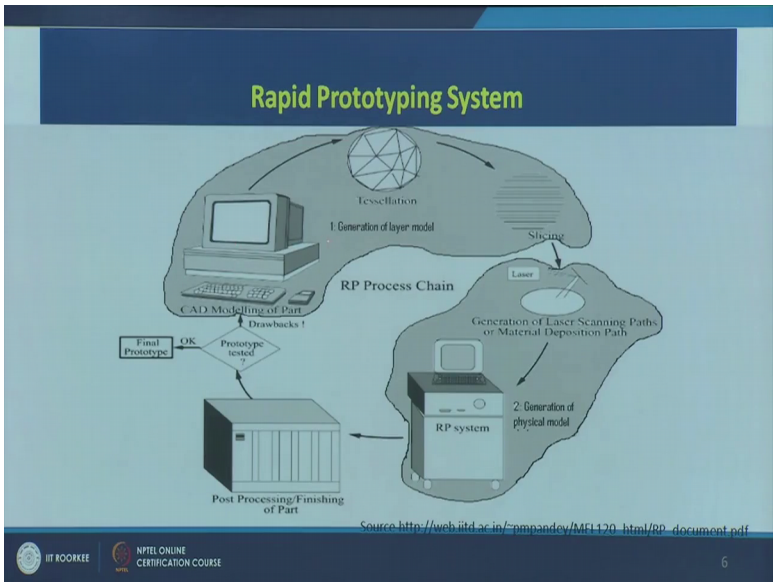

Now, this is the rapid prototyping system as explained earlier. So, here we can see we have a CAD we have a desktop system. So, our CAD model can be here now that CAD model first step is generation of the layer model. So, here we will generate the different layer model. So, this is slicing you can see, slicing means how many layers will be there. So, after slicing all this I have told you three steps the first 3 steps create a CAD model of the design convert the CAD model to STL format slice the STL file into thin cross sectional layers. So, these are the first three steps that involve the software intervention or using a software any standard modelling software we can do this thing. And finally, in this stage we will convert that file into the physical product and there you can see generation of laser scanning path of material or material deposition path.

So, here we are using a laser gun as an input in our physical model to convert the raw materials into the prototype. Now raw material can be in the powder form, it can be in the polymer form, it can be in the layer form or a sheet form. So, it can be in any form we are just trying to understand the fundamental concept of rapid prototyping. So, we have a raw material this is written here RP system and here we have generation of the physical model. So, broadly in this figure we have two major steps first one is generation

of the layer model which requires your CAD file and then tessellation and slicing. So, this is layer one or first step, this is a second step generation of the physical model which I have already explained. First 3 steps are related to the stage one that is generation of the layer model and the next two steps cleaning and the physical model are the generation of the physical model.

So, these are the two major steps and finally, post processing finishing and other things then the prototype is tested if it is we will go for the final prototype if it is not there are some problems found here found here we will again send it for CAD modelling the model will be changed, all changes will be incorporated in the CAD file here, again it will be sliced, again physically the prototype will be fabricated cleaned, again it will be checked whether it is or not and then if it is we will go for the final prototype. So, this is a RP system standard system involves software as well as hardware intervention.

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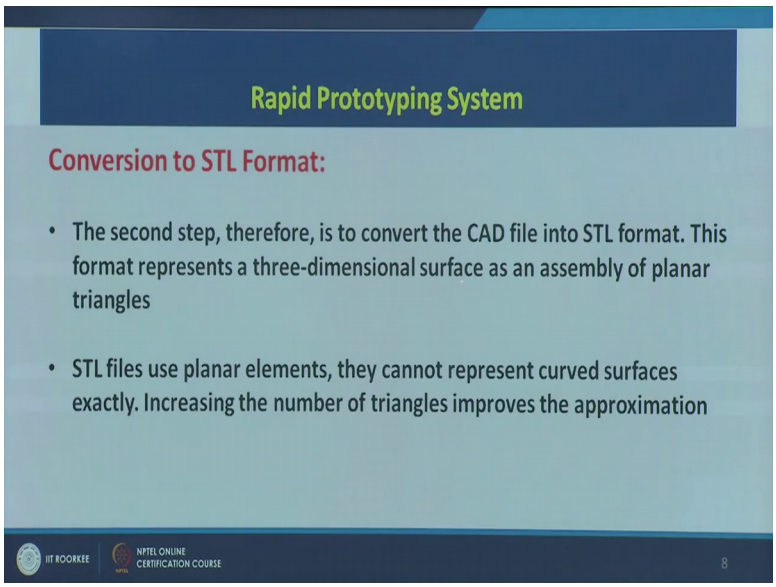

Now, we will see one step at a time. So, we can see here first step is create a CAD model of the design. So, we will see all these 5 steps one by one quickly we will try to go. First is CAD model we already had a discussion on CAD, how CAD system can be used and what is CAD and what are the advantages of using CAD what are the softwares that can be used for computer aided design and we have taken one or two examples also. So, you can use any standard modelling software that is a CAD software and then we can just model that thing on our screen.

So, first the object to be built is modelled using a computer aided design software package that is CAD, solid modular such as pro engineer tend to represent 3D objects more accurately then the wire frame modular such as auto CAD and will therefore, yield better results. So, I am not proposing any particular software there are number of softwares which can be used for creating the solid models of your designs. So, you can use any standard CAD software for generating your design or generating the CAD file of your designs because that is important that CAD file has to be given as an input to our RP system for producing or fabricating the physical model or the prototype.

So, solid modular then this process is identical for all the RP techniques. So, whatever techniques I have named two three techniques RP techniques like stereo lithography apparatus, 3D printing or we can say laminated object manufacturing selective laser sintering in any particular technique you need to generate the CAD file of your design that is primitive or that is the most important step.

Once you have the CAD file then you need to convert it to the STL format the second step therefore, is to convert the CAD file into the STL format this format represents a three dimensional surface as an assembly of planar triangles. So, that was written there tessellation if you again go back to that this design tessellation is written here the representation of a surface in triangular form. So, that is we can say a three dimensional surface as an assembly of planar triangle. So, you now divide it, represent the surface in a planar manner then STL files use planar elements they cannot represent curved surfaces exactly increasing the number of triangles improve the approximation.

So, here we will see we will play around with the density of the triangles and we will see how it best represents the planar surfaces. So, this is the second stage converting our CAD file into the STL format.

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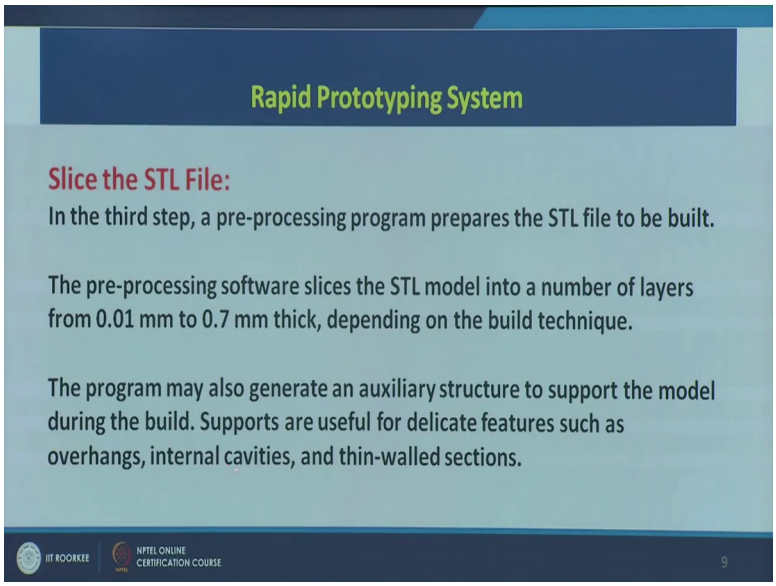

Third is slice the STL file once this process has been done, we will see that the actual fabrication or actual processing of the model will take place in how many steps. So, we will slice it accordingly and we will see what should be the thickness of the individual slice.

So, in the third step a pre processing program prepares the STL file to be built the pre processing software slices the STL model into a number of layers from 0.01 millimetre to 0.7 millimetre thick depending upon the build technique. Build technique is a standard name for any particular process which can be used it can be stereo lithography apparatus or laminated object manufacturing. So, this layer thing we have to finalize depending upon the technique maybe for one particular technique we may go for 0.5 millimetre thick layer this is the third step.

The program may also generate an auxiliary structure to support the model during the build supports or useful for delicate features such as over hangs internal cavities and thin walled sections. So, three special cases are given we are going to produce overhangs internal cavities are required in our prototype or thin walled sections are there in our prototype for that we require the supports. So, here the program will also generate support structure fall. So, there will be support structure which will help to build this model layer by layer.

Now, suppose we have to make a ladder. So, in between there will be different steps. So, from side we may require some support. So, that support structure will also be defined and designed by the help of a program and this support structure later on can be cut and removed once your prototype is ready, so that support structure also it can be done by the you by taking care of the capability of the software or the versatility of the software will help us to design that support structure also.

3 steps we have seen first is generation of the CAD model, second one is conversion of the CAD model into the STL format, third is slicing of the STL file into the different number of layers. Now fourth is the actual building up or for actual fabrication of the model or the prototype layer by layer construction, so fourth step.

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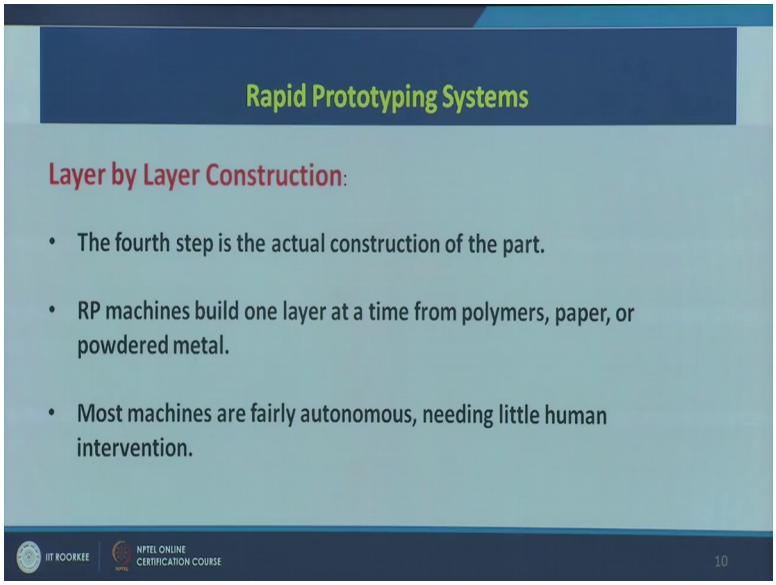

The fourth step is the actual construction of the part. RP machines build one layer at a time from polymers paper or powdered metal. As I have already told we can use any type of raw material polymers papers or powder in order to convert it into the final prototypes or this is a raw material that goes for the conversion of the prototype. Most machines are fairly autonomous needing little human intervention. So, no human intervention is required most of the machines are fully automatic in nature.

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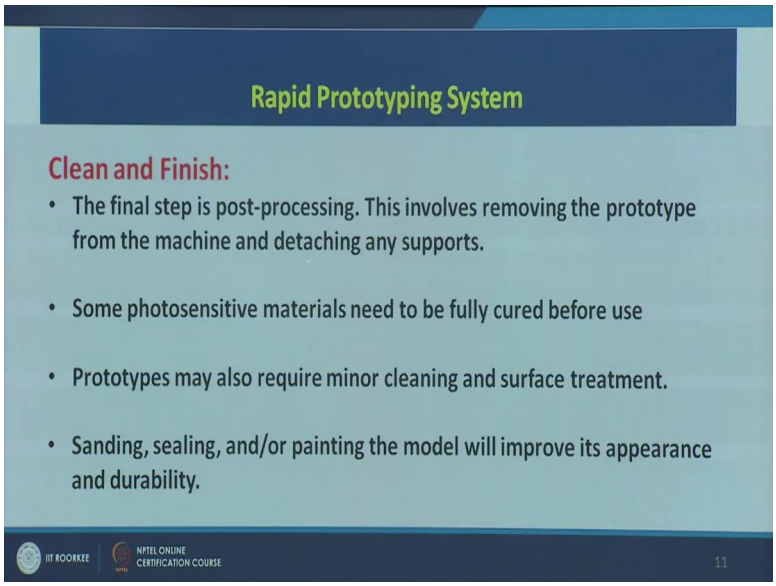

Then the last step for any rapid prototyping system is the clean and finish. The final step is post processing this involves removing the prototype from the machine and detaching any support. So, at third stage in the STL file when we were slicing it in to layer by layer. So, we have designed the support structure also for special cases like overhangs or any special feature to be or internal cavities to be support generated in the model. So, we have design a support structure.

So, during the building layer by layer this support structure would also be build up which we do not require which is not a part of our actual design. So, that will be removed at this stage clean and finish some photosensitive materials need to be fully cured before use now the prototype may have been developed, but we need curing process we may need to keep it in an oven at a specified temperature for the complete curing of the polymer to take place.

So, therefore, some polymers may require that step also prototypes may also require minor cleaning and surface treatment for many cases it may be required. Sending sealing and or painting the model will improve its appearance and durability. So, last step is taking out of the prototype and then cleaning, finishing and doing some surface treatment for its uses as a prototype.

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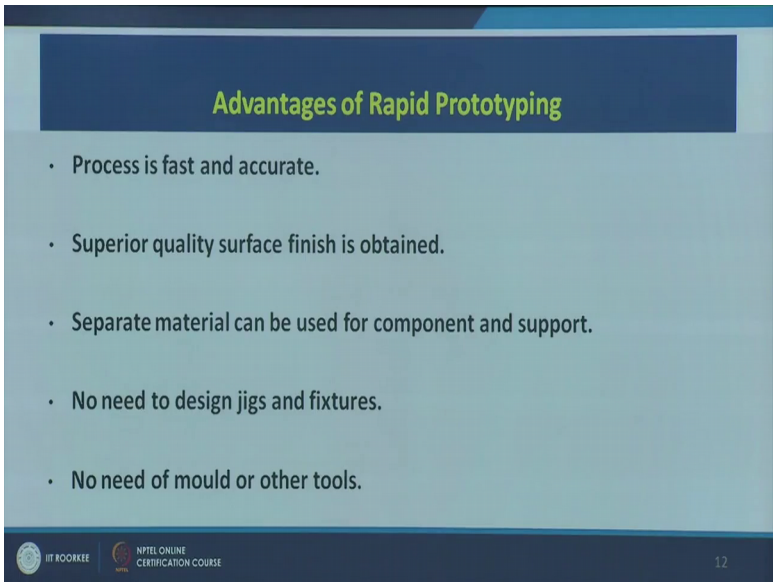

Now, what can be the advantages of rapid prototyping? We have seen that there are majorly 5 steps let me just revise quickly in 1 minute, first is you need to have a CAD file, second is this CAD file needs to be converted into the STL format, then the third is we need to slice the model the drawing into its individual layers because most of the rapid prototyping machines build the model layer by layer by layer. So, we need to divide that how many layers should be there and what much should be the slicing criteria and then we will actually make the product prototyping any rapid prototyping machine and fifth one is once the prototype is ready we will take it out we will clean it we will remove any support structure that has been built up, and finally we can use the prototype if it is the functional prototype we can use the prototype and see the working and the functioning of the model or the design.

Then what are the advantages now quickly let us see, this process is fast and accurate without any human intervention since human intervention is minimised accuracy can be a certain process is definitely quick, superior quality surface finish is obtained even once we take out the prototype we can finish it for superior surface finish. Separate material can be used for component and support that also facility is available that the actual model is made up of material x and the support structure can be made up of material y that is possible. No need to design jigs and fixtures as I have already explained in the first part of our today's discussion, no need of mould or other tools.

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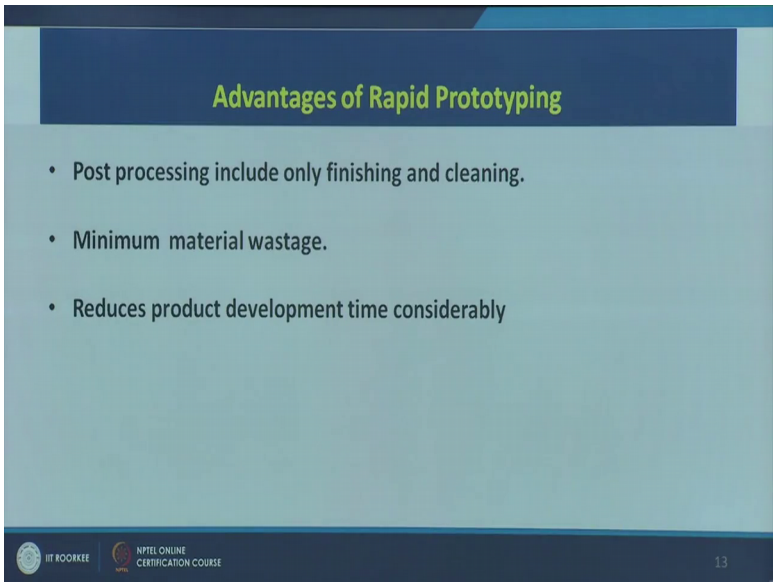

Post processing includes only finishing and cleaning not much post processing is required in case of rapid prototyping, as in case of products made by suppose casting is used as a technique for making the prototype we need to cut the runners and the risers and all those things and then we need to sometimes finish the casting also to get the desired shape. Here all those things are not required only finishing and cleaning required minimum material wastage as we can see now lot of material is wasted after the casting process.

It reduces the product development time considerable this is the first thing with which I started today's discussion that the product development time is most important for the organisations and if we spend lot of time on prototyping the product it may not be a healthy practice. Therefore, in order to reduce this product development time we can focus on the technique of rapid prototyping. Maybe in our last session that is scheduled maybe this week only we will finalize and see that what are the various rapid prototyping technique.

So, we started with the conceptual design of the product in our week 1 and finally, we are ending, we will be ending may be in the last session with a functional or a partially functional prototype of the design that we have done over the last 4 weeks and once the prototype is found the final manufacturing of the designed or the product can start.

Thank you.