Product Design and Development
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Lecture - 20
Rapid prototyping processes

[FL] friends, finally we have reached the last session of our course on Product Design and Development. As all of you are aware that the course was divided into 4 weeks and the last week out of the 4 weeks is focused on learning the various design guidelines related to development of the product; like related to assembly and manufacturing of the product. If you remember in the first lecture in this week we have discussed the concept of DFMA that is design for manufacturing and assembly.

In our second lecture we have seen that what design guidelines should be taken into account when the product has to be assembled using the manual assembly. In third session we have discussed that what are the design guidelines to be taken into account when the product has to be made by different manufacturing processes, in which we have seen the most important manufacturing process casting machining moreover we have seen related to the plastics parts manufacturing and the most important process of plastics parts that is injection molding that was just an overview of the guidelines that an engineer should know or should keep in mind while he is designing a product.

In our 4th session we discuss the basic concept of rapid prototyping that when our design is ready, we have to fabricate the product, what types of concepts are there regarding the prototyping. Initially the prototypes were made using the conventional methods of manufacturing that is casting forging machining etcetera.

Currently the best method of prototyping is the rapid prototyping because the product development cycle time is very very important. So, the companies want to make the prototype as quickly as possible. We have discussed the concept of rapid prototyping and what are the various steps involved in a rapid prototyping process, we have not discussed any specific process, but we have seen in general that what are the steps for any rapid prototyping process; there are basically 5 steps involved in any rapid prototyping process and we have discussed that in the previous class.

In today's session that is last session of our course on product design and development we are going to discuss the rapid prototyping processes, we will see at least 3 or 4 processes that can be used for developing the prototype, what is the process mechanism of those processes, and try to relate what we have covered already in our last session the concept of rapid prototyping with the actual process our math our objective will be to understand that what are the what is the mechanism of the process and how the process actually takes place.

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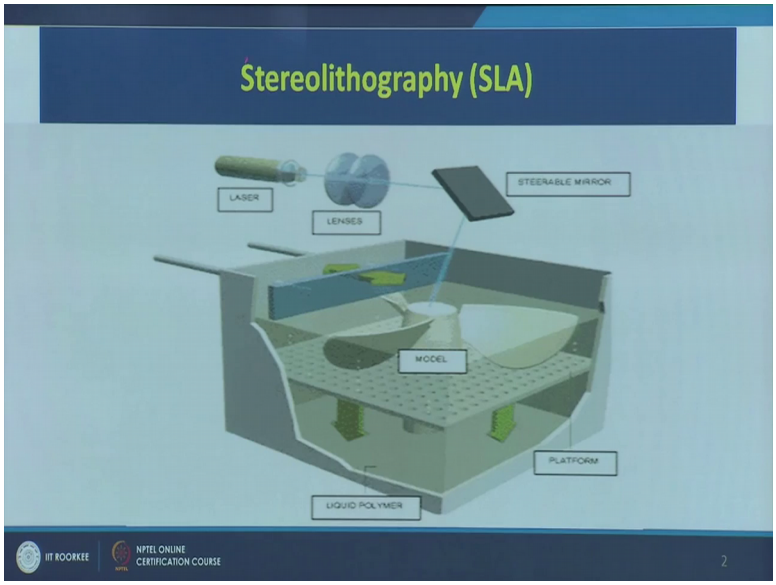

Let us see the first process that is Stereolithography SLA. If you remember in our last class we have seen that 5 steps are required for making a rapid prototype or making a prototype quickly, what was the first step we require a cad file or a cad model of our product. So, first input will come from the cad model, the input will go to this laser gun, and then there are focusing lenses, and then this will focus it on to the raw material which will be converted into the product.

The first step was we require a cad model, second step is it will be converted into SLA file, third step is it will be the model will be sliced into it is individual layers, and depending upon the overall thickness of our prototype we may divide it into 20 layers or 30 layers and the layer thickness may vary from 0.7 millimeter to a few millimeters not too much of we can say not very high thickness will be there for a single layer. So, layers will be very thin layers in case of any rapid prototyping process. There this model we can

see a fan blade is being constructed, but it will be constructed layer by layer by layer by layer by focusing this laser on to the raw material.

Let me tell you here it is written liquid polymer. So, majorly we will be focusing on 3 processes today one is the Stereolithography apparatus SLA, second one is selective laser sintering, and third one is laminated object manufacturing all these 3 processes are common processes for making the prototypes easily or for making the prototypes quickly.

Now, why these 3 processes have been selected because finally, the prototype is made up of the raw material based now based on the raw material we can have different types of rapid prototyping processes, we may have a liquid as a raw material, we may have a powder as a raw material, or we may have a solid sheet as a raw material. In case of SLA we have a liquid polymer as a raw material, in case of selective laser sintering we have powder as a raw material, in case of laminated object manufacturing we have a sheet as a raw material. So, we have a solid raw material, we have a powder raw material, and we have a liquid raw material. So, you can you can emphasize that rapid prototyping is based on different types of materials, even we can use polymers we can use powders we can use metal.

We can make prototype of different types of materials using the rapid prototyping process, but we have to judiciously select that which rapid prototyping process will be applied for which particular application that is the material of the prototype will dictate the type of rapid prototyping process that we are going to use.

Now, here I was emphasizing on the rapid prototyping process, this is Stereolithography and here we see we have a laser gun lenses, then there are focusing lens, and this is the model that we are creating, and this will be created layer by layer, and we will try to understand that how we can make a 3 dimensional model layer by layer using this arrangement. So, first thing is we need to have a cad file of this fan blade model that is one thing raw material is photosensitive liquid polymer, why photosensitive that we will see later because the laser has to cure that polymer into from liquid to solid, therefore it should be sensitive to the UV laser.

Therefore, we need to have a photosensitive polymer and here the product will be made layer by layer one layer at a time and the curing of the polymer will take place selectively and we will be able to make cover model.

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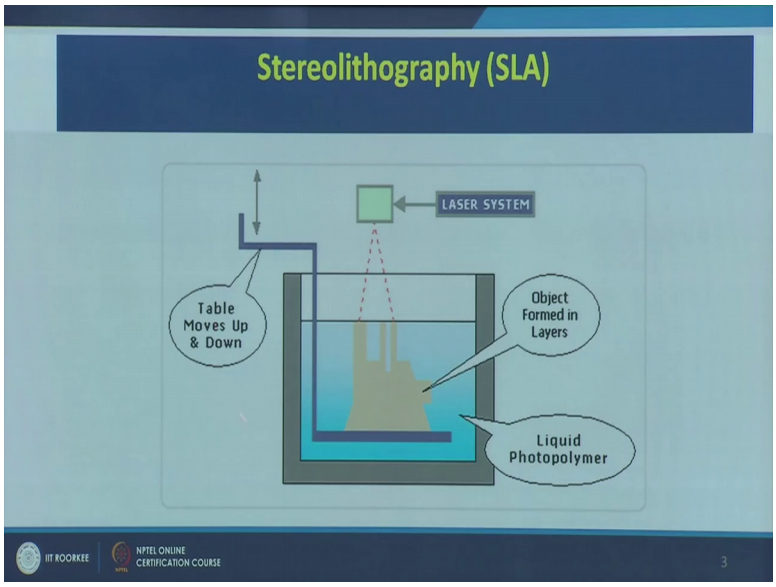

Now, let us see the try to understand the basic fundamental of this working system the input to this laser that the movement of the laser will be gun laser gun will be controlled by the cad file. Now cad file has all the data that what is the final shape of the product that we want to make, now this gun will be controlled by that and moreover this platform also will be controlled this platform on your screen you can see purple colour platform.

So, initially this platform will be at the top and only the polymer required for 1 layer 1 layer of the product all the prototype will be on top of this platform, and laser will selectively sinter or selectively not sinter sorry sinter is not the right word it will cure because here we are using a polymer sinter sintering of powder will be done in selective laser sintering, but here the laser gun will what it will do it will cure it will cure the polymer selectively as per the shape of the model, and then this platform will be lowered down this platform initially the position of this platform will be here first position then once the first layer has been cured this platform will be lowered down.

Another thickness of polymer will come on top of the initially cured layer and then again the laser gun will cure selectively depending upon the shape that particular polymer that has come over the first layer. Then again the platform will be lowered down the third

layer the polymer for the third layer will come on top of the second layer again the laser will selectively cure the third layer and similarly layer by layer by layer by layer the platform will keep on coming down and the laser will selectively cure the polymer and finally, we will get our product. This is a very fast process because quickly we are producing or curing the polymer and the polymer from liquid is getting converted into solid on the on the curing process.

Now, some of you may be wondering that how 1 layer will stick to the other layer. So, there is a phenomenon in which we will over cure the first layer now suppose this is a thickness this is a exaggerated scale never we will get a thick this much thickness, but just to explain I am taking this thickness now suppose this is a thickness of the first layer and laser has cured this material and it has become partially solid.

Now, the top layer second layer again will be of this much thickness and this layer has to stick to this layer. So, what we are going to do we are going to over cure this layer maybe the top portion we will cure up to this much thickness. So, this material will join to each other and here we will have bottom layer and the top layer. This portion we will over cure slightly. So, that this layer the second layer joints with the first layer, and similarly when the second layer has been cured we will deposit the third layer and over cure the third layer slightly, that it joins with the second layer. So, the layer by layer first layer, second layer, third layer, fourth layer slightly over curing the layer to be deposited will result in joining of the different layers.

Here we can see that this is the object being formed the yellow colour geometry you can see it is a complicated geometry, we will see some of the geometries that have been made by the rapid prototyping process which otherwise would have been very very difficult, but using this technology of rapid prototyping these geometries can easily be created. This is a table which moves ups and down depending upon the requirement there is a laser system this is object that is formed and the blue colour portion is the liquid photopolymer which is sensitive to the u v laser. So, these are the important components of any SLA system.

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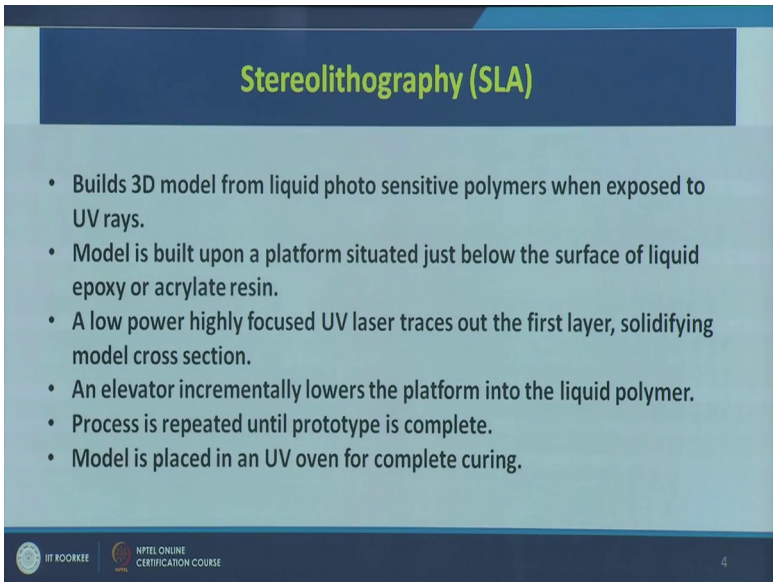

Let us see let us try to understand read what I have already explained, this Stereolithography builds 3D model from liquid photosensitive polymer already I have explained when exposed to UV rays; when exposed to UV rays. That is one thing model is built upon a platform situated just below the surface of a liquid epoxy or acrylate resin. So, this is maybe one type of resin which can be used so, you have a platform you have the resin on top of the laser will cure it then this platform will go down this movement will be governed by the software, it will move down only to ensure that another layer of polymer comes over the platform which is again cured again it will go down the laser will cure the third layer and similarly this process will continue and we will get a solid prototype of which is the cured prototype from the liquid polymer.

So, a low power highly focused UV laser traces out the first layer solidifying model cross-section an elevator incrementally lowers the platform into the liquid polymer, process is repeated until the prototype is complete, model is placed in a UV oven for complete curing. Sometimes we may get a solid model where the polymer may not have cured completely. So, we will take this model out of the rapid prototyping machine or Stereolithography apparatus and put it in the u v oven for the complete curing of the model.

In this way what are the inputs the inputs basically are the cad model of the final prototype that we want to make or the cad model of the product that we want to produce

for prototyping we require that file, then that file needs to be converted into STL format from STL format we need to slice a model into the individual layers, because now we have seen that the model is created layer by layer by layer by layer. So, we should know that how many layers will made makeup the complete prototype and then layer by layer a rapid prototyping machine will create a model from the liquid photopolymer, using the UV laser gun and it can be converted into a final prototype. So, this is the process mechanism of Stereolithography apparatus.

Now, the second is the selective laser sintering in which we will use powder as a raw material in first case what was the raw material the raw material was liquid photosensitive polymer see in selective laser sintering we have powdered material as the raw material.

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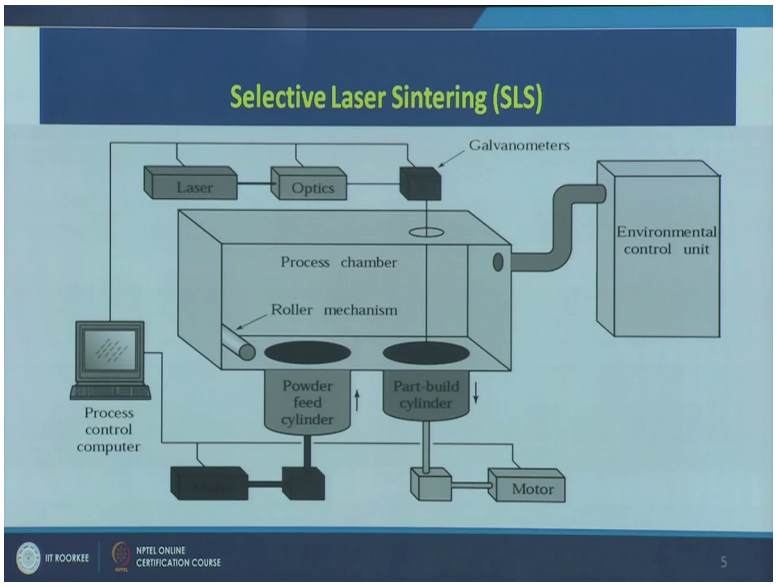

This powder will be converted into the solid form after the sintering process and we will get our product in this case our focus will be to sinter the powder that is we will heat the powder. So, that the powder becomes solid it melts and it forms a layer.

So, here also these are the important things again there is laser system here again for ensuring the sintering of the powder then optics to focus this lens and then there is a roller mechanism powder feed cylinder this is the input from where the powder will come and then this will role the powder here optics will focus the laser on top of this powder and this is the part build cylinder there is a motor which will ensure the

movement of the part because we need to make the part in 3 dimension, it is not a 2 dimensional prototype it is a 3 dimensional prototype. So, we need to ensure the movement of the table. So, that a third dimension is also created.

For example all if the mechanical engineers can appreciate in a milling machine we have 2 axis x and y our table can move in x and y direction, but in order to do 3 dimensional shape we need to move the table downwards and upwards also the tool will in milling machine will be rotating or revolving around it is axis. So, it can be a vertical milling machine, it can be a horizontal milling machine, but the table can move in x y direction as well as in the z directions.

Similarly, in rapid prototyping system also we have to ensure the gun can move in x and y direction here, but in order to generate the third dimension either we need to move the gun up and down or we need to move the table up and down and in many cases we will see the table we will move as in case of Stereolithography the platform was moving down incrementally layer by layer by layer.

Similarly, in selective laser sintering also the movement to the table has to be provided to ensure the third dimension to the platform because the 2 dimensions can be covered by the movement of the laser gun. So, here we have the powder feed input will come from a roller mechanism to ensure the spreading up of the powder and then the optics will sinter the powder accordingly.

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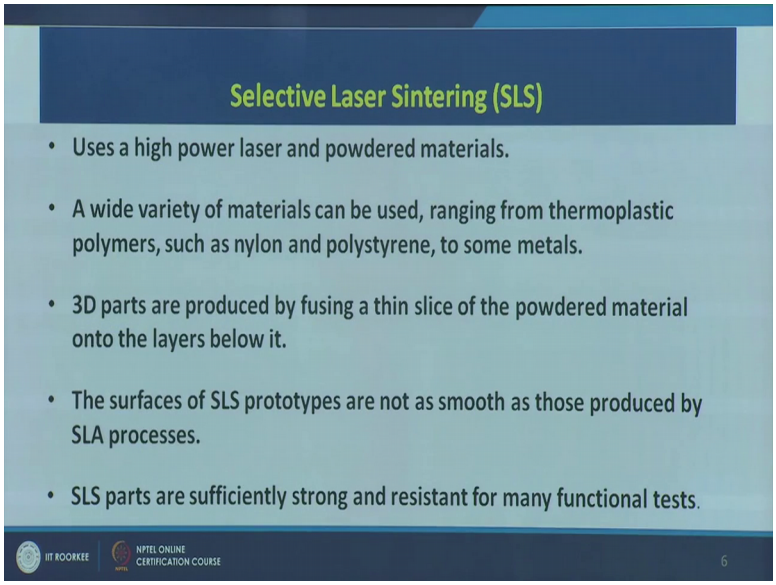

Let us now read quickly how selective laser sintering is done it uses a high power laser and powdered materials I have told you that deliberately we have selected 3 processes in first process the liquid photopolymer is used as a raw material in selective laser sintering we are using powder as the raw material and in the next laminated object manufacturing we will be using sheets as the raw material.

So, here powder is the raw material uses a high power laser and powdered raw material a wide variety of materials can be used ranging from thermoplastic polymer, such as nylon and polyester into some metals. In many cases some powdered metals can also be used as a raw material for making the prototypes quickly using the process of selective laser sintering. So, you have raw materials like nylon and polyester. So, you can use polymers also here you can use metals also 3 dimensional parts are produced by fusing a thin slice of the powdered material on to the layer. So, we will try to fuse the material layer by layer by layer. So, that we are able to get a 3 dimensional prototype.

The surfaces of stereo selective laser sintered prototypes are not as smooth as those produced by SLA processes. So, surface finish in SLA is not that good SLA parts are sufficiently strong and resistant for many functional so, the prototypes that you make using the selective laser sintering process are functional and can be used for carrying out different types of tests.

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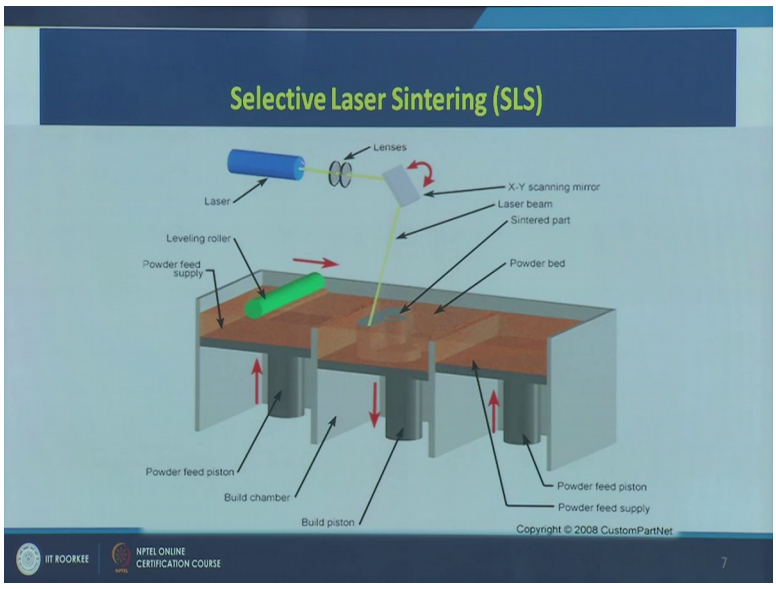

Now, this is a working model of selective laser sintering system here we can see there is a laser there are lenses and then there is a focusing scanning mirror arrangement x y scanning mirror arrangement here and this is the part being manufactured you can see here. This is a build piston as I have told you movement has to be provided to the table accordingly and there is a rolling arrangement which will roll the powder, this is a powder feed piston. So, the powder will be fed from here roller will rule the material spread it in the form of a film or a it will ensure thickness and finally, the laser beam will sinter the material as per the shape.

Basically our cad model that we have in our software will guide the movement of the powder feed motion, build motion also and then this is again powder feed from both sides, powder can be fed. Because in one side when the powder is coming from here roller can feed the powder and feed it on the build table and then the roller will come in this direction. In the second cycle again the powder will come from here and roller can move from right hand side to left hand side again feed the powdered material here and then take a position on the left hand side.

This 2 way powder feeding mechanism can be done, but the otherwise the process mechanism more or less is same we have a table here on which layer by layer by layer this layer will sinter the powder material and the prototype will take it shape based upon the movement of the laser gun and the sintering of the powder here on the build table.

So, this is a selective laser sintering process again we can just look and read the process details on the slide I have tried to explain.

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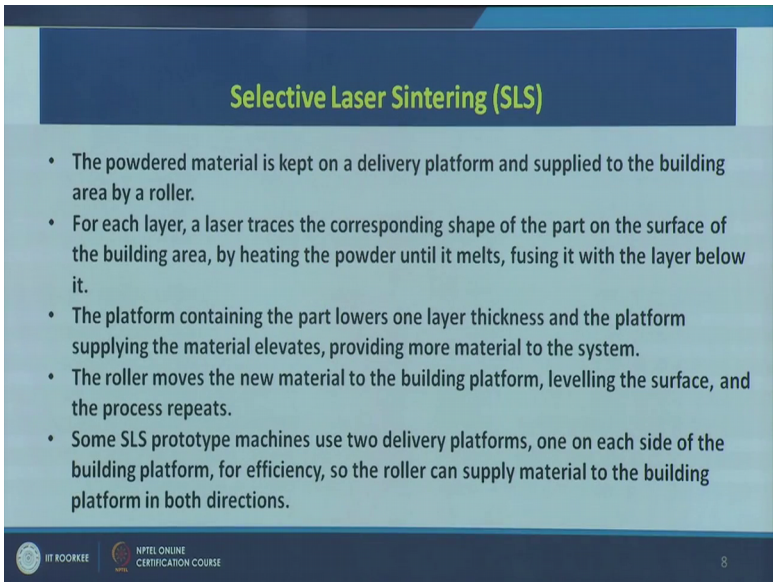

If anything is left we will again discuss that thing the powdered material is kept on a delivery platform and supplied to the building area by a roller. So, this is the roller green colour roller the material will be fed from here and it will be rolled on to on it to the working area or the build area with the help of a roller. For each layer a laser traces the corresponding shape of the part on the surface of the build area.

The laser will trace the corresponding shape now corresponding shapes from where the laser will get an input it will get an input from the cad model or the cad file that has already existing. So, based on that input the laser will trace the corresponding shape of the part on the surface of the building area by heating the powder until it melts fusing it with the layer below it. Already the in first layer we will make leave the laser as per the design or as per the shape, once it is solid it will go down again powder will be given as a input by the roller the laser will again trace the path as per the cad model and again it will melt the metal or the powder whatever is the material and it will stick to the first layer. So, layer by layer we will make the model in selective laser sintering also.

The platform here we can see the platform containing the part lowers 1 layer thickness and the platform supplying the material elevates providing more material to the system. So, the where the job is being made that will platform will come down layer by layer by layer, and the section from where the material has to be fed it will raise up and supply the material the roller will feed the material to this table and the laser will sinter this material

and the sintered material will stick to the already solidified layer and part layer by layer we will make the prototype.

The roller moves the new material to the building platform leveling the surface and the process repeats as the diagram explains some selective laser sintering prototype machines used 2 delivery platforms one on each side of the building platform for efficiency. So, the roller can supply material to the building platform in both directions this I have already explained here we can see there the material can be supplied from both sides in this case and this is your building platform where the prototype is being built.

So, the process mechanism I think is absolutely clear to all of you that how a powdered material can be converted into a solid prototype using a laser gun and a input of cad file which gives the shape of the final product. These are 2 processes we have seen we have used a photosensitive polymer with a u v laser and converted it into a solid prototype in the Stereolithography technique and in selective laser sintering we have taken a powder using the laser gun we have sintered the powder into the solid form using layer by layer by layer technique. So, 2 techniques using different types of inputs I i think is clear to all of you.

Now, let us see the third technique that is laminated object manufacturing in sheets in which sheets of raw material will come and will be cut as per the requirement and layer by layer we will make our prototype. So, that is a laminated object manufacturing technique.

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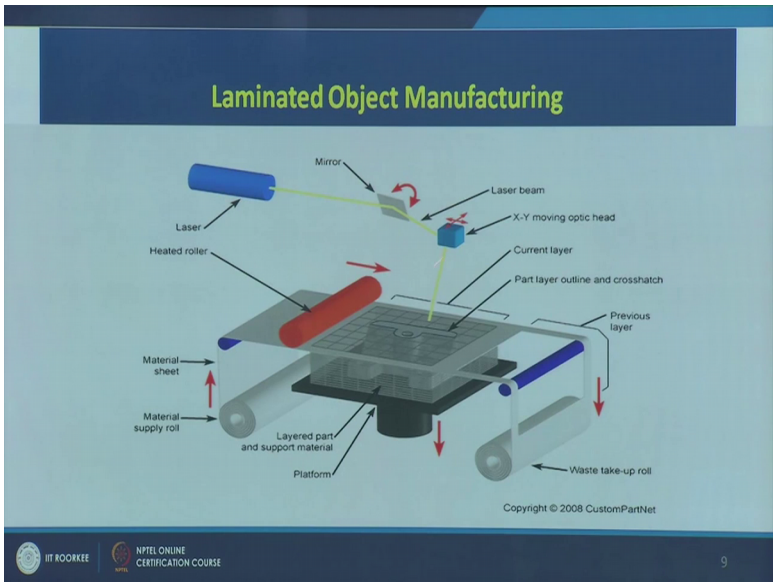

Let us see this we have already seen. So, this is a diagram for laminated object manufacturing here also we see there we are using a laser again there is a mirror here you can see that is why optic head which is used for cutting this sheet into the desired form, and here also we have a heated roller which will roll the sheet on to the build platform this is a platform, which will be lowered layered part and support material there we can see inside this is the part which is being manufactured.

The raw material this is a material supply roll so, if you see 3 types of raw materials can be used and we have discussed today. So, this is a material supply roll here input and this is a waste take up roll from which the material which was required has already been cut here. In laminate object manufacturing again we need to have a cad file of the shape that we want to produce, we need to have a laser system for cutting the sheets into the desired shape we need to have a platform for controlling the z dimension of our prototype and x and y will be taken care by the laser only there is a take up roll or waste take up roll in which the used material will be collected and this is the raw material which is a material sheet.

So, the material let us see step by step how it will happen, where a material take up roll this is a input material it can be we will see, it can be an adhesive paper adhesive coated paper adhesive coated metal sheet. So, the raw material will go from here the roller will heat it and supply it is a heated roller and will supply it to the build platform this is a you

can say waste portion here checked portion and then the first sheet will come here through the laser it will be cut as per the required drawing or the required cad model and then that roller will move forward this take up roll will take the used material.

Again in the then the platform will lower down another thickness of the material will be supplied or another sheet will be supplied to this build platform, again the laser will cut as per the required, and the second sheet will get stick to the first sheet and the used sheet will further move forward, platform will lower down another layer will be supplied, and layer by layer by layer by layer the complete model will be built.

This is where we are using a sheet as a raw material for making a 3 dimensional prototype of any product for which we have a cad model available.

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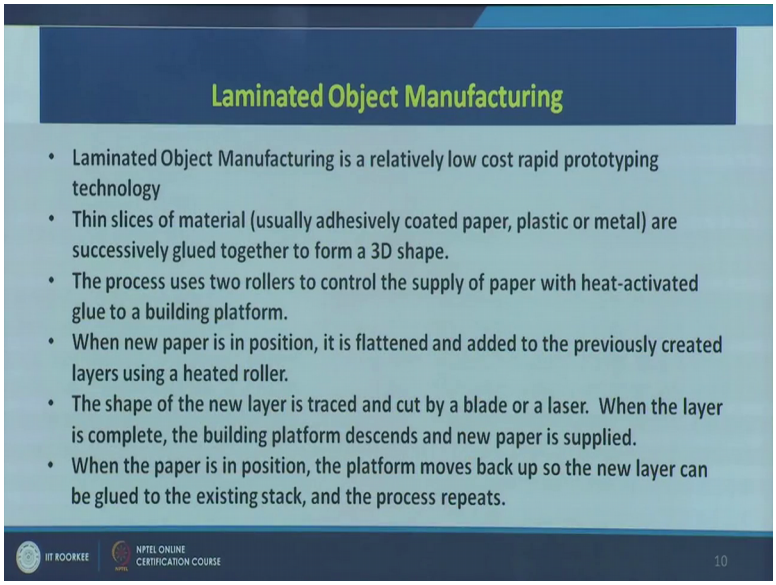

Let us read the details about laminated object manufacturing I have tried to explain it with the help of a diagram in laminated object manufacturing is a relatively low cost. So, rapid prototyping technology thin slices of material now what is a raw material I have explained it is the sheet, usually adhesively coated paper plastic or metal are successively glued together to form a 3D shapes. So, each layer will be glued together to the next layer and we will get a 3 dimensional shape.

The process uses 2 rollers to control the supply of paper with heat activated glue to a building platform. So, again in all cases there is a building platform material on which

the raw material supplied in this case it will be supplied with the help of 2 rollers. When a new paper is in position it is flattened and added to the previously created layers using a heated roller. So, heated roller will ensure that one layer sticks to the other layer, then we have to cut the desired portion the shape of the new layer is traced and cut by the blade or a laser when the layer is complete the building platform descends that is the building platform goes down and the new paper is supplied or the new sheet is supplied which I have already explained.

When the paper is in position the platform moves back up. So, the new layer can be glued to the existing stack and the process repeats. We can see that layer by layer by layer by layer we can produce a 3 dimensional prototype using the rapid prototyping process that is laminated object manufacturing.

We have seen 3 different types of processes that is SLA, SLS and LOM and these 3 types of processes used different types of raw materials, and the basic mechanism that is step by step layer by layer building remains the same only the raw material is changing the other details are more or less the same we have a cad file we have ARP machine and RP machine is converting our cad file into a 3 dimensional physical prototype.

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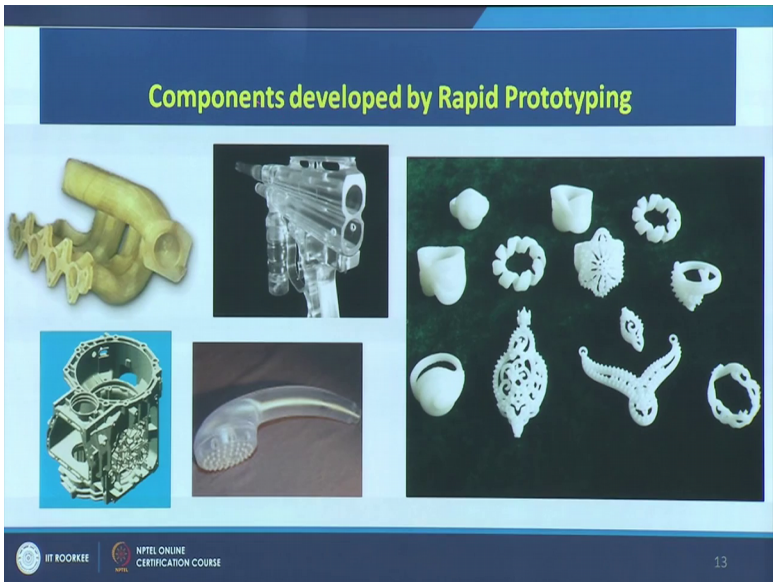

So, with this we come to the application area, quickly I will skip one or 2 slides here we can see the components developed by rapid prototyping.

If you see the complexity of these parts or these components if we need to produce them using any conventional manufacturing technique it would be a very very difficult or a very very cumbersome procedure, but using rapid prototyping we can make these prototypes very quickly and these prototypes can even be functional prototypes and I as I have told in the previous session they can also be uses as patterns in casting process for performing the foundry operations.

So, you can see the complexity of the parts and these parts can easily be made by rapid prototyping process only thing that we need is a accurate cad file of these shapes. If we have a cad file the machine has the capability with the help of certain support structures it will be able to produce these shapes.

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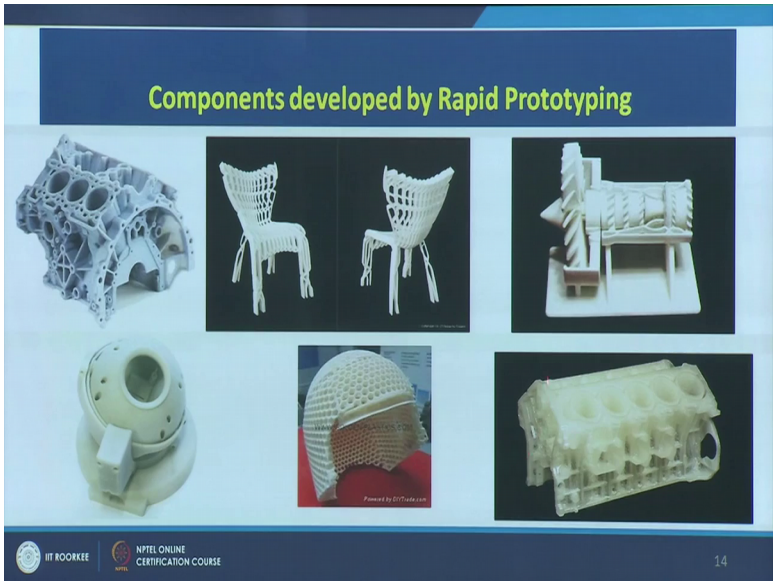

You can see the other shapes which are complicated can easily be made by the rapid prototyping process.

So, with this we come to the end of our discussion on this course on product design and development I have really enjoyed discussing these topics with all of you and I am open to all kinds of questions maybe I will try to answer them to the best of my abilities. If you feel you have any doubt related to the discussion that we have taken for the last 10 hours or maybe you have certain suggestions you are free to write to me on my email I D I will be more than happy to answer the queries as well as the suggestions that you will

give will help me to improve the discussion further. And with this I thank all of you for joining this course.

Thank you very much.