Advanced Manufacturing Processes
Prof. Dr. Apurbba Kumar Sharma
Department of Mechanical and Industrial Engineering
Indian Institute of Technology, Roorkee

Module - 5
Other Advanced Processes
Lecture - 2
Rapid Prototyping Technology (RPT)

Welcome to this session on rapid prototyping under the course advanced manufacturing processes. In the last session, we have discussed about high energy rate forming process, its principles, features, different techniques, requirements and applications etcetera. In this session we will move towards a new manufacturing technique which represents a new generation in manufacturing technique itself. This is called rapid manufacturing rapid prototyping manufacturing.

So, this is basically developed owing to the need of the customer that they have very less patience to wait for the product to come. That means the lead time which is called manufacturing lead time for any product now are getting squeezed day by day, people do not have time or the customers do not want to wait for the product to come out in the market, rather if they want to order today they want to get the product also instantly. This is not the situation with the final product where the customer wants to use it immediately, but the situation is similar in other cases as well like say for example, one needs to cast a product, we need the pattern.

This pattern fabrication itself takes some time that means there is a lead time for in that phase itself before the casting can be initiated. Again, the casting process has its own processing time. Therefore, if these processing time say for example, for pattern making can be squeezed down then also there is an advantage as far as the gain in manufacturing time is concerned or in other words we can say there is a time compression we can achieve by compressing some lead times or manufacturing times at different phases of manufacturing.

So, this led to, these type of situations from the customers as well as in the manufacturing shops led to some new concept. People started thinking can we manufacture the product directly from the computer itself means in almost all manufacturing situations we use computers for modeling, for analysis and so on. And most of the drawings nowadays are being produced using computers and they are being send to different shops or different phases for a further processing say CAD drawing will be generated for any parts to be produced.

Then it will be sent for process planning rather process planning also can be generated in the computer itself nowadays with advanced software technologies. Then this will be subsequently transmitted to the cams shop or the CNC machines, where actually the product will be machined or produced. However, if one can produce the product from the CAD terminal itself by some mechanism then probably we can avoid some in between phases and also the delay due to the transportation or the transmission what we call and then their processing and so on. This has led to this concept tad.

Since, we are already having the technology of producing, printing the two, two dimensional letters or some drawings on a sheet of paper like say small thin sheets like this, that means we can produce some output on this plane sheet of papers and that we can read, we can use, we can see. In fact this is a product being produced in two dimensions which has got x and y dimension and we are capable of reading it, using it, interpreting it rather it gave to the concept that if we can build another dimension into it.

So, instead of the drawing is made on this or the section is made on this as a 2 D, can we build up some material on this, on the other direction, if we call this is as x, this as y, can we build another dimension in this say this is the z direction, then this will give us nothing but a 3 D product. And this is what generally we do in the conventional machining or other fabrications that means we obtain a 3 D product rather than a 2 D product. So, this is the background or the basic of this process.

Of course, there are different techniques to achieve this, to realize this 3 D products, this is what I have indicated at this moment is one of the concepts or the basic concept based on which the other techniques got developed subsequently. Let us discuss some of the important or widely popular techniques in this series, in these sessions, two three sessions we will try to divert on this. Hope, it will be useful and interesting for you. As I have already discussed about the background of this rapid prototyping techniques, this can be put in that, this age of fast growth that is the technology is evolving very rapidly, the customer demands very fast delivery of their intended product.

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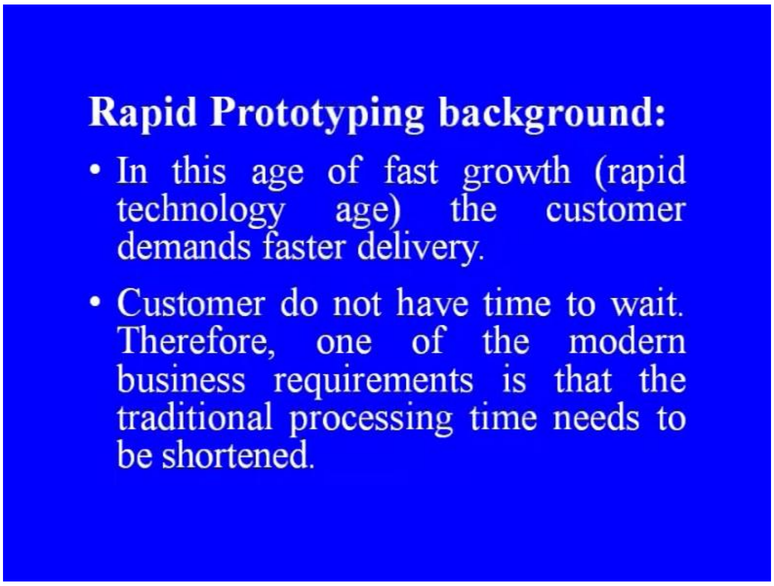

Customers do not have time to wait. Therefore, one of the modern business requirements is that the traditional processing time needs to be shortened.

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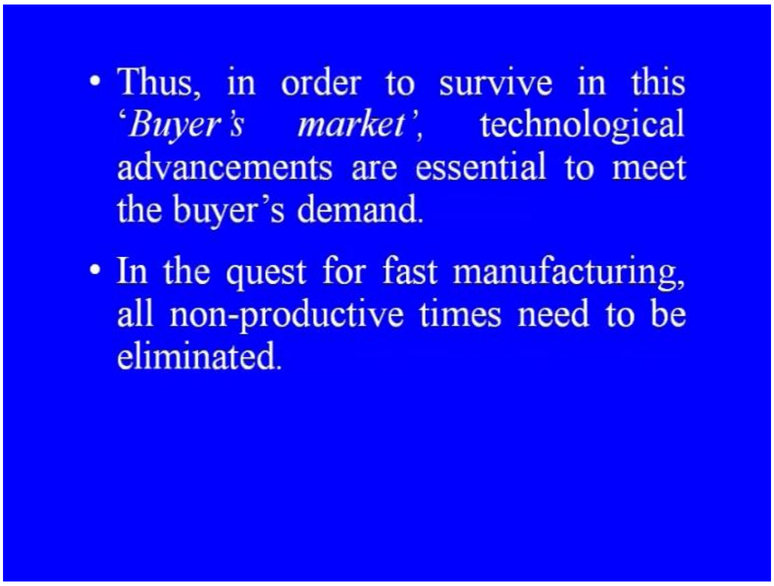

Thus, in order to survive in this buyers market; technological advancements are essential to meet the buyers demand as well. Nowadays, the market is no longer the seller's market which used to be few decades ago, that means whatever the manufactures produce in whatever timeframe, the customers are supposed to consume those or buy those products. They do not have the flexibility or choice to go for a product of their choice at their own time, which was called or referred to as seller’s market, but nowadays the scenario is changing totally.

Now, the buyer wants to have something at their own convenient time and the supplier will have to be able to make it available to him at that moment otherwise the buyer will switch to another able supplier or manufacturer. He has choices therefore; to be on this fray the manufactures will have to adopt, rather they have been adopting new technologies, so that this time, lead time what I was talking about at the beginning of this session can be squeezed. In the quest for fast manufacturing all non productive times need to be eliminated from the production line.

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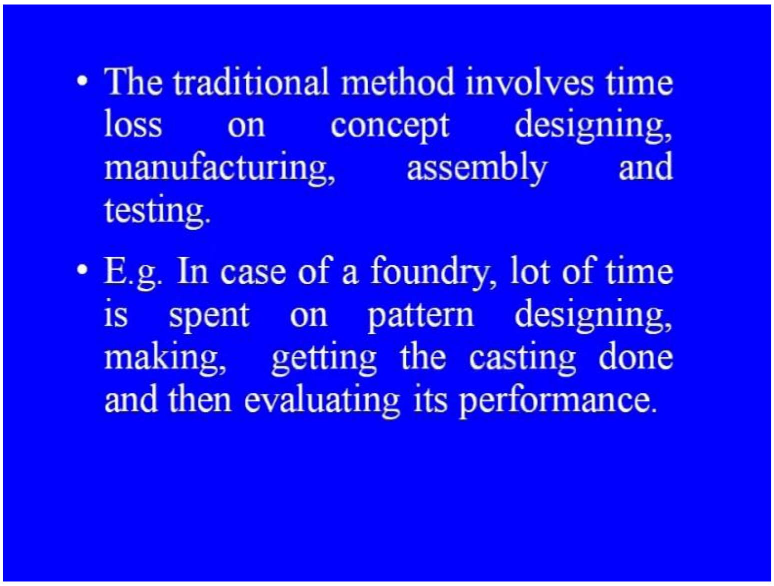

The traditional method involves time loss on concept designing, manufacturing, assembly and testing. For example, in case of a foundry a lot of time is spent on pattern designing, pattern making, getting the casing done and then evaluating its performance.

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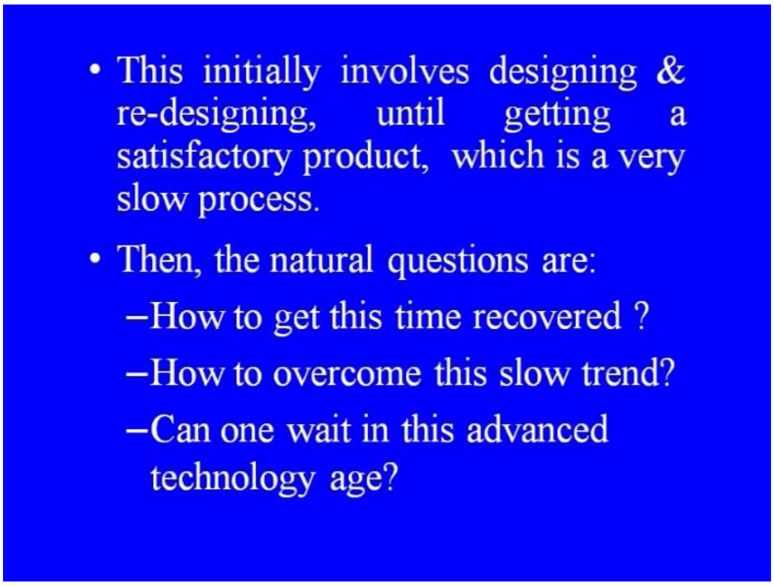

This initially involves designing and redesigning, until getting a satisfactory product which is a very slow process. Then, the natural questions are how to get this time recovered or how to overcome this slow trend? Can we wait in this advanced technology age?

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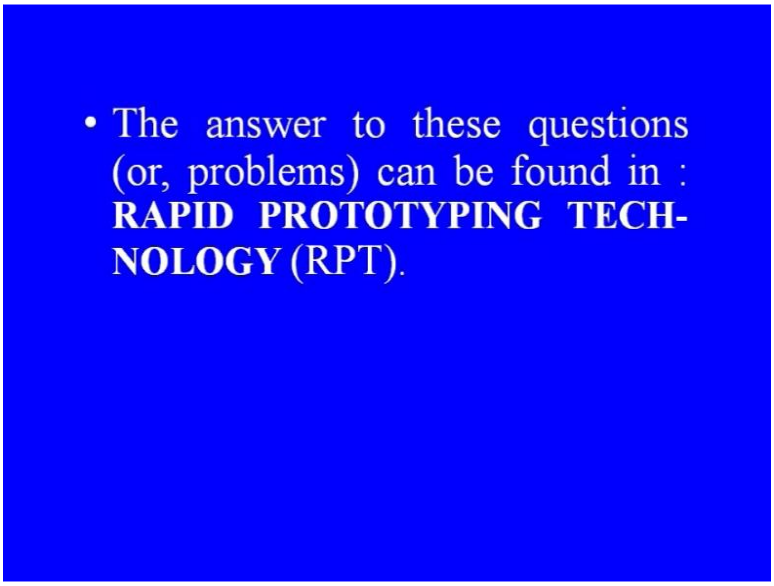

The answer to these questions or rather problems can be found in rapid prototyping technology, in short it is known as R P technology or RPT.

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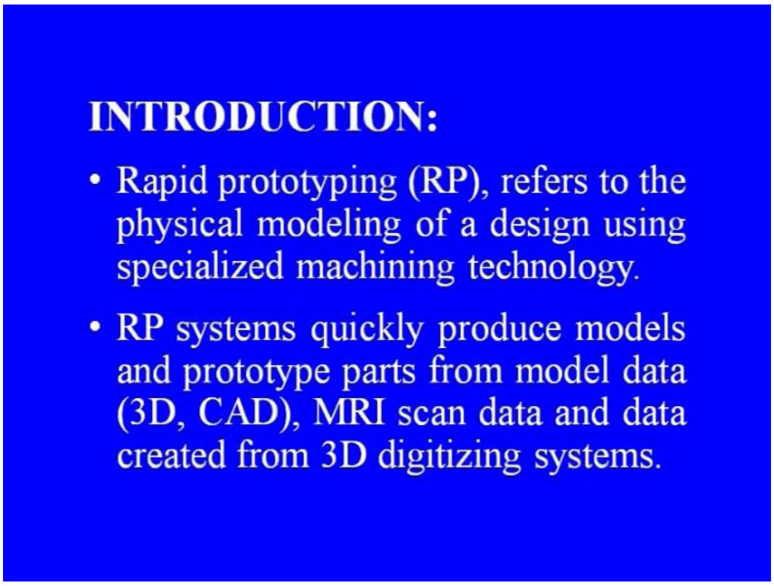

Rapid prototyping refers to physical modeling of a design using specialized machining technology. Rapid systems quickly produce models and prototype parts from model data may be 3 D model, CAD model, MRI scan data and data created from 3 D digitizing systems.

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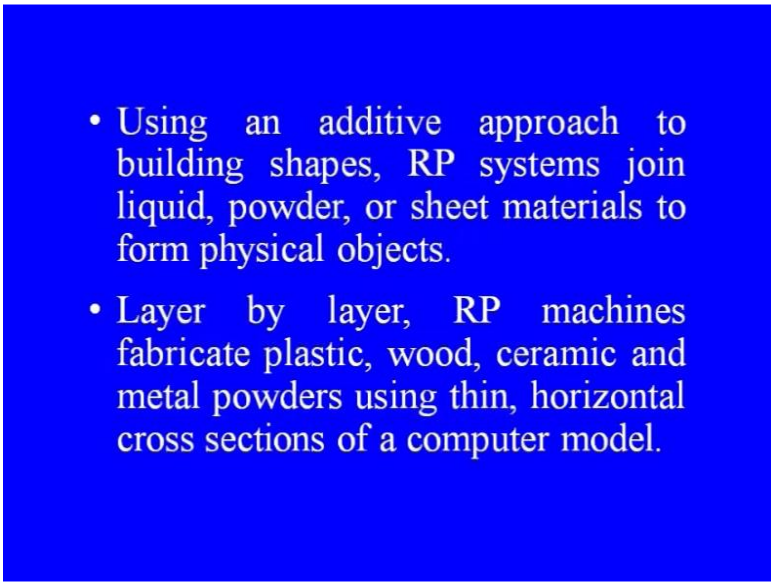

Using an additive approach to building shapes, RP systems join liquid, powder, liquid, powder or sheet materials to form physical objects. Layer by layer, RP machines fabricate plastic, wood, ceramic and metal powders using thin, horizontal cross sections of a computer model.

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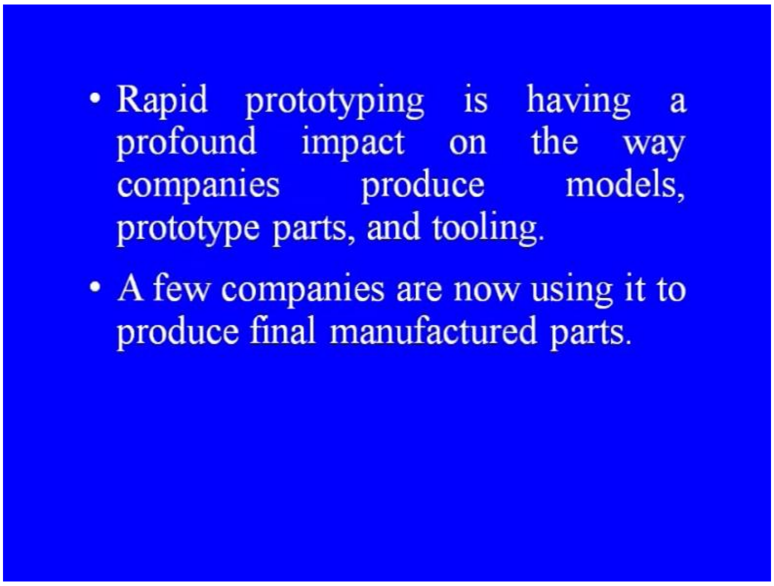

Rapid prototyping is having a profound impact on the way companies produce models, prototype parts and tooling. A few companies are now using it to produce final manufactured parts. Now, let us look at different steps in RP technology, rapid prototyping technology.

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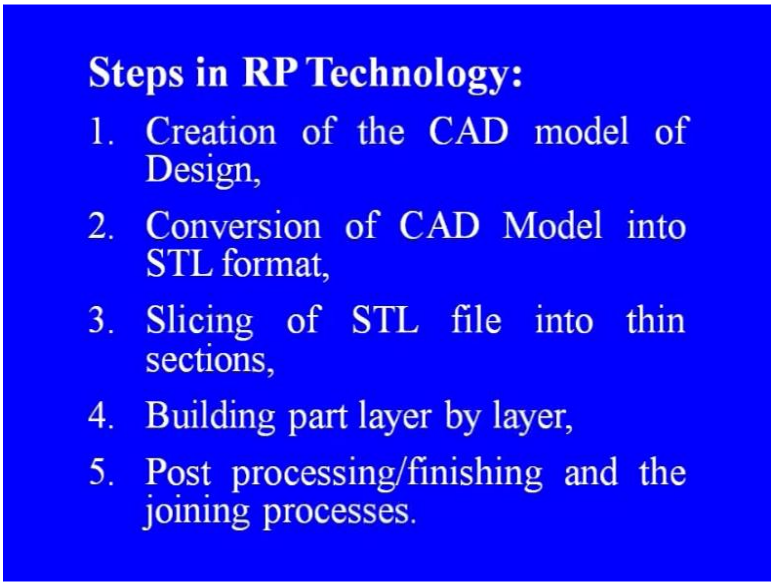

The first step being a CAD model is to be produced, for the design of the product to be produced a cad model is necessary. Then followed by this in the second step this CAD model is converted into STL format that is again the digital phase only. Then this model is sliced into thin sections say for example, if the product height is of 100 millimeter. This is to be sliced; this height is to be sliced into suitable thicknesses, which can be realized in one go of the machine.

That means we can have 100 slices of 1 millimeter thick or 1000 slices of 0.1 millimeter thick and so on. This will be depending on the capability of the machine or it may also depend on the accuracy required for the product. Of course, the time and economics is also involved, more number of slices means there will be higher time for production. Then followed by this step is next step is building the part layer by layer. These number of slices will have to be built one layer upon the another like this, so that say for example, if there are 1000 layers or 1000 slices in making one 100 millimeter product, then there, there will be ideally 1000 layers placed on top of another like this; and that will make up the final 100 millimeter tall or height product in the final shape.

Of course, if some finishing, surface finishing are to be done finally, with some secondary processing depending on the aesthetics requirements or depending on the functional requirements of the product then probably we have to adopt some more over design or some tolerances have to be given depending on the situation. Then the post processing or finishing of the designing process, next step. This is what I was referring to as to in order to achieve the required surface finish probably or exact product requirement this post processing is being carried out.

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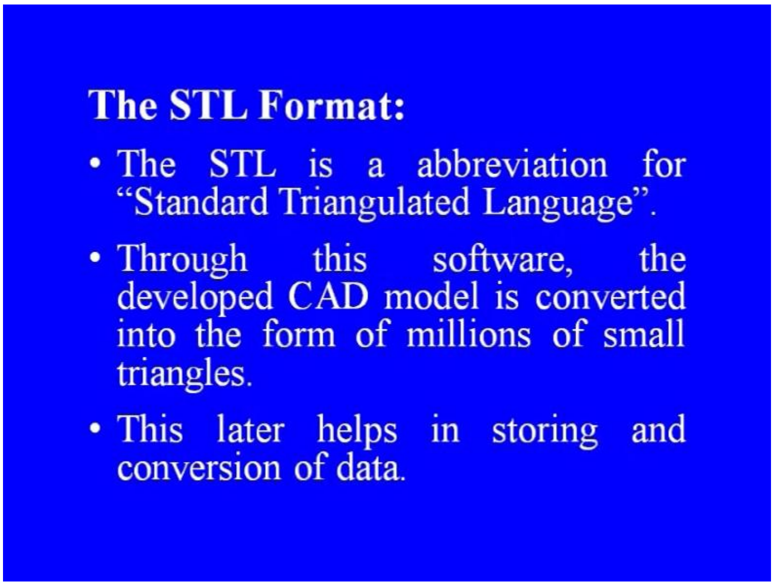

Now, let us see, what is a STL format? The STL is a abbreviation for standard triangulated language. Through this software the developed CAD, CAD model is converted into the form of millions of small triangles. This later helps in storing and conversion of data.

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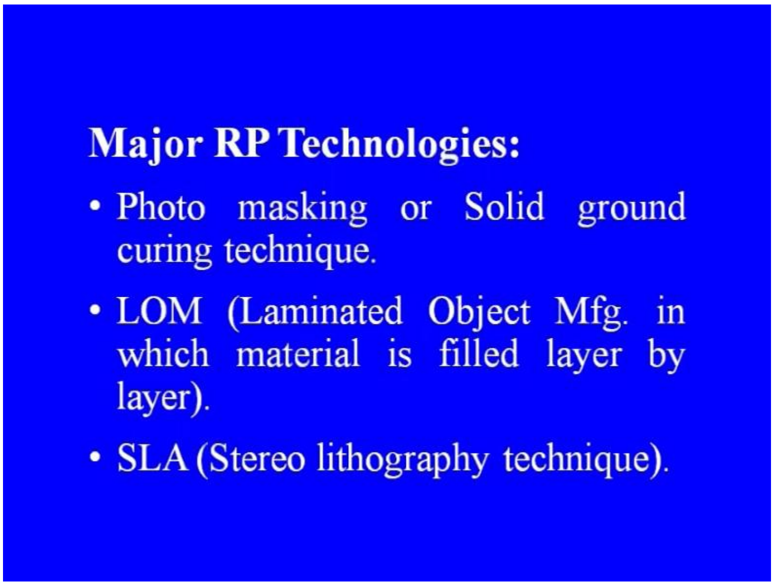

Now, let us look at the major RP technologies. Photo masking or solid ground curing technique is one of the techniques, then another very popular and widely used technique is LOM or laminated object manufacturing in which material is filled layer by layer. Another is SLA, stereo lithography technique.

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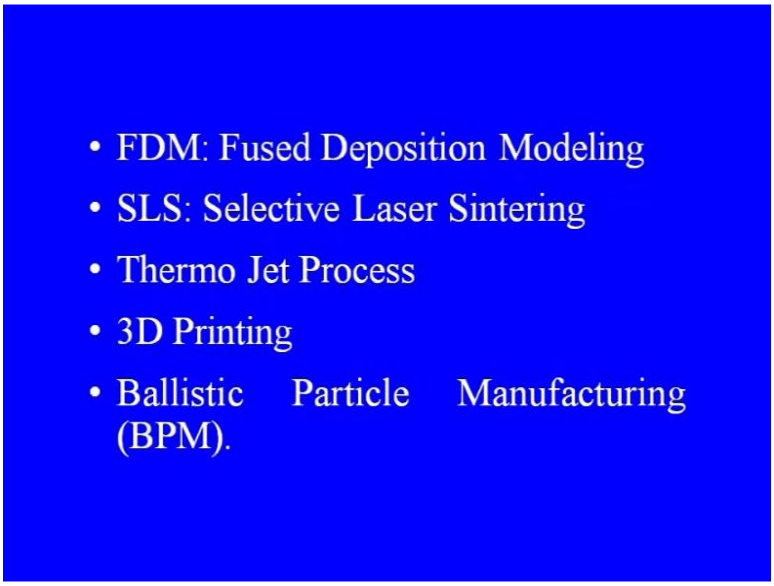

Others are FDM that is fused deposition modeling, SLS selective laser sintering, then thermo jet process, then 3D printing process which I have referred to at the very beginning of this session. Then another is ballistic particle manufacturing in short called BPM process. Now, let us look at briefly what is photo masking or solid ground curing technique is all about.

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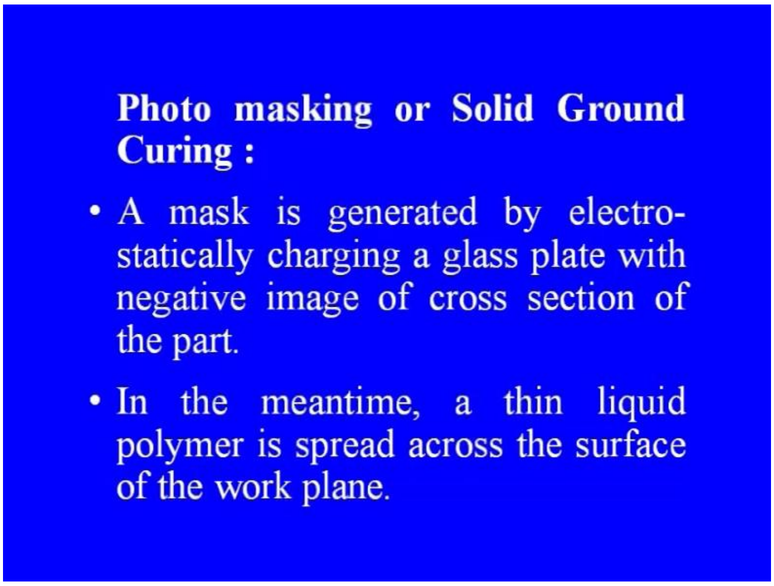

A mask is generated in this process by electro statically charging a glass plate with negative image of cross section of the part. In the meantime, a thin liquid polymer is spread across the surface of the work plane.

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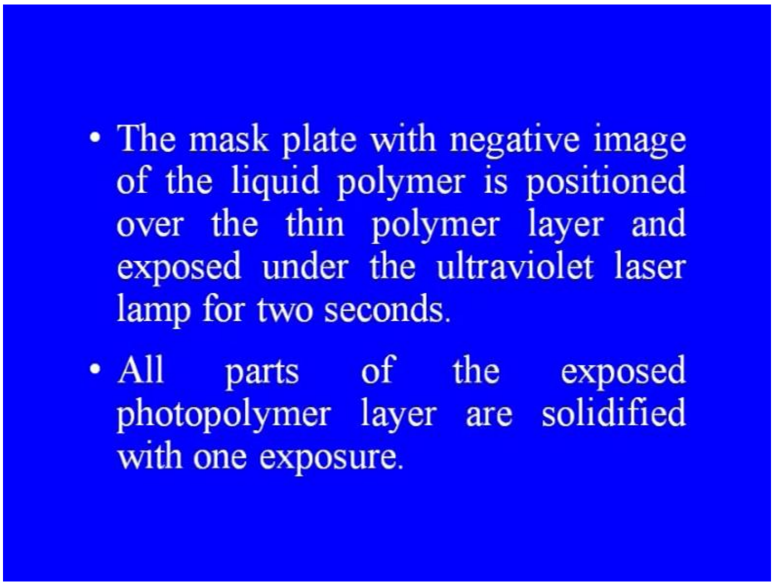

The mask plate with negative image of the liquid polymer is positioned over the thin polymer layer and exposed under the ultraviolet laser lamp for two seconds. All parts of the exposed photopolymer layer are then solidified with one exposure.

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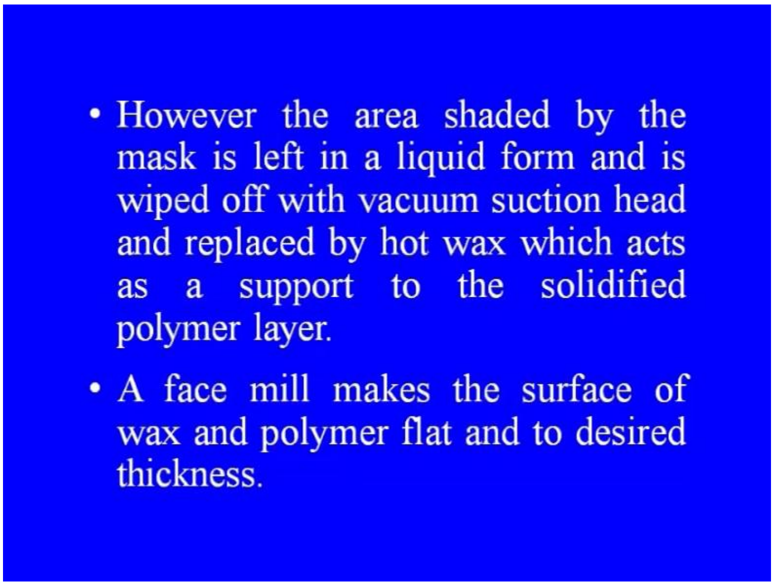

However, the area shaded by the mask is left in a liquid form and is wiped off with vacuum suction head and replaced by hot wax, which acts as a support to the solidified polymer layer. A face mill makes the surface of wax and polymer flat and to desired thickness.

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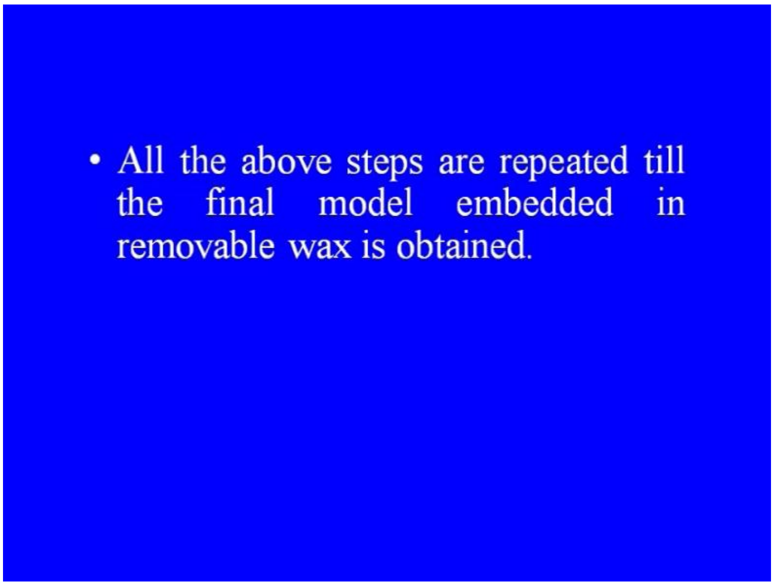

All the above steps are repeated till the final model embedded in removable wax is obtained.

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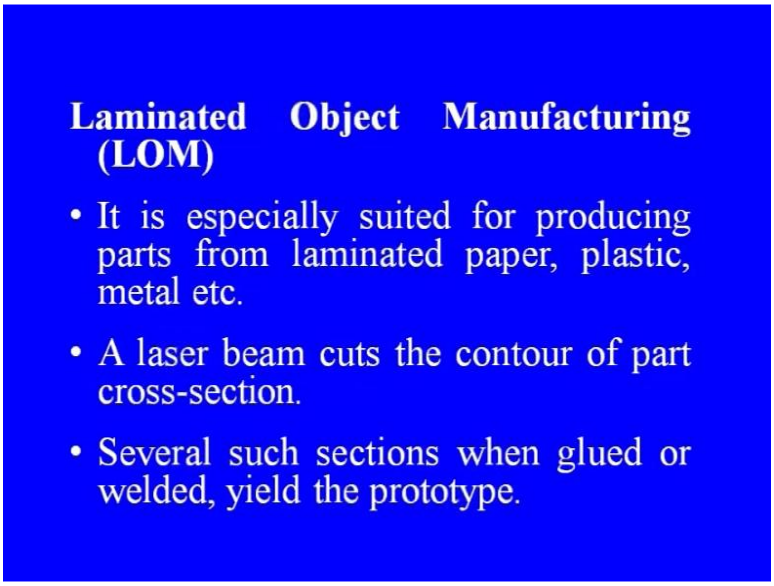

Next, let us discuss another very popular technique that is laminated object manufacturing or LOM technique. It is especially suited for producing parts from laminated paper, plastic, metals etcetera. A laser beam cuts the contour of part cross section. Several such sections when glued or welded, yield the prototype.

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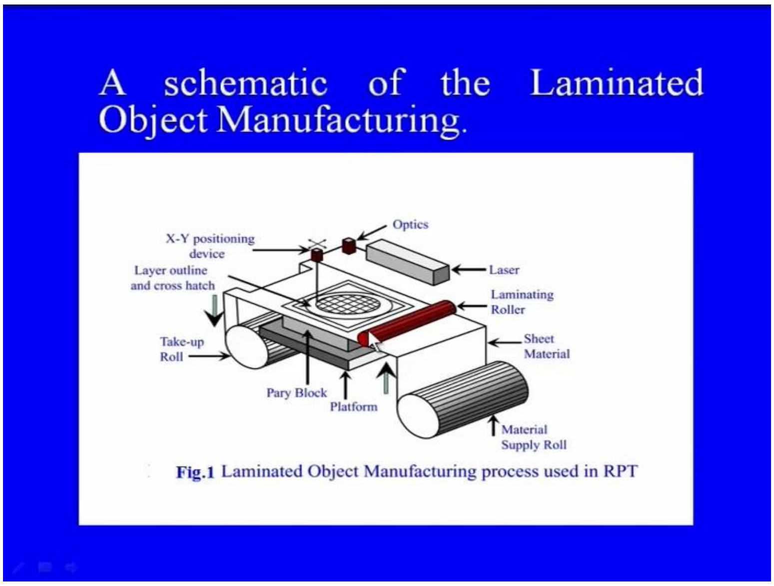

This is a schematic displayed on the screen of this laminated object manufacturing process. So, this is the material supply roll that is the sheet and this is coming through this which will be found here as a take up roll and this is the roller also called laminating roller which will be responsible for rolling the material over here. This will be, this is the laser source which is being directed through some computer control or the x y positioning device like this depending on the shape of the product.

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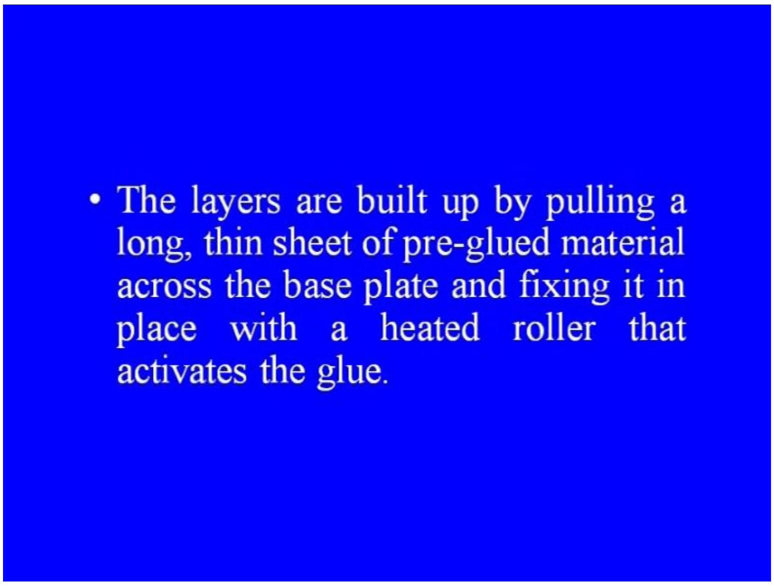

The layers are built up by pulling a long thin sheet of pre glued material across the base plate and fixing it in place with a heated roller that activates the glue. As we have already discussed in this figure, so this here already glues will be there and this roller is is a hot roller. So, as soon as this is being rolled over, so this hot roller will transfer some energy, heat energy to this and under this the glue will get activated and will get sticked to the product. And this platform will get lowered by a distance which is equivalent to the thickness of the plate or the object in this particular section.

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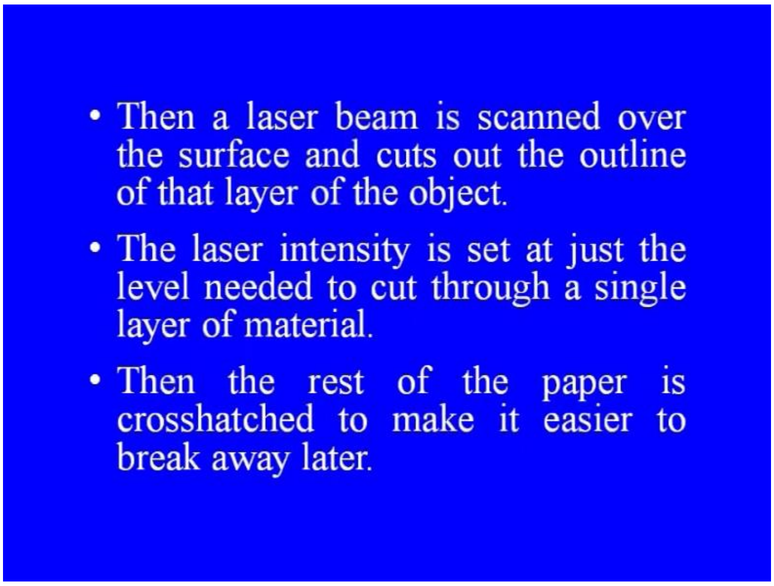

Then a laser beam is scanned over the surface and cuts out the outline of the layer of the object. The laser intensity is set at just the level needed to cut through a single layer of material. Then the rest of the paper is crosshatched to make it easier to break away later.

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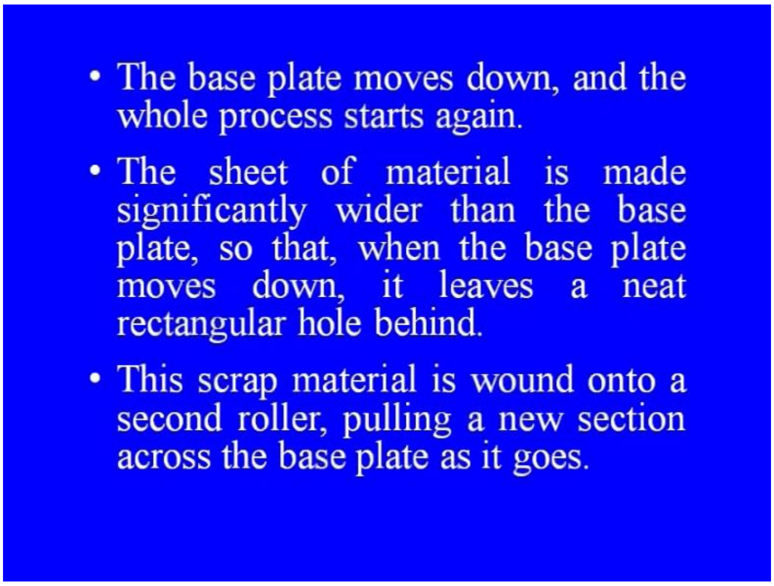

The base plate moves down and the whole process starts again. The sheet of material is made significantly wider than the base plate, so that when the base plate moves down, it leaves a neat rectangular hole behind. This scrap material is wound onto a second roller, pulling a new section across the base plate as it goes.

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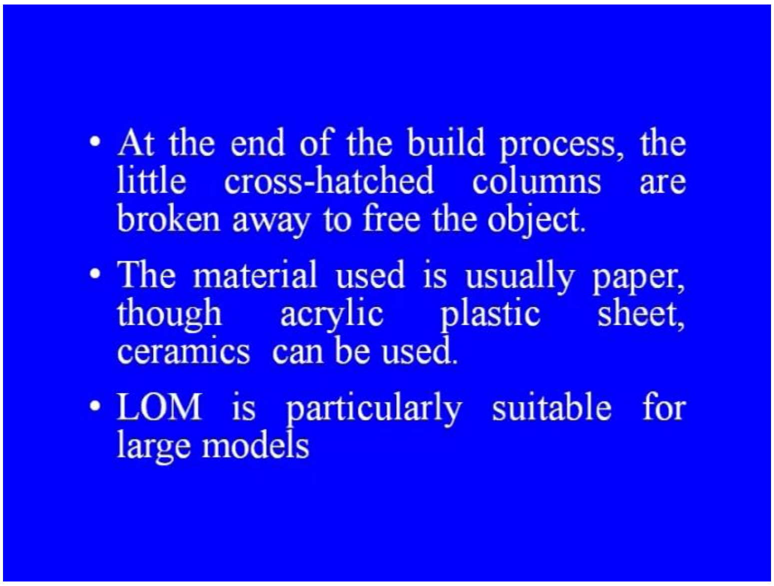

At the end of the build process, the little cross hatched columns are broken away to free the object. The material used is usually paper, though acrylic plastic sheet, ceramics can also be used. This laminated object manufacturing process is particularly suitable for large models. Next, let us discuss another important technique in this series, which is stereo lithography technique.

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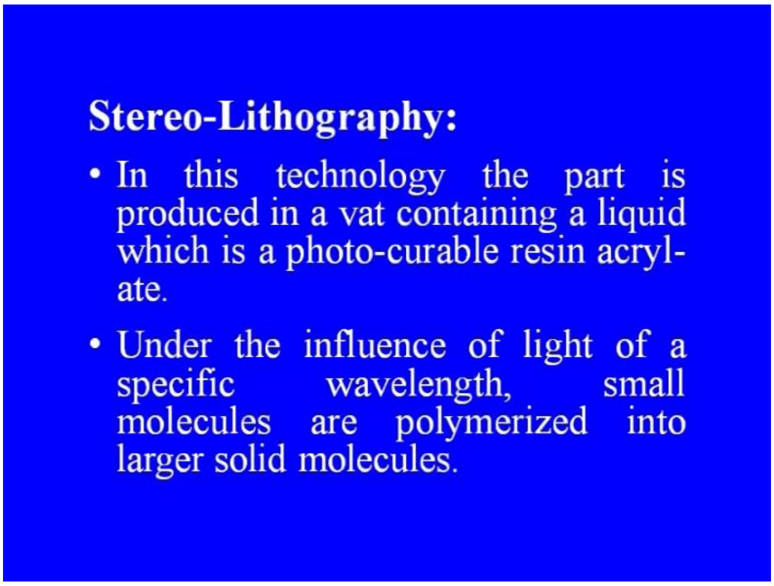

In this technology, the part is produced in a vat containing a liquid, which is a photo curable resin acrylate. Under the influence of light of a specific wavelength, small molecules in this liquid are polymerized into larger solid molecules. This is the basic principle involved in this process. Therefore, the selection of that particular wavelength of light is critical in this process.

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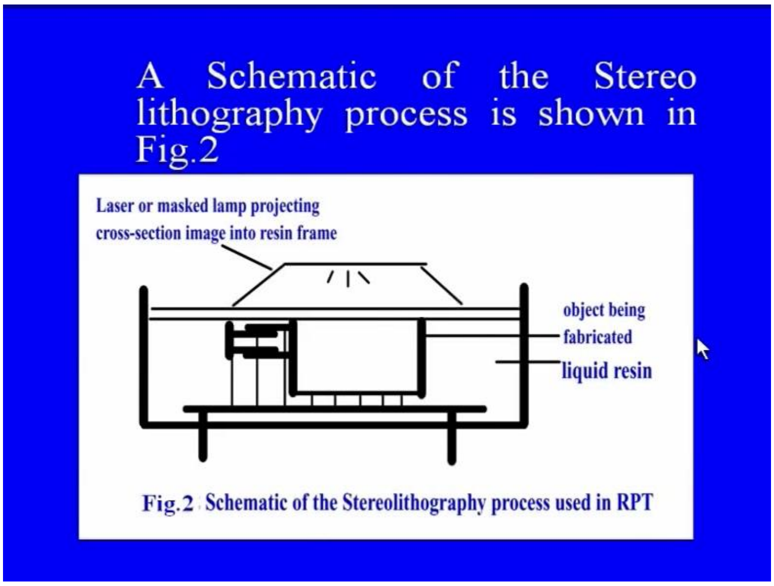

So, this is the schematic on the screen of the stereo lithography process. This is the light emitting device and this is the object being fabricated. This is how the light will fall on the area of interest and this is the liquid, liquid resin which will get solidified or form large molecules under the action of this light, particular frequency of light falling on to it, remaining portions will be masked.

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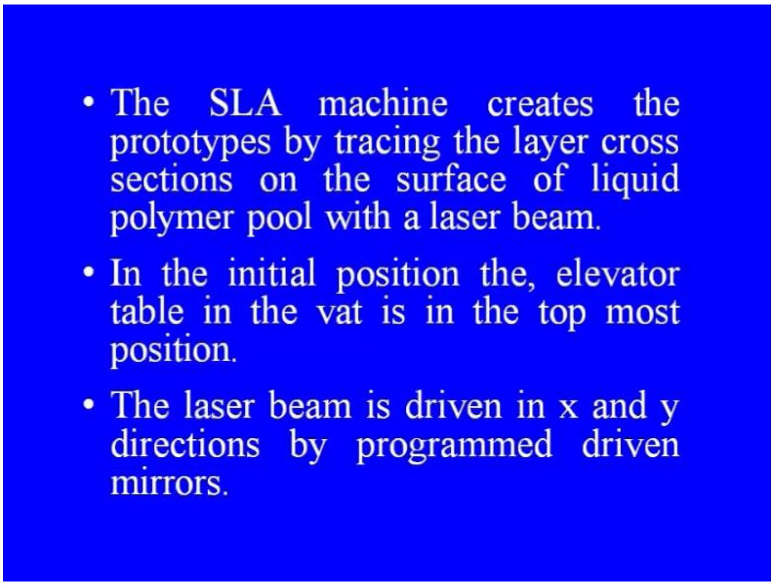

The SLA machine creates the prototypes by tracing the layer cross sections on the surface of the liquid polymer pool with a laser beam. In the initial position the elevator table in the vat is in the top most position. The laser beam is driven in x and y directions by programmed driven mirrors.

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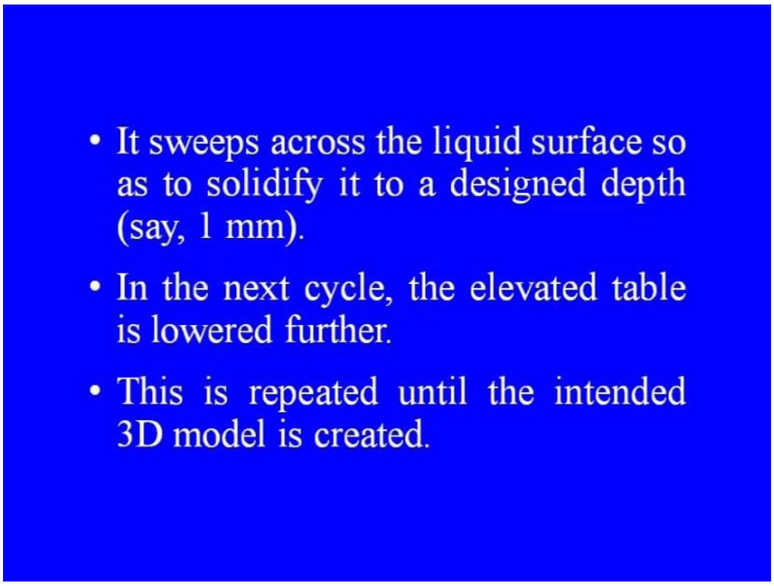

It sweeps across the liquid surface so as to solidify it to a designed depth say for example, 1 mm. In the next cycle, the elevated table is lowered further as in the case of LOM we have seen. The table is lowered subsequently or in its cycle by a thickness that is being built in the current iteration. This is repeated until the intended 3D model is created.

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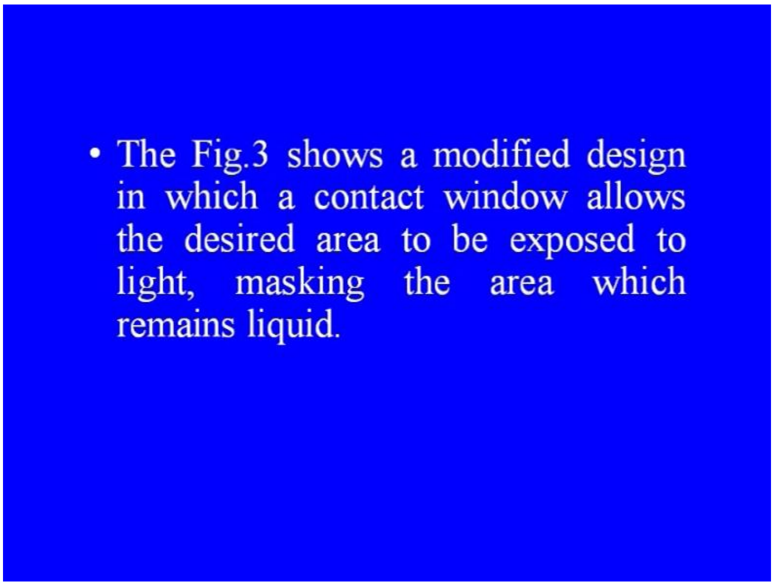

The figure shown in the next screen shows a modified design in which a contact window allows the desired area to be exposed to light, masking the area, which remains liquid. Next, let us discuss another important technique that is FDM, fused deposition modeling.

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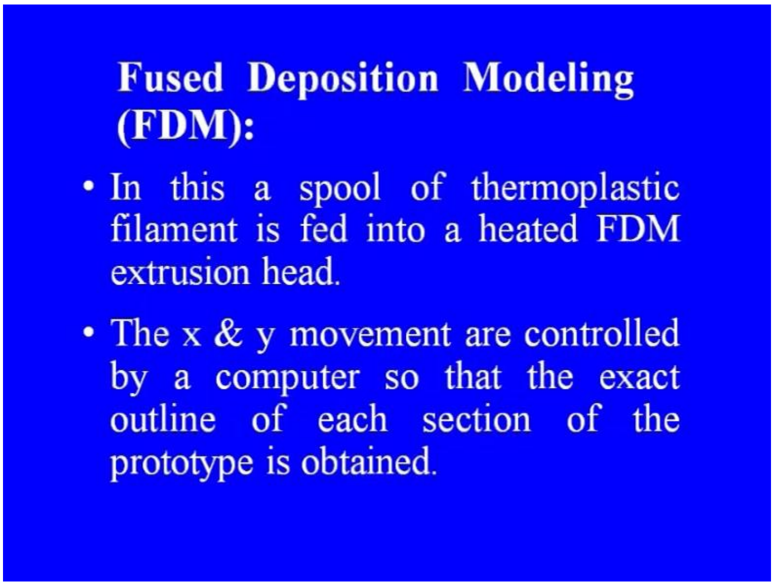

In this a spool of thermoplastic filament is fed into a heated FDM extrusion head. The x and y movement are controlled by a computer, so that the exact outline of each section of the prototype is obtained.

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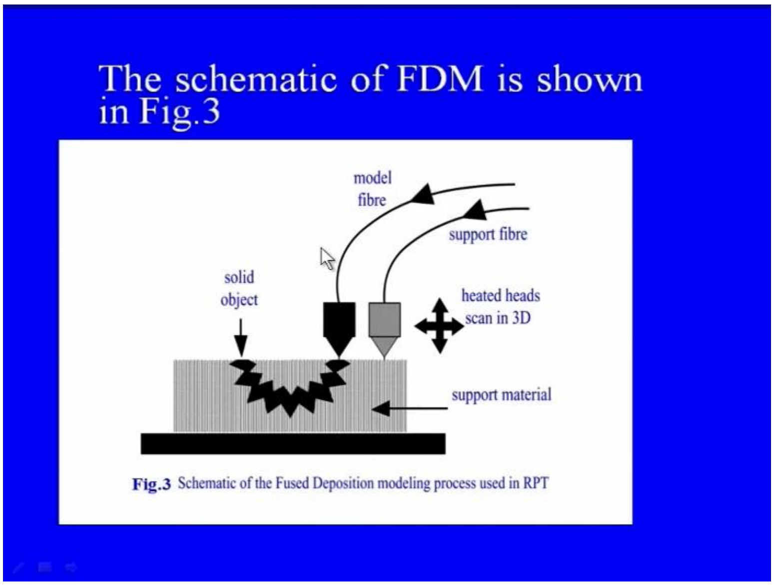

This is being showed in the screen. This is the support material and this is the solid object being produced. So, this is where the model fiber is coming and this is the support fiber that means it provides mechanical support to the model, so that distortion is prevented or minimized to be fair enough. And for scanning there will be a t d, 3 D control mechanisms will be there which will guide these heads in all three directions.

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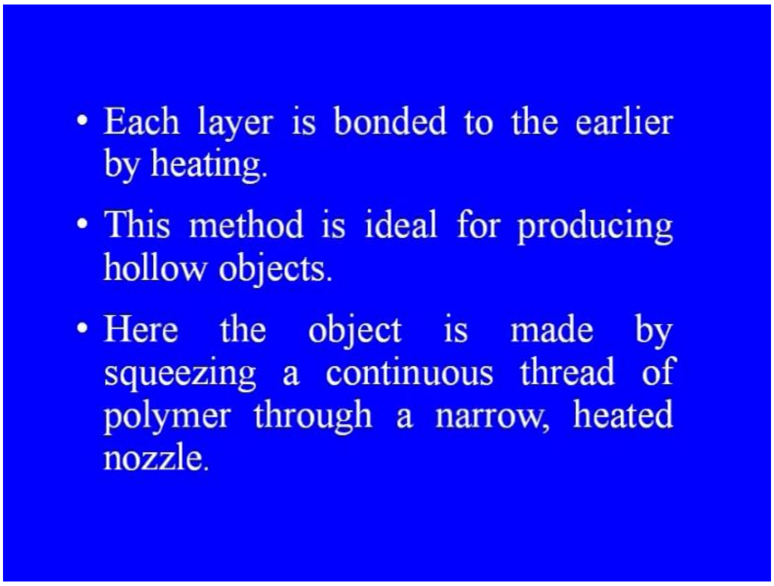

Each layer is bonded to the earlier by heating. This method is ideal for producing hollow objects in particular. Here the object is made by squeezing a continuous thread of polymer through a narrow heated nozzle.

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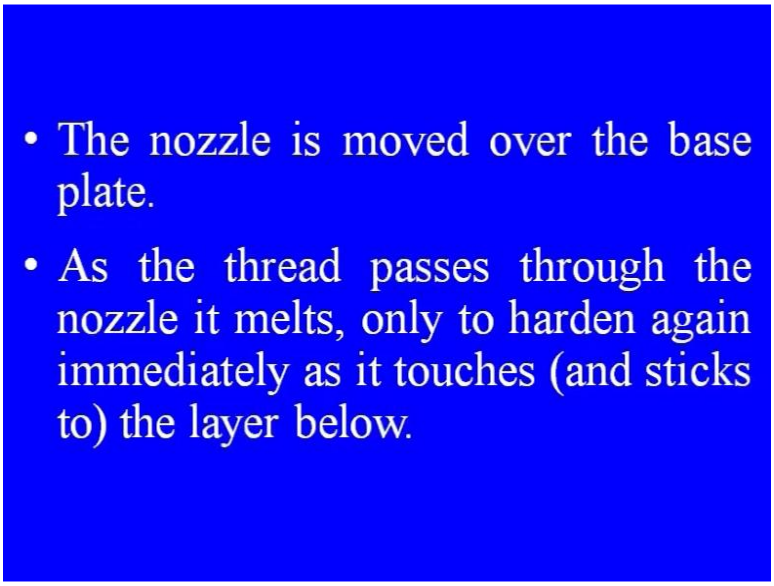

The nozzle is moved over the base plate. As the thread passes through the nozzle it melts, only to harden again immediately as it touches the layer below.

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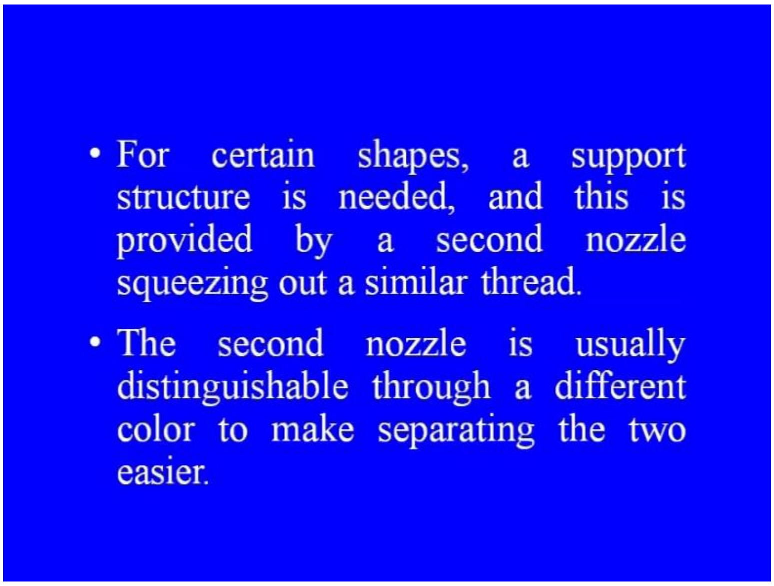

For certain shapes a support structure is needed and this is provided by a second nozzle squeezing out a similar thread. The second nozzle is usually distinguishable through a different color to make separating the two easier. This we have seen in the previous figure. So, here this is the support nozzle which has got a different color, so that we can easily distinguish which one is the actual model fiber and which one is the remaining the support material.

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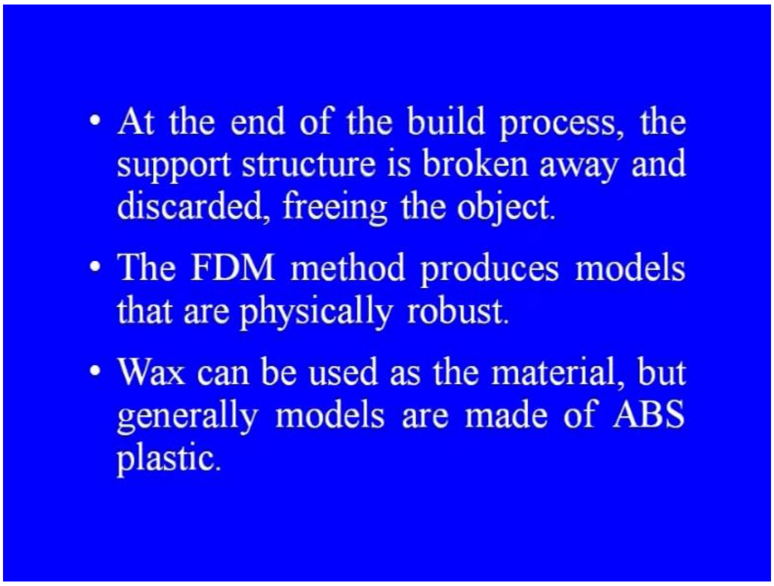

At the end of the build process, the support structure is broken away and discarded freeing the object. The FDM method produces models that are physically robust. Wax can be used as the material, but generally models are made of ABS plastic. Next, let us discuss about another popular process that is selective laser sintering process.

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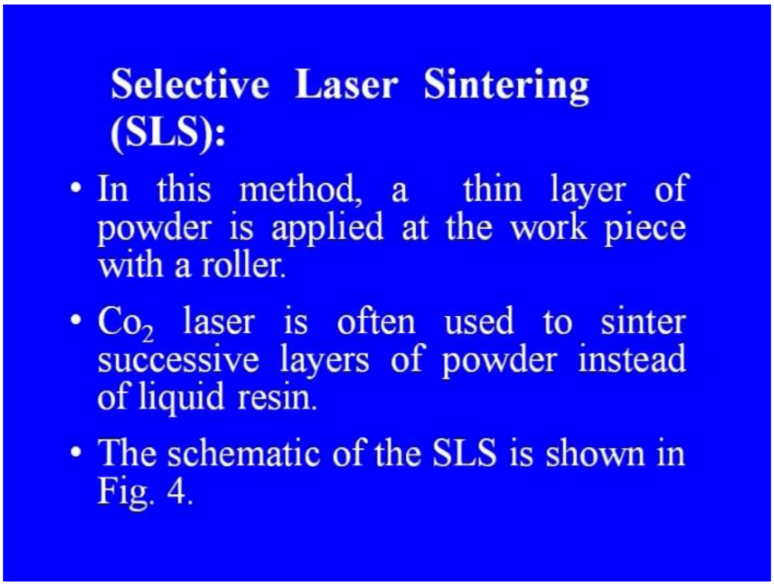

In this method, a thin layer of powders is applied at the work piece with a roller. Carbon di oxide laser is often used to sinter the successive layers of powder instead of liquid resin. The schematic is shown in this figure.

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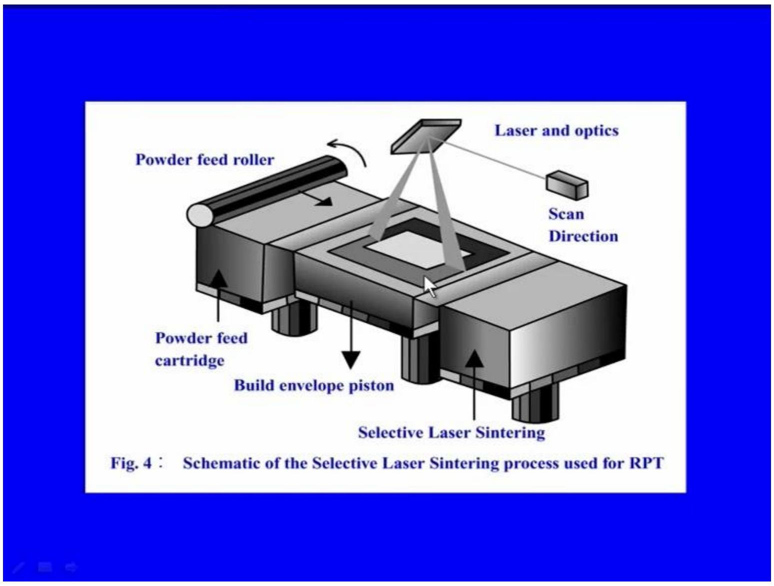

The figure is in the screen now. So, here so this is the powder layer, this is being uniformly placed by this roller. So, here the powder will be there and this roller will spread it over this area of interest and since it will be moving or rolling over this at an uniform pressure. Therefore, the thickness of the powder here will, will be uniform. Now, this powders, which are very loosely bonded, this powders may be very dry powders at different sizes and they may be very loosely bonded, they are usually loosely bonded that means free flowing powders.

And now they will be melted by using this laser. This laser power will be adjusted as per the requirement of the material, say for example, if the powder is of low melting point material. So, low energy laser is required, low intensity of laser that means power density should be low and this is scanned in that area of interest say, say for example, here it is shown a rectangular area. So, this can be scanned or projected, the laser can be made on, on to incident, made to incident on this area of interest as per the program.

Now, the area on which the laser is falling will get heated up, melted and the powder particles will get fused like this, that means it will form a layer by themselves. Then as this layer gets formed or melted and cured this table will be, will be lowered down by the amount that is equivalent to the thickness of this layer being deposited here or created in this iteration. Then the cycle will repeat, a fresh layer of powder will be spread over this area by using this roller, which will make a uniform layer of powder and then the laser will be applied again to fuse them on top of the previous layer.

Just remember we have formed a layer prior to this which is a solid layer now. Now, this fresh powder layer will get sticked or get fused on to that layer, on to the previous layer. And now, there will be a height build up on this that means the product will be built up in the third direction now and this will be at the end of this cycle, at this end of this particular iteration again this table will be lowered by exactly that equivalent to that thickness of that layer. So, that fresh powder layer can be spread over this for the process to continue.

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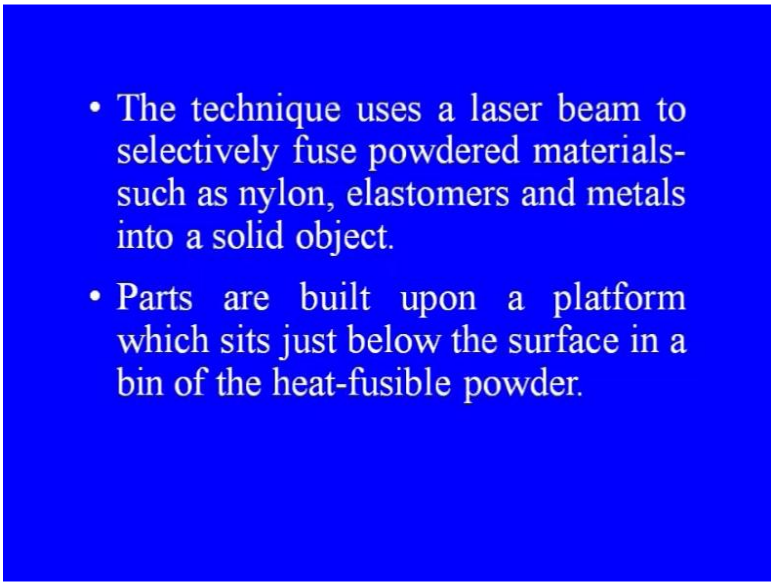

The technique uses a laser beam to selectively fuse the powdered materials such as nylon, elastomers and metals into a solid object. The parts are built upon a platform which sits just below the surface in a bin of the heat fusible powder. One thing to be, should be remembered here that as we have seen in this previous figure on the screen. So, this entire area of powder need not be fused by sintering or by incident by applying this laser to incident on this, say for example, here it is a kind of squared rings.

In this area only laser is allowed to fall and this area only will get deposited or melted and got bonded to the previous layer. And the powders in this area will be selectively remaining in the powder set only which in the next or subsequent stages will can be removed that means it will form a a hollow object in this case. However, in the next iteration probably or different geometry can be scanned and can be produced, that is that is why basically it is called selective laser sintering process, selectively we can melt the powder particles and formed the solid out of this.

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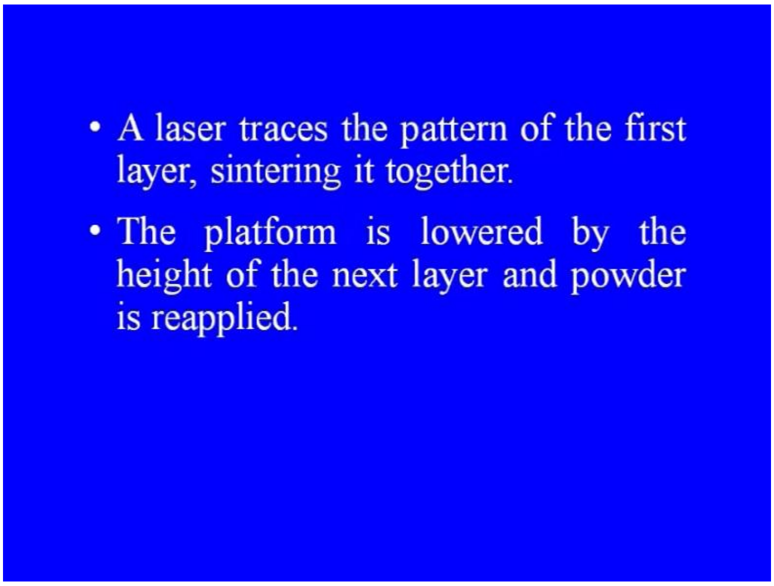

A laser traces the pattern of the first layer, sintering it together. The platform is lowered by the height of the next layer and the powder is reapplied as I have already indicated.

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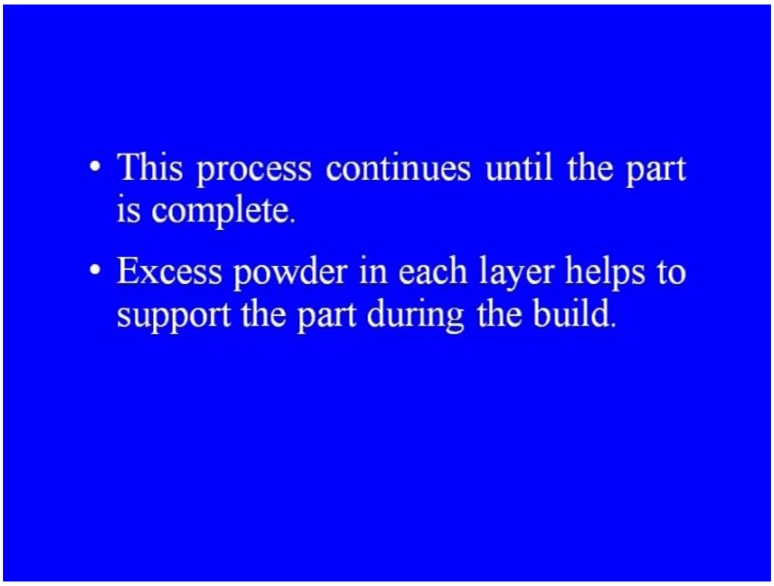

This process continues until the part is complete. Excess powder is in each layer helps to support the part during the build up phase. Then, another process that is three dimensional system. Let us discuss the steps involved in this process.

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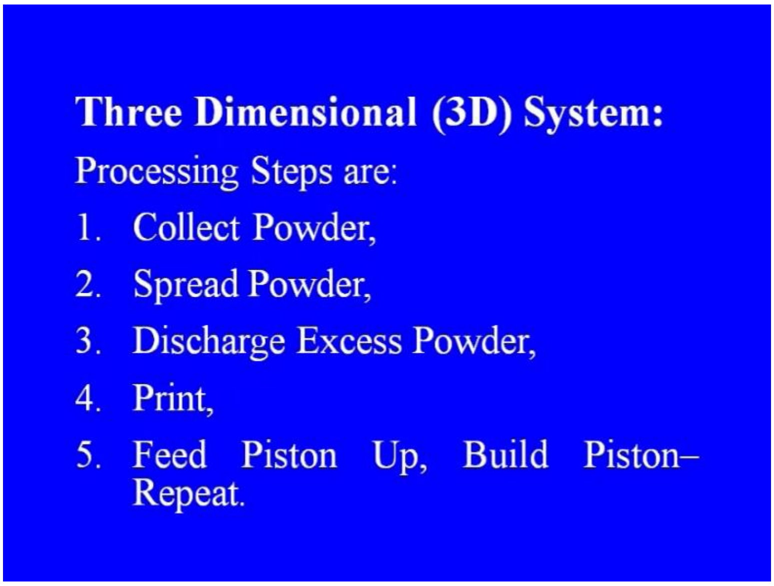

In this 3D process of rapid prototyping system the first step is to collect the powder, spread the powder in a desired shape, then discharge excess powder, then print and then feed piston up, build the piston and we have to repeat this step.

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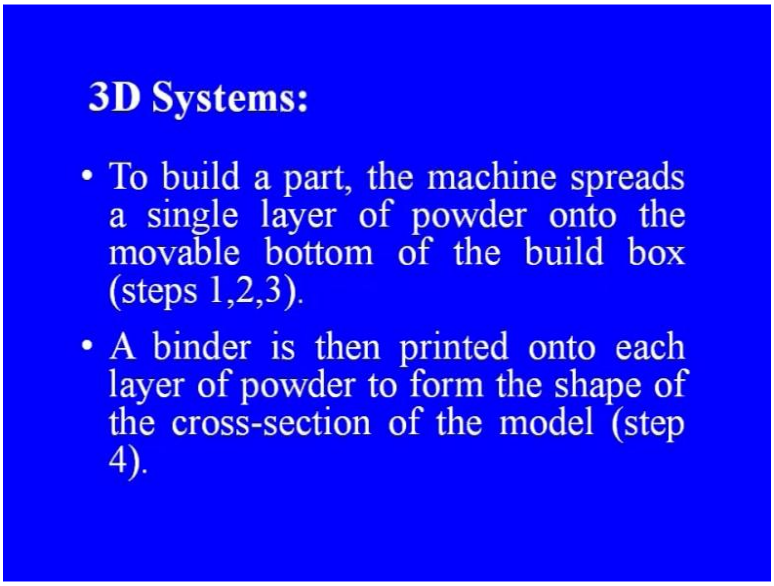

In this system to build a part the machine spreads a single layer of powder onto the movable bottom of the build box. Then, a binder is printed onto each layer of powder to form the shape of the cross section of the model.

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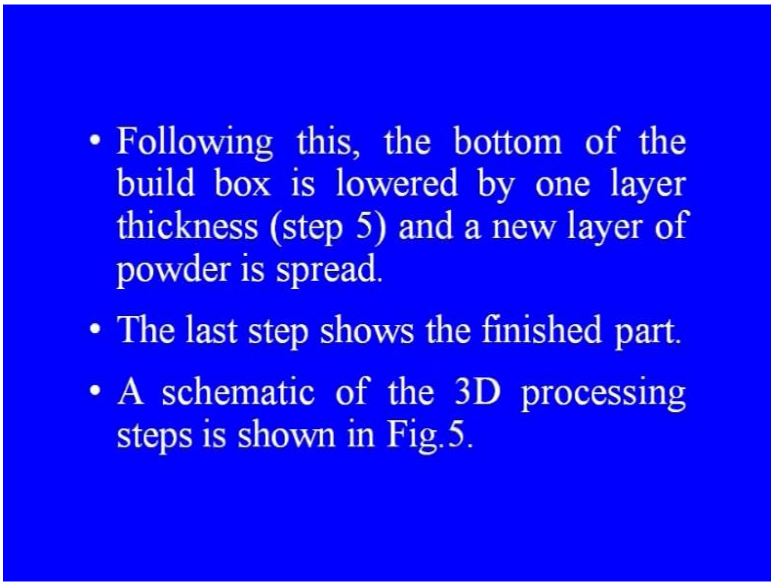

Following this the bottom of the build box is lowered by one layer thickness and a new layer of powder is spread. The last step shows the finished part. A schematic of this is shown in the figure. So, this is the figure in the screen.

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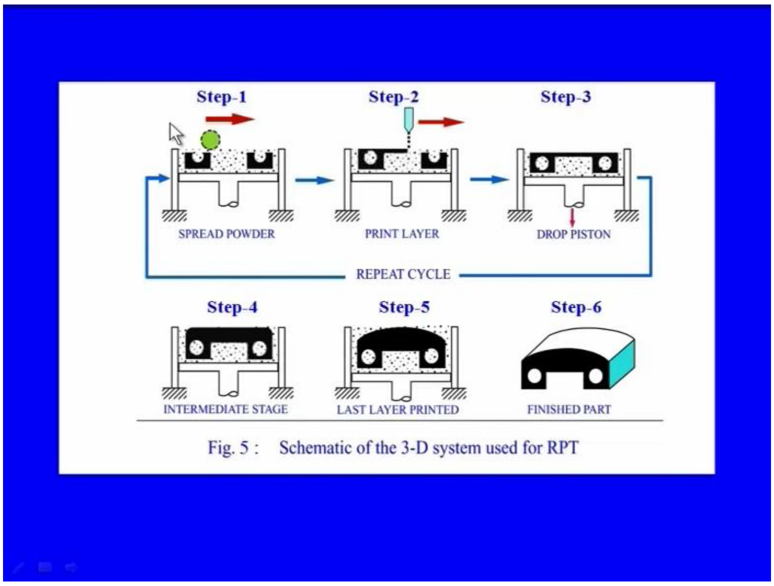

So, this where the powder is being spread and then this is liquid is being placed and then this is the drop piston, piston will be lowered here and so that it facilitates the new layer to be deposited. So, these are the main steps where powder will be spread, here the liquid will be added, that is also called the print layer or formation of the print layer, then dropping the piston by the thickness, so that a new layer can be added on to it. We can, you can notice a small height difference here, which will facilitate the addition of powder in the subsequent steps.

This this is how the object will be built successively like the thickness here will be increased or the shape will be built, successively this will be lowered and the powder will be placed, ink will be, ink or the material will be placed over it according to the shape of the material. This is nothing but the 3 D printing system, which I was talking about at the beginning of the process.

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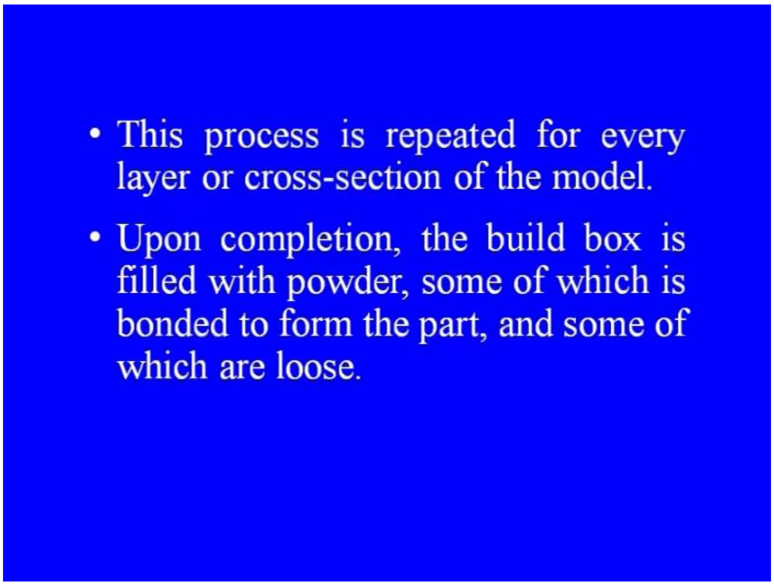

This process is repeated for every layer or cross section of the model. Then upon completion the build box is filled with powder, some of which is bonded to form the part and some of which are loose.

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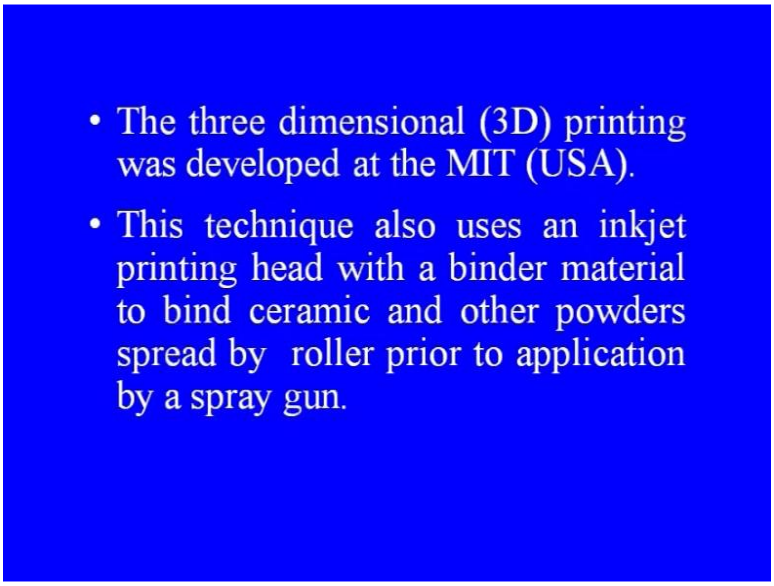

The three dimensional printing was developed in the Massachusetts Institute of Technology, USA. This technique, technique also uses an inkjet printing head with a binder material to bind ceramic and other powders spread by roller prior to application by a spray gun.

Now, let us summarize what we have discussed in this session. In this section, we have discussed about the principles of rapid prototyping technology, the back ground that led to the development of this rapid prototyping technologies, then some major rapid prototyping processes, their features, the principles, how they are being built and few applications. We hope this session was informative and interesting.

Thank you.