Design Practice - 2
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Lecture - 31
Different Types of Rapid Prototyping Technologies

Hello and welcome to this design practice to module 31 I would like to talk today a little more into the rapid prototyping concept. We already saw that you classify the processes into different categories based on what is the starting material so you could either have a good base rapid prototyping or a solid based prototyping and then finally a powder based prototyping.

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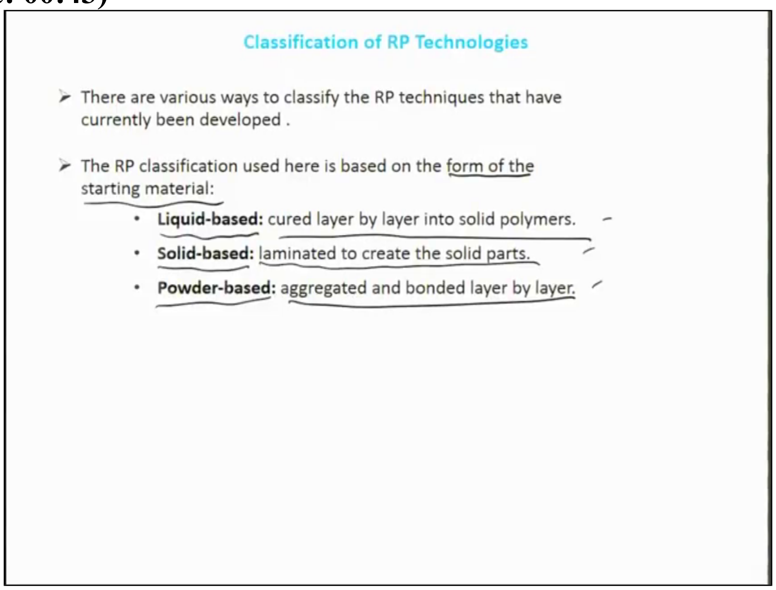

So, we will go ahead and start you know looking at each of these processes and how they are.

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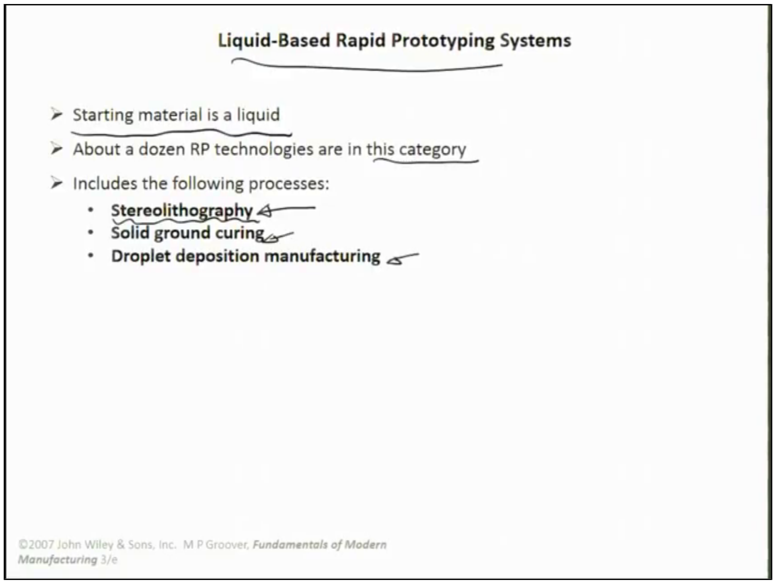

So, let us talk about when the starting material is liquid okay. So, this is the liquid based rapid prototyping process. So, there exists about a dozen RP technologies in this particular category but I am going to actually talk about the few which are most widely used. So, if we looked at the different aspects of you know this technology so the one of the most widely used processes or tools is the stereo lithography.

Then of course you have solid ground hearing and droplet deposition manufacturing but mostly in the industry also the accuracy and the precision of micro electronics particularly necessitates the use of something like stereo lithography which is based on a liquid resist a photoresist.

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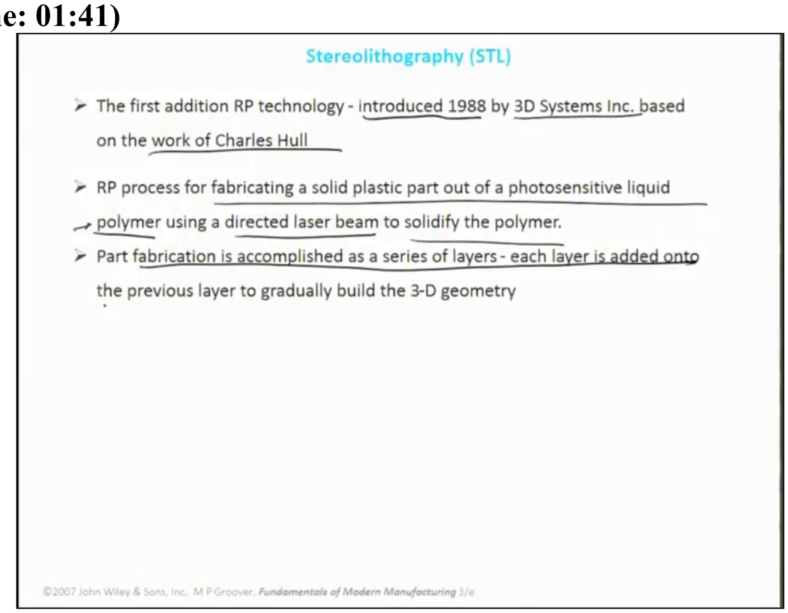

So, let us first actually go a little into the history of the STL process. It was introduced way back in 1988 by company called 3D systems incorporated and this was based on the work of Charles

Hull on this process for fabricating a solid plastic part out of photosensitive and liquid polymer called photoresist otherwise used a direct laser beam to solidify the polymer and this solidification step would then take place layer by layer.

Based on different depth of focus of the particular laser head and also the movement of the stage in a manner so that every time the stage would move in fresh liquid resist would come into the gap between the solid part formulated by curing in the previous step and the particular glass-bottom okay the the rising glass bottom. So, basically every time this action would happen every time there would be a curing step and then layer by layer you could synthesize pretty much all complex 3d geometry.

So, you can think of it that the fabrication is accomplished it is a series of layers each layer is added on to the previous layer to gradually build the 3D geometry.

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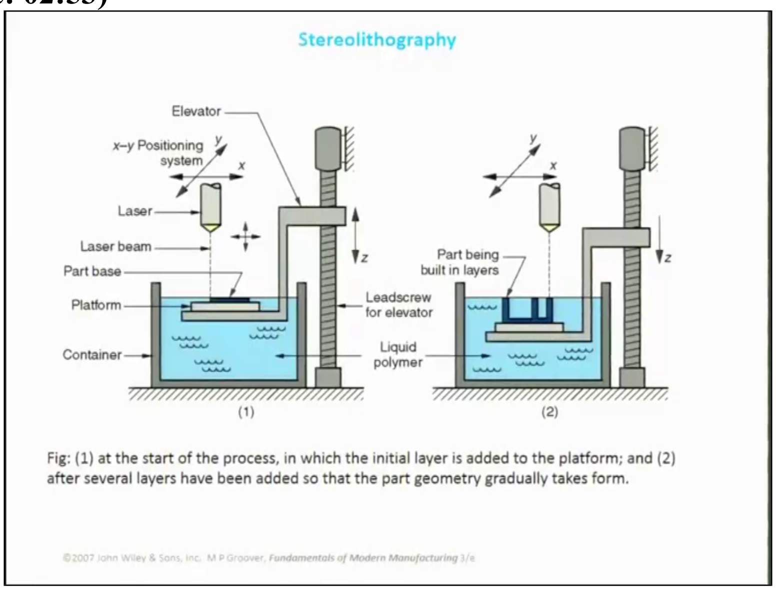

And this is how the process looks like you can think of easy stage this is the glass bottom actually or you can say there is a platform and you know what we are essentially doing is to use a variable depth and depth of focus laser beam to guide into this resist here which is actually a liquid polymer and using a platform to have with the fine resolution to create okay layer by layer either top-down or bottom-up okay off a complex geometry.

So, in this particular case if I wanted to section eyes the geometry that is being made here there would be various sections possible okay. So, I can split this whole geometry into different layers and you can think of it that in that this particular region you know there is a solid part here and there is a liquid part here that means this process this particular region here is not developed okay or not cured.

So, the curing action would only happen here and the laser would be switched off while scans in this portion again switching off on in this particular area of in this again area and also whenever the laser is switched off there is actually liquid resist left over and when it is switched on there is solid resist left over and layer by layer this way you can fabricate the parts. So, at the start of the process in which the initial layer is added to the platform this is how the continuous laser light would operate.

And then after several layers have been added the part general geometry generally get you know graduates into a certain form and shape which is represented in this particular figure here. So, every time a solid part is formulated let us say the platform goes down what happens is it is covered with fresh resists and the fresh resist can again be cured either in selected regions or in totality so that you can have a complex shape being realized.

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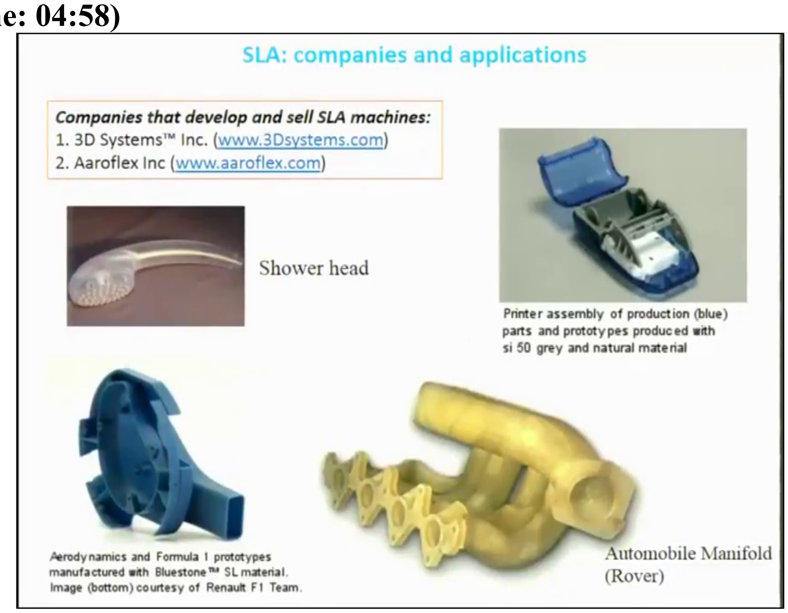

So, if I looked at you know the the aspect of what was this resist and how it would behave there are many details which I have covered in my past lectures particularly when we were talking about MEMS based sensors etc where we detailed about how you know there can be classification into positive resist and negative resist. And what is the chemical principle behind you know a weak acid liberating protons.

So, that it participates and cross bonds creates a 3 dimensional network of bonds and then you know you could remove the areas which are not bonded so well and which results in a solid structure. So, we looked at both the aspects that is the positive tone aspect and the negative term respect of the resist in great details earlier. The other you know; so there are there are different companies which have been involved in developing these complex shapes using the stereo lithography process.

Some of the examples here are this again the showerhead printer assembly for production of parts and prototypes you can also look at this Formula One prototypes you know aerodynamic and Formula One prototypes all the automotive manifold okay. They are all being developed using steel with lithography systems.

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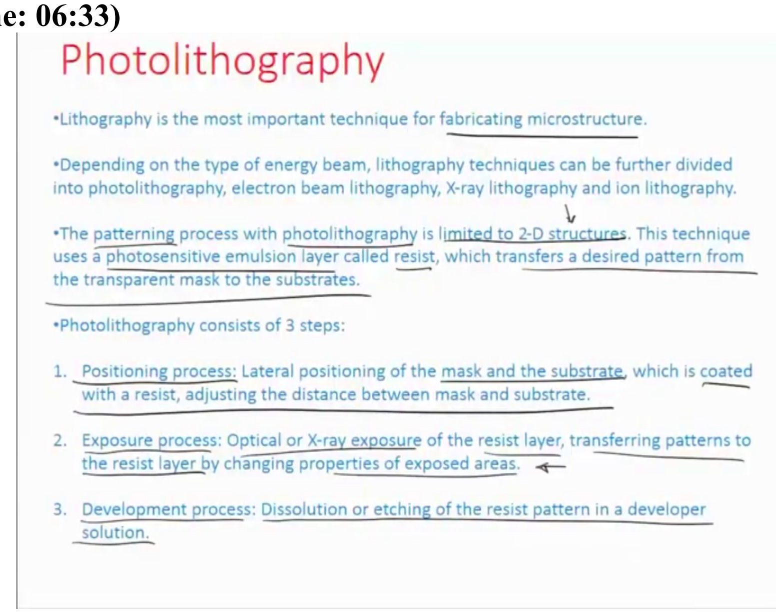

And just as a recap I would like to just take you through the very basic essentials of lithography we have talked about fabricating of microstructure where you know the the issue was that of patterning using this technique photolithography we said that it is limited to 2d structure. But let us see in the next step for example or even if you saw in the earlier step how 2D can be extended to the 3D that technique uses the photosensitive emulsion layer called resist which transfers a desired pattern from the transparent mask to the substrates.

As you probably recall photolithography consists of the positioning process where there is a lateral positioning aspect of the mask with respect to a substrate, substrate being coated with resist and you know it is followed by adjusting the distance between the mask and the substrate so that there is no gap in contact with lithography particularly between the mask and the substrate then you do the exposure the photo exposure where you use optical or extra exposure of the resist layers.

Transferring patterns to the resist layer by changing the properties of the exposed area in this context you had already seen how a negative tone resist behaves. The final process is the development step where wherever there is cross bonding the remaining regions have to be removed or dissolute it away so you have dissolution or etching of the resist pattern developed solution.

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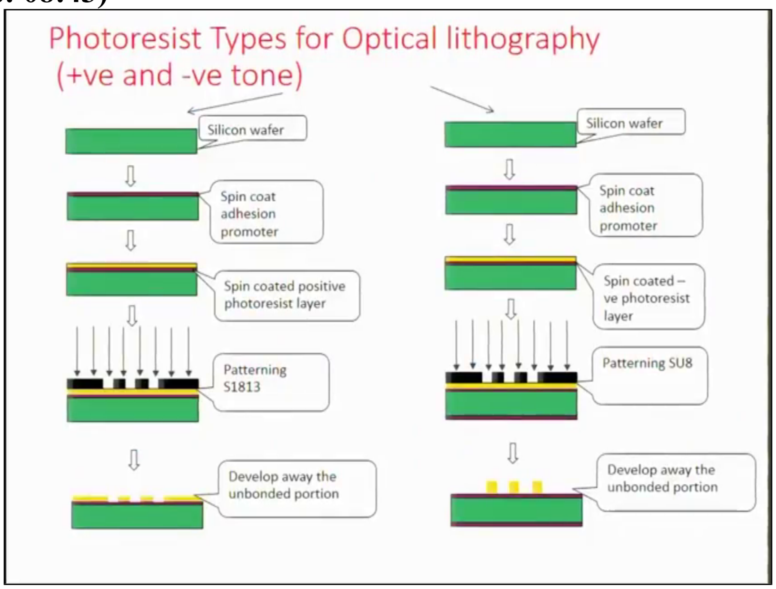

So, these are the three steps of lithography which are being carried out here you can see there is a positive and negative tone resist. This right here is how a negative tone a positive tone resist would work which would create vias wherever exposure has taken place in this case exposure is in across these domains the white areas of the mask and in the negative tone resists wherever there is exposure this cross bonding.

So, this is exactly the state back region in the particular lithography module. So, let us look at some more applications you already saw one application in stereo lithography. Let us talk about solid ground curing.

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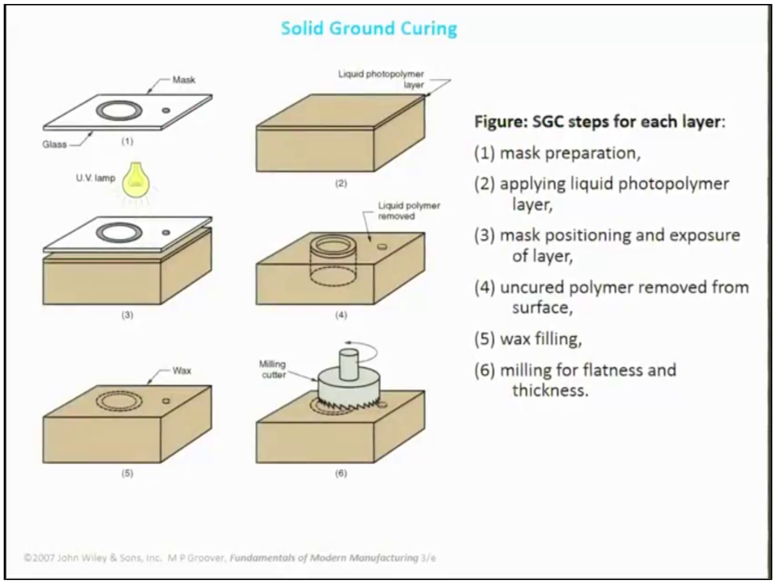

So, this is another very important process associated with building of 3D parts 3D features and layer by layer manner. And how do we do it we design a mask in this particular mask you can see again the black and white regions and the white regions correspond to light getting through and black basically is one way light is obstructed or blocked. The first thing we do is to spread a liquid for the polymer layer and the top a substrate surface.

Align a mask on the top of the surface and lamp you know use a UV lamp to expose the exposure makes light pass through the mask in the stages which are marked right here. And the light does not pass through the black stages here or black portions here. So, wherever there is black portion the light gets obstructed okay and in this particular case if we use a positive resist you can think of the positive you know for the polymer to be de-bonded a slice light falls over it.

So, you have wherever the light is falling down the photopolymer would be dissolvable so it can be dissolved away. And wherever the light is not falling there is going to be a resultant structure or a feature a 3D feature in place. Now when we remove liquid you know remove the liquid polymer which is not cross bonded so remember in steel lithography we were trying to get the liquid polymer again and again.

In this case we are going to liquid remove the liquid polymer which is not cross bonded or which is exposed in this particular case de-bonded so that liquid goes away the moment that happens we cover this with a wax layer okay. So, you can say that this is also sort of equivalent to the lost wax method which talks about particularly in investment casting where you know you know that you create a feature or a shape in wax and then later on that acts as a core and you can have you know metal flow over it and you can retain the wax out so, that there is a cavity which exists okay.

So, in the same manner in this particular case we can we can couple this as a you know process between the lithography and the lost wax method. So, when you coding this 3D feature which has been formulated on the top of the surface here with wax, the wax kind of embeds look at how this feature getting is getting embedded the lines here are dotted shows that it is a hidden layer okay.

And the wax formulates a layer on the top we can actually have a micro milling cutter which removes the wax to a sufficient extent. So, that it just starts exposing the small solid layer okay maybe machining a few mills of the surface which probably let us the second let us the system ready for second step of exposure. We then repeat this process again. So, we coat the liquid polymer again we do a photo masking again.

Now this time there has to be an alignment between what was outlet in the first step that resist and the second outlet so you should have alignment marks on the mass so that it comes and sits on the top of the you know the backs layer and then again you know the thickness of the liquid polymer layer would again get cured in places where it is not exposed again remove the remaining region which has been exposed through the through mostly aerodynamic wiper.

In this case you know the liquid polymer is such that whenever it is not cross bonded to the substrate or to itself then it is flowable enough and the viscosity is low enough for the liquid to deride of the surface. So, you deriding liquid of the surface again thus keeping a small solid portion on the top okay. Again do the wax coating again do the micro milling and in this manner you build this particular cylinder hollows hollow cylinder layer by layer.

So, I hope you understand what I mean by solid ground curing so in this case you know we finally obtain a shape which is a cylinder with wax in and out of the cylinder. So, X is present in this region and this region you could actually melt the wax out and retain the polymer okay. So, that is how so wax gets melted at a reasonable temperature which may not be the softening temperature of the polymer.

So, you can choose the polymer in that manner and so with the lost wax process the hollow cylinder gets retained okay. So, this is how you do the solid ground curing it is another form where liquid pre polymer of photo you know photoresist nature is applied for building of parts okay. So, you saw in step one how a liquid polymer would do serial lithography with a laser beam and a lot more complex optics getting into place with different depths of focus.

So, that you can have a layer by layer build up in second step you saw how you know with the tedious way of just exposing through mask and with probably less expensive optics you could actually build up a layer by layer structure. Thus you know taking off or getting off the wax and retaining the structure.

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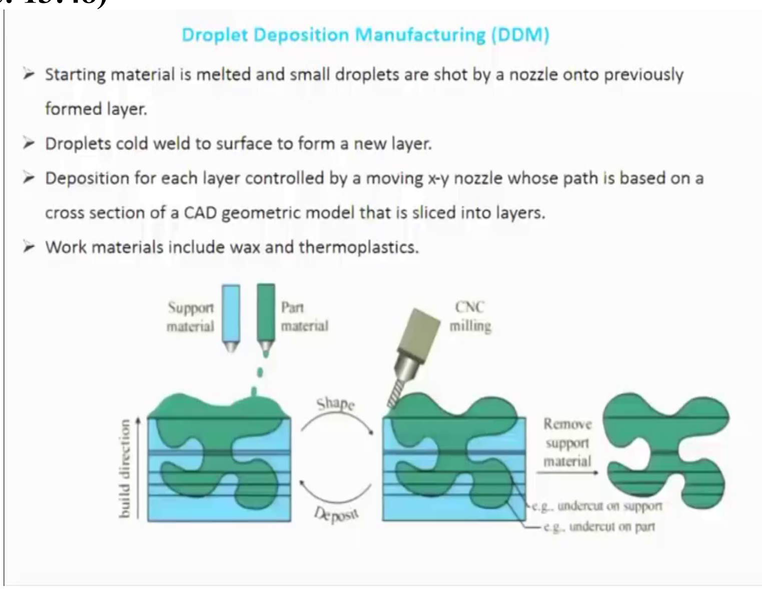

In the third phase we will talk about another very interesting droplet deposition manufacturing which is actually based on again liquid formulation here as you see the starting material is melted okay and the small droplets which are shot by a nozzle onto a previously formed layer. For example in this particular case let us say this is a complex shape being built along a direction which is in this direction the build direction.

So, what you are essentially doing is you are having the nozzles typically loaded with two different materials which are molten okay one is actually the material which would formulate the part the other is a support material which would come off okay support material could typically be a wax layer again which could be melted away and so the part can get out okay the wax is just sort of housing for the part the final part geometry which is going to get created.

So, the first step here is that you develop precision XYZ stage to have the part material follow a CAD package so let's say the there is a splice plot coming from the CAD of a certain 3d geometry and the splice plot has certain areas along which a nozzle had to be has to be guided or let us say a dispenser has to be guided. So, this module follows that path okay. So, there is a certain section in which this material needs to be deposited in the CAD the information comes out in terms of coordinate locations and the tool follows this particular dispenser follows that particular path and outlays the part material okay.

While the remaining regions are filled with let us say wax which is the support material in this particular case. So, it also follows the same pattern and generates a wax and then what we do is we try using a CNC milling tool to take off a shape of the you know particular material to an extent that only the layer thickness which is in question is remained okay. So, that is a precision system which is associated with this process maybe with the camera and with a scale you could actually gauge what is the extent of Z which is needed corresponding to the layer thickness.

And remaining can be shaved off in this manner so once this material this extra material has been shaved off the layer is prepared for the next round of printing again where the next splice which comes up as information from the CAD packet gets outlet in terms of areas which are coated with wax and areas which are coated with the solid material. Obviously in a layer by layer manner a very complex part like this can be built in this manner.

Every time milling it and shaving it to the layer thickness that is intended obviously this is not really a perfect example of additive manufacturing because using a lot of material. If you if you control the droplet spraying in a certain manner it may be possible that you minimize that but there is of course a loss and a subtractive aspect of this process. So, it is not a pure additive process but eventually when you get rid of the support material that is the wax this particular part which is otherwise a very complex geometry minutes in a build in as built part by part or layer by layer manner.

So, the various steps are drops cold weld to the surface from a new layer depositing each layer controlled by XY nozzle whose path is based on the splice plot the cross section of a CAD geometric model okay that is sliced into layers okay. And the work materials can be a support material which is wax and a thermoplastic of which the final material would be built off. And similarly you can get rid of the wax and create the part an independent part rise or come up okay of this whole process.

So, typically it is a batch process you can fabricate many parts at a time using one stage and one cavity in which wax and thermoplastic can be alternately printed and so you can have a high yield process again starting from you know the liquid starting material or liquid thermoplastic material.

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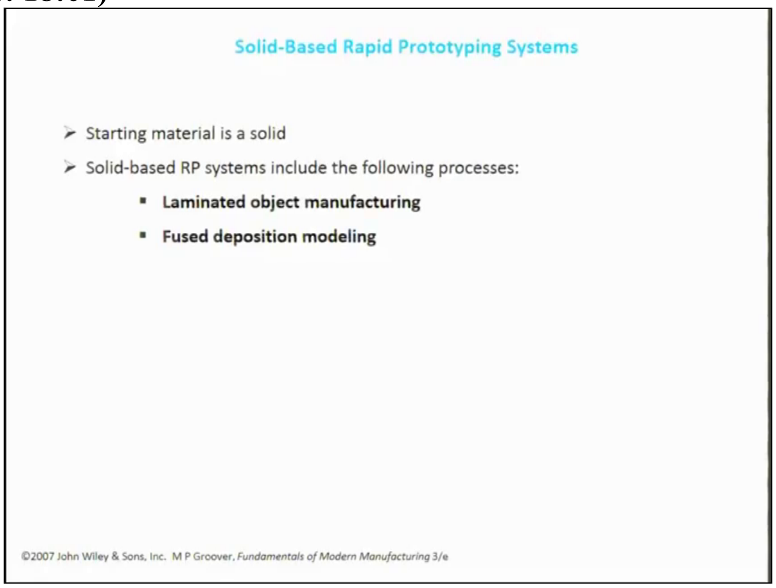

So, these are some processes which are liquid based we will also talk about certain other processes which are based on solid materials or solid starting materials. So, one of the typically there are again almost about 7 or 8 such processes which exist but we would be looking only at the very critical ones okay which are being very widely deployed okay within the industry as well. So, you earlier saw how in the SLS method also there were half a dozen processes but sorry the liquid based method also.

There were half a dozen processes and we only focused on to a few very important ones in the same way in this solid based method the most important is a laminated object manufacturing and you know one which is really, really very well known the fusion deposited modeling using the position modeling is actually a very helpful tool for polymer based parts rapidly being produced it is in true sense an additive manufacturing process.

Although there is a need for you know complex 3D parts to have support base and typically the support bases are low density you know prints in comparison to the main part which is probably a high-density print. So, in a way we are trying to optimize the material loss so that the process can be more economical and so therefore the fusion deposition modeling is also a very well accepted process with an industry particularly there are space industry as well.

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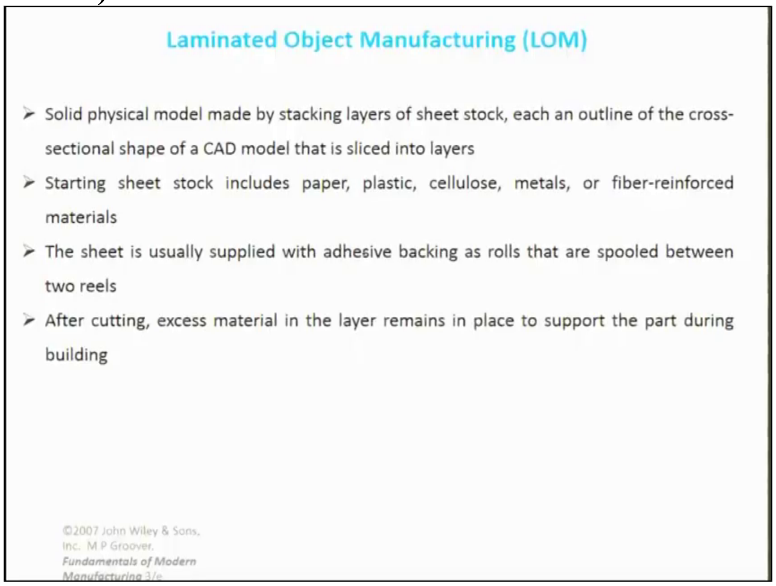

So, let us talk about these two processes and how they are done so let us look into what is the laminated object manufacturing method. So, as the name suggests the object is made out of laminates and the laminates are further pasted or stuck to each other so that they can build up a part each laminate is positioned as a splice information coming from a 3D geometry and formulates one layer of the geometry and in the physical sense of the physical real world.

So, the solid physical model is made by stacking layers of sheet stocks each and outline of the cross sectional area of the CAD model which is spliced into layers again okay starting the sheet stock may include materials like coated papers paper coated with a decimal for example they could include plastics they could include cellulose even metals metal strips or fiber reinforced materials provided.

They have a way and means they have ways and means to bond to each other and they can be stacked up and get the requisite amount of strength that they should possess. So, the sheet is usually supplied with adhesive backing as rolls there are spooled between two reels after cutting excess material in the layer it remains in place to support the part during the building.

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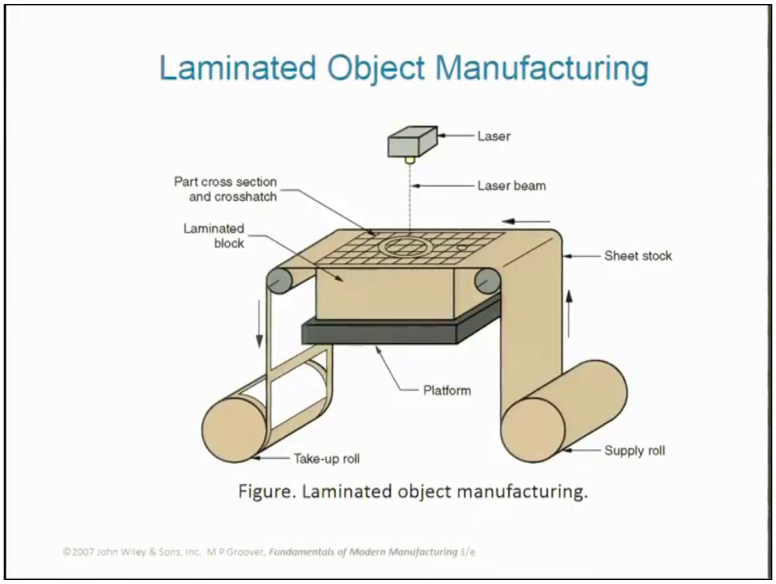

Let us look at a small schematic which shows how this is done so you can think of a laser cutting tool here which is actually creating a so this right here is the supply role as you can see the role that comes will obviously have the principal material which may be a metal or a plastic or a paper or a plastic you know or a thin sheet of plastic etc. And it will also have an adhesive layer on the top okay and they are done in a manner so that you can typically make the layer get protected through a a paper or something which can be removed as the sheet is rolled up.

So, the sheet is rolled out through this set of rollers roll 1 and roll 2 and on the other side there is a again take up a role which takes the paper and folds it again back into a roll bundle okay. So, there is a roll opener here and there is a roll there is a rolling system here which will take up the roll okay. And in between there is a work stage as you can see from which the material the flat material passes between roller R1 and R2 and is held at a certain pressure.

So, the idea here is that whatever material is now stuck to the base of this particular substrate you do laser action on the top and cut the different parts. So, in this case you can see there is a hatched cross section cross hatching which has to be cut on the plastic part the the plastic part has been cut and cleaved on the side. So, that probably this was the early early so you know the layer is already stuck and so what is going back is this hollow into the roll.

And so you can actually do various processing using a laser head in terms of cutting action etc on this particular you know geometry and in this manner you can build layer by layer the material the idea is that later on the cross hatching is typically done because you know we want to remove these portions out easily. So, that the part which is actually not crosshatch remains back. This cross hatching probably is at a level or a dimension where a slight amount of effort releases these very easily okay.

Because they are smaller in size in comparison to the overall part size and so the idea here is that these are all our blocks which are being formulated with the part and these blocks are getting lost okay. While supporting the part as the part is getting built up three dimensionally. So, so basically the purpose of the laser is to actually give a primary cut to this object right here and a secondary cut in terms of cross hatching and making small sections which can later on come out and release this part to be an independent part structure and this is done layer by layer.

So, that again the same cylinder that we are looking in the solid curing the solid ground curing okay gets built up in this particular manner through laminates okay or layers of plastic. So, this is another very interesting way of you know a solid starting material based rapid prototyping. So, I am going to close this particular module in the interest of time in the next module we look at and the other process that is FDM process in a slide slightly more details as of now thank you very much, we close this module.