Computer Integrated Manufacturing
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Lecture 38
Rapid Manufacturing (Part 1 of 2)

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The next most important topic of discussion in this course is going to be on Rapid Manufacturing. So it has two terms, manufacturing and then it has also one more term called rapid. So this is going to be the talk of the town, this is going to be the future. Today, when we are talking about the mass customization, so the batch size becomes idealistically one.

So, for every individual manufacturing, an item or a product which will exactly suit to him is nothing but mass customization. In mass customization rapidly manufacturing the product is one of the most important topic which is discussed.

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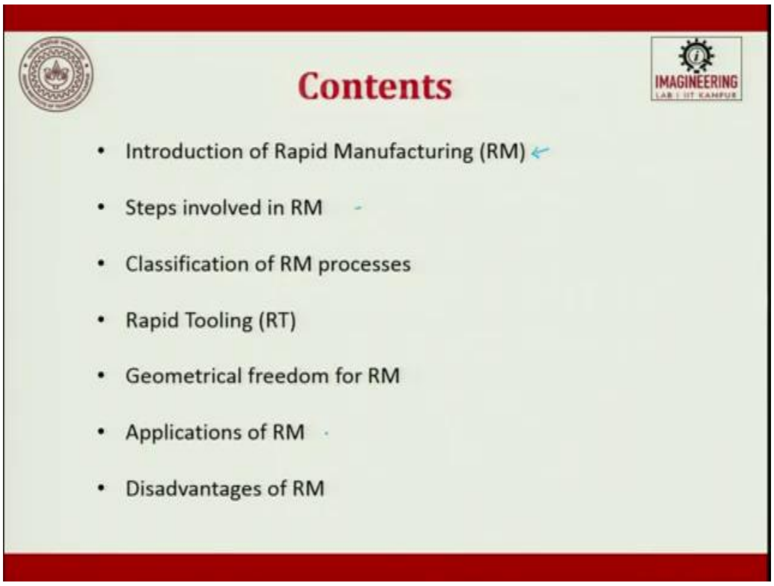

In this topic, we will first see what is rapid manufacturing? then we will see steps involved in rapid manufacturing, classifications of rapid manufacturing process, rapid tooling then we will see geometrical free form for rapid manufacturing then applications for rapid manufacturing and finally disadvantages for rapid manufacturing.

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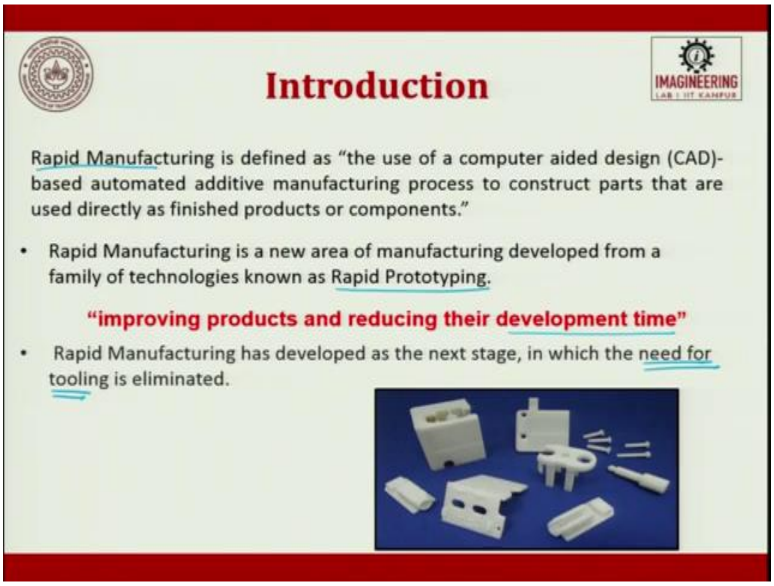

So to define rapid manufacturing, we are using this definition, the use of CAD-based automated additive manufacturing process to construct parts that are used directly as finished products or components is nothing but rapid manufacturing. There is a big difference between rapid prototyping and rapid manufacturing.

In rapid prototyping, we quickly produce a prototype which is used to check for dimensions, form, fit and, customer feedback but whereas here we are trying to say whatever gets produced is going to be the finished part which can directly get into usage. Rapid manufacturing is a new era of manufacturing developed from a family of technologies known as rapid prototyping.

So rapid manufacturing got evolved from prototyping. So why did this evolution happen and how did this evolution happen? Because in this prototyping there was always a restriction of the material which did not allow this prototyping to be directly used. Today, people have started working on it and people have understood how to make material such that on that material you do a process and convert it into a final form.

So improving products and reducing their development time was prototyped initially thought of to improving products and reducing the developing time directly towards the final product is rapid manufacturing. Rapid manufacturing has developed as the next stage in which the need for tooling is eliminated. This is very important.

So when I said mass customization, the part has to be produced, the product has to be produced to individual customers. If that is the case then we need to have machines and tooling. So now the advantage of rapid manufacturing is going to be eliminating those tools which are involved in producing.

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So why rapid manufacturing? It is a technique for manufacturing solid objects by the sequential delivery of energy and, or material to specified points in space to produce parts. Please see, lot of keywords, manufacturing technique for producing solid objects in a sequentially delivery of energy.

The energy can be heat energy, the energy can be light energy, the energy can be in terms of glow also, energy and the material to the specified point in the space, in the space specified points, so where I want a material that is what we are trying to say specified points in space to produce parts.

So why is rapid manufacturing very important? Because it talks about mass customization. So more customer, because once it is customized more customer satisfaction. Even today if you walk down to any of the chain coffee shops you would get the consistent same coffee at every place. If you wanted to smally customized for your taste currently the machines do not allow.

So what is happening? Mass production of coffee, mass production of beverages, mass production of shoe, all these things are produced keeping cost as a constraint and now what you do is you try to fit into the constraints whatever is given there and you start enjoying the product. So that is not mass customization.

More customer satisfaction with highest integrity leads to rapid manufacturing or there is a need for rapid manufacturing to go to this. High speed for manufacturing complex parts. See today, many parts in the aerospace industry and defence they are made out of rapid manufacturing, even in automobile.

So what is the big advantage is they are able to make complex parts which were not even earlier thought of in conventional machining. So in conventional machining, there might make 6 parts and then spend lot of time in assembling the 6 parts when they do that they get into error so all those things are thrown away in rapid manufacturing.

Then eliminating tooling cost, simple and automated operations, personalised product becomes conceivable, designed freedom gets enhanced to minimize this sustaining engineering changes. So that is also rapid manufacturing, on-demand manufacturing and finally use of reverse engineering for making components is also possible which leads us to rapid manufacturing.

For example, if you want to make a shoe, the first thing is we are now currently only measuring the length but truly speaking a foot is a 3 dimensional one, you have to measure the length as well as in the z-direction whatever it is, so some might have broad foot, some might have small foot, right?

So if that is the case, so we first scan the data of the foot, from the scanned data you manufacture a shoe, so that is what we are trying to talk about use of (rear) reverse engineering for rapid manufacturing.

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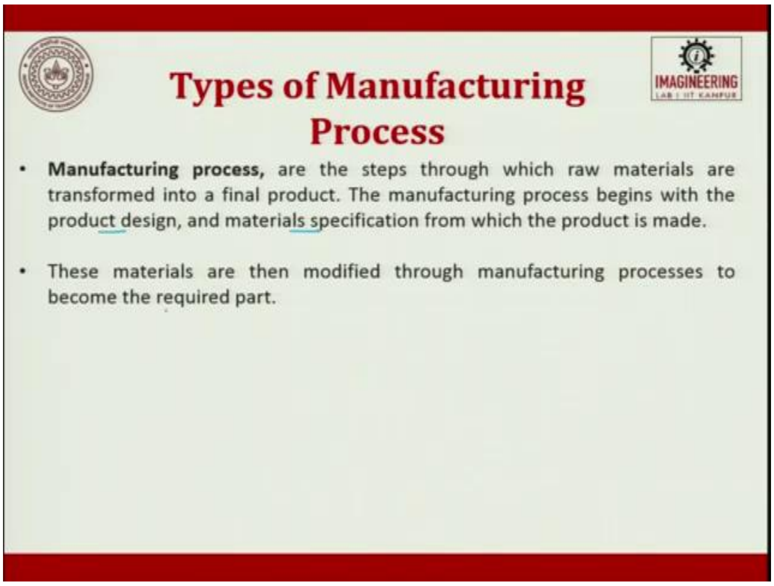

So when we talk about manufacturing process, manufacturing process are the steps through which raw material are transformed into a final product. The manufacturing process begins with a product design, material specification from which the product is made. So manufacturing also uses minimum man material and machine such that lot of value addition happens in each process to meet out to customer requirements. These materials are then modified through manufacturing process to become a required part.

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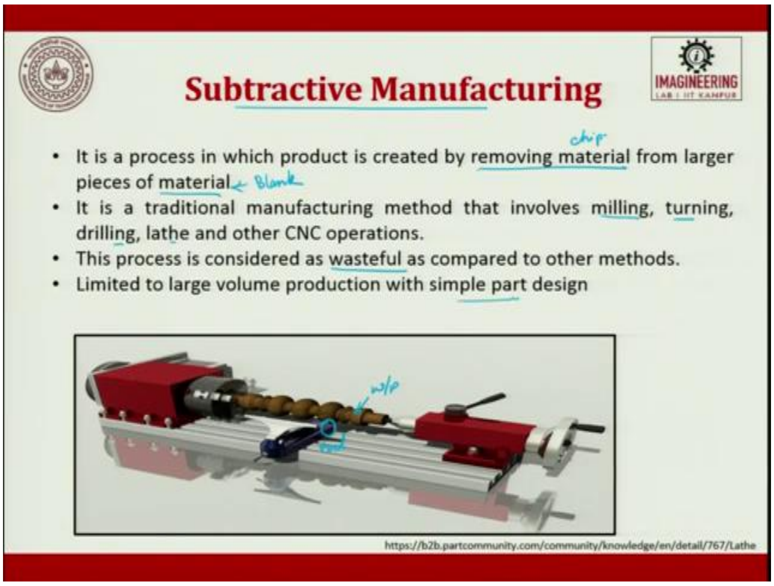

So, in manufacturing, you have several verticals. One major vertical today wherein which we do lot of mass customization is by doing subtractive manufacturing process. In this process in which the product is created by removing material from large pieces of material or suppose removing chip from the blank or a raw material.

So here this is the most exhaustively used even today highly appreciated manufacturing technique which can help you towards mass customization today. But this also depends on buying a capital intensive machine for doing the product. It is a traditional manufacturing method that involves milling, turning, drilling, lathe, and other CNC operations whatever it is.

So here the most basic understanding is the work-piece should be softer than the this is the work-piece, it has to be softer than the tool or I will put tool has to be harder than the work-piece and the tool is given a relative motion to generate whatever geometry you want. This process is considered as a wasteful as compared to that of other methods because you first may spend lot of energy in creating a blank and now you spend lot of energy in removing the chip from the blank to produce it.

So, this process is nowadays are not even thought of, or they are said this process are not falling under the gamut sustainable manufacturing limited only to large volume production because the tooling might be costly, the machine might be costly, so making one-one piece and then making the money out of it is next to impossible. Limited to a large volume production with simple part design is possible.

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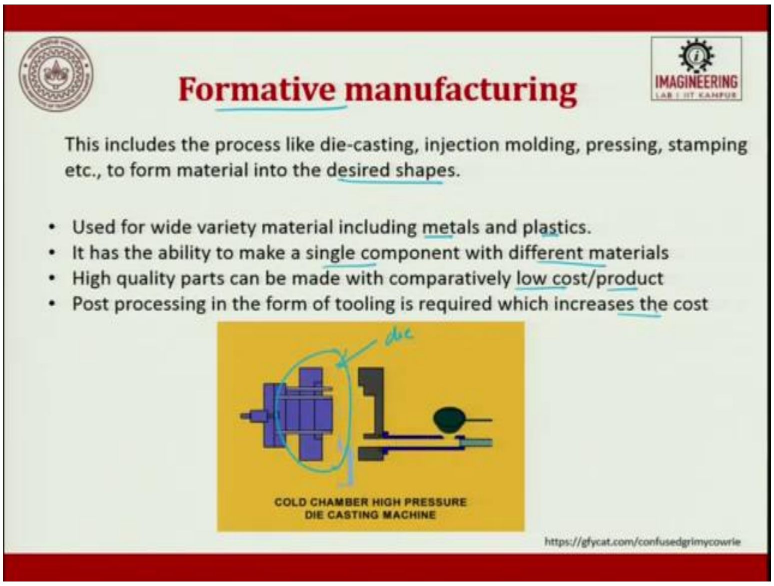

The next one is formative manufacturing wherein which it is a constant volume process there is no change in volume between the raw material taken and the output produced, so this includes the process like die-casting, injection molding, pressing, stamping, etc to form material in the desired shape, so here you will have a die, and this will be a die.

This die are pretty expensive and then the raw material will be injected or poured into the die to get the output. The moment I say die you should have at least 10000 pieces, 1000 pieces to produce such that you can think of an economy. This is a capital intensive manufacturing process uses a wide variety of material including from metals to polymers it has the ability to make a single component with different material.

You can have inserts fitted and when you inject it, so in the polymer and the inserts stays back and then you get, so that is why they say single component with different material can be there for example plug, what you use for electrical appliance, you will have a steel insert and then you will have a rest made out of polymer.

The high-quality parts can be made with comparatively low cost and products but it is all possible when the production rate is high. The post-processing in the forming of tooling is required with increasing the cost.

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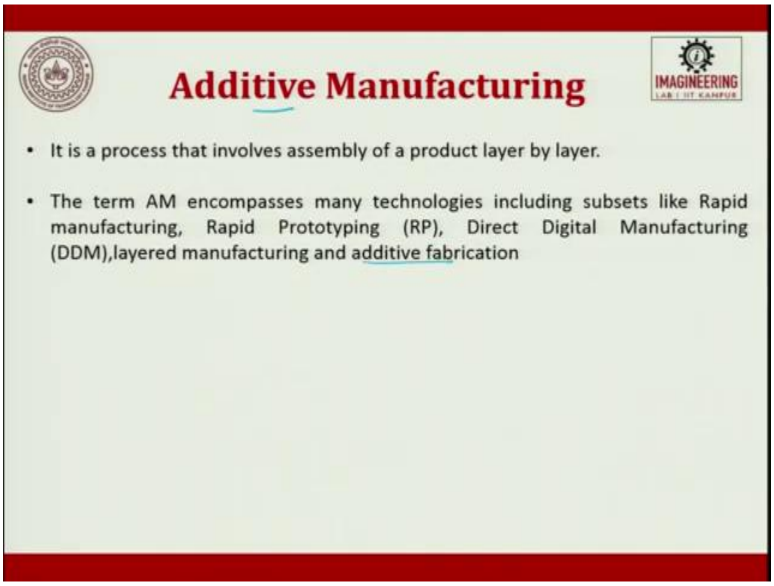

The next one is additive manufacturing. It is a process that involves assembly of your product layer by layer, okay. So for example, if you want to construct a 3D object, even today what we do is we divide into several small pieces, so these pieces can be something like a cuboid or it can be a work-cell.

So assembling several of the volume pixel, work-cell you will try to produce an output. So additive manufacturing here we try to take a building block, join the building block exactly to the shape what we want, so here there is nothing called material removal for generating the required output.

Of course, there is a secondary process that is not very dominating. It is a process that involves assembly of products layer by layer. The term AM encompasses many technologies including subsets like rapid manufacturing, rapid tooling, direct digital manufacturing, and layered manufacturing and additive fabrication.

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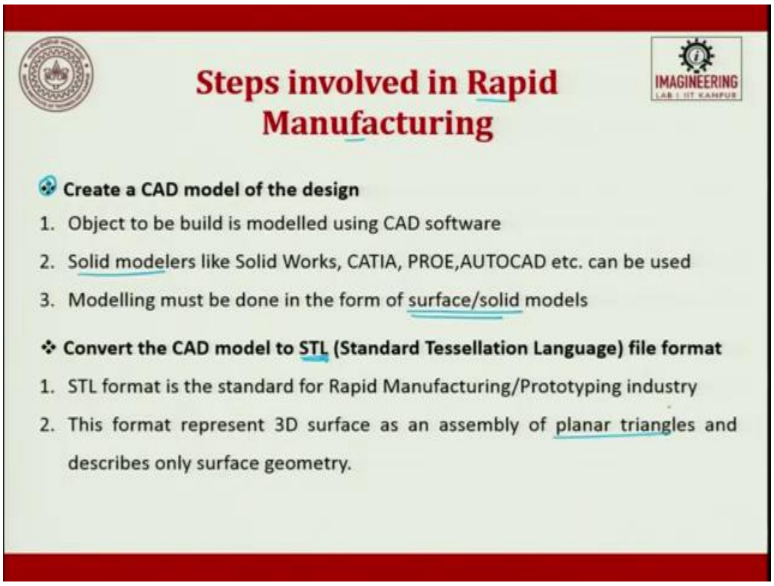

So what are all the steps involved in rapid manufacturing or additive manufacturing? First step is going to be create the CAD, the first few lectures what we saw in the CAD, first two weeks we discussed about CAD, so creating a CAD model of the design is the first step in the rapid manufacturing.

The objects to be built is modelled using CAD software. So we saw the several transformations which are happening at the back end of a CAD software so that is what is used. So the object to be build is modelled using a CAD software. The solid modellers like solid works CATIA, PROE, AUTOCAD, etc. can be used. There are several modellers.

Modeling must be done in the form of a surface or a solid. This is very important. We have to either make a solid model or a surface model. So CAD creation will be the first step. The next step is going to be converting the CAD model into STL files. STL is nothing but Standard Tessellation Language file format.

STL format is the standard for rapid manufacturing/prototyping industry. This format represents 3D surface as an assembly of planar triangles and describe only surface geometry. So we have a solid, we are talking about only the surface, now this surface will be cut into several small planar facets. Why are we doing it?

Because this planar facets you can draw a normal to the planar face and then you can say whether there is a presence or absence of material. So that is why we make these planar triangles and then we try to draw a normal to the planar triangle to describe the surface geometry.

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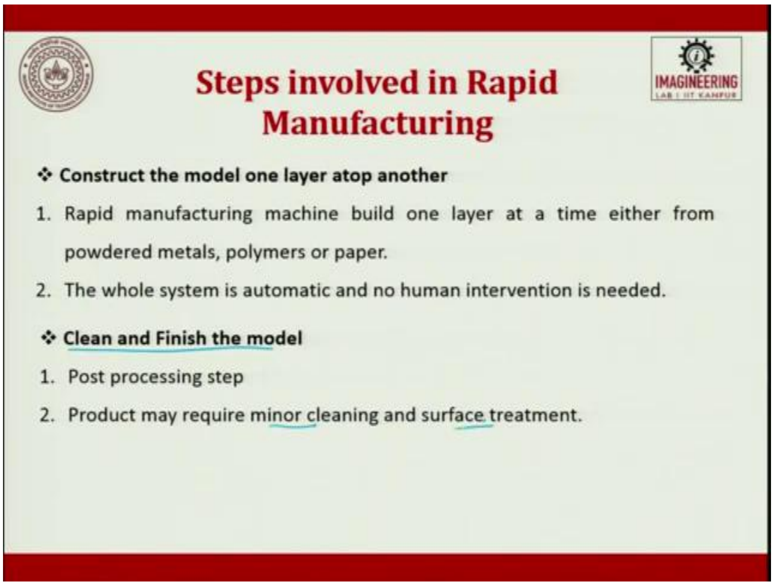

The third one is going to be construct the model one layer on top of another. So the third step is going to be layer by layer, that is going to be the third step. So now you have made facets after that what you do is, along the Z direction you cut the object into several thin layers, right? After you cut this thin layers, the next step is going to be construct the model one layer atop another.

Rapid manufacturing machine builds one layer at a time either from powdered metal-polymer or paper. The whole system is automated and no human intervention is needed. Then once the object is made you will have small errors which are getting developed or it might need post-processing operations in terms of giving colors, strengthening, whatever it is.

So what we do is we try to do a last post cleaning operation which is nothing but cleaning and finishing the model. Post-processing steps are involved. The product may require minor cleaning and surface treatment to meet out the requirements.

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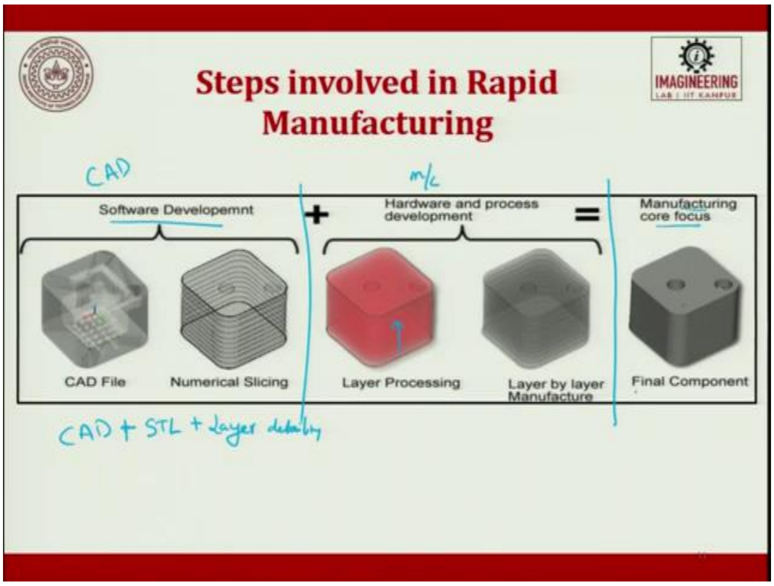

So this is what we have discussed until now. So we will try to divide it into two steps so this first step is all done in a CAD software, so software development a CAD file is drawn, so here then you make facets then after facets, you will try to make layers. So CAD, then CAD then the next step is going to be STL, then it is going to be layer by layer, layer detailing, that is what it is nothing but the slicing.

All these things are done at CAD environment then after that CAD environment the data is transferred to a rapid prototyping machine and this is the hardware where the machine is there, so hardware and process development so the layer by layer whatever you cut the object is getting processed and developed layer by layer by layer and then what you do is you try to develop the final object.

If there is a cleaning required, you clean or do a post-processor and finally you take a component out, so manufacturing core focus is there and final component can be made.

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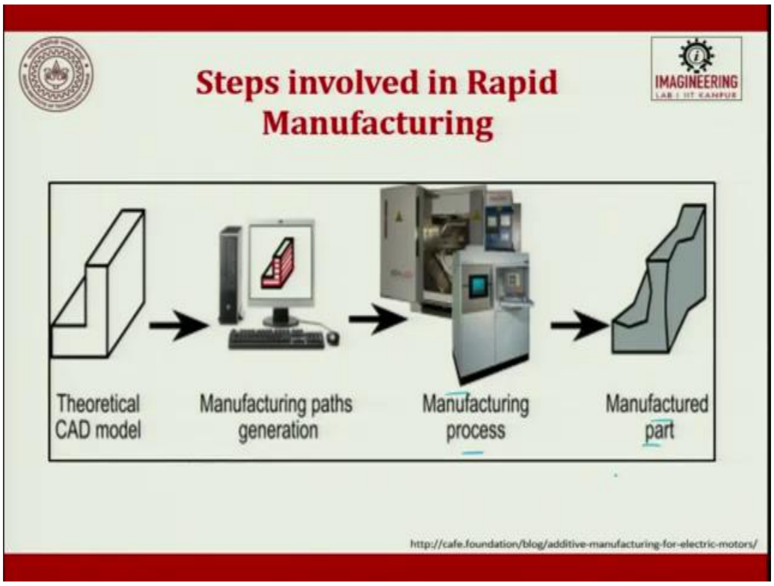

So this is what is given in the picture form, that was given in a schematic form this is given. So what are you trying to generate in this software numerical here when you start doing it, so you are also trying to develop not only layer by layer when you do layer by layer you are also trying to develop the path, tool path motion. You are trying to develop a tool path motion, okay.

So then CAD, theoretical CAD model is developed. From the theoretical CAD model you try to develop the manufacturing path generation and this path will be transferred to a rapid prototyping machine and that is the manufacturing process and finally what you get is a manufactured part.

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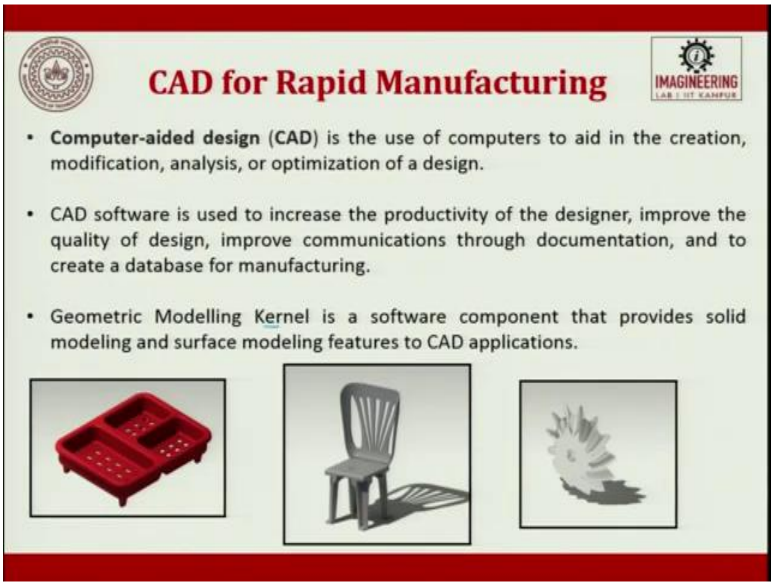

So CAD for rapid manufacturing: CAD computer-aided design is used of computers to aid the creation, modification, analysis, or optimization of the design. You can use all. By the way, you can also try to optimize your design. Today, that is what people are working on topological optimization trying to reduce the usage of material, okay.

Then the CAD software is used to increase the productivity of the designer, improve the quality of the design, improve communication through documentation, and create a database for manufacturing. The geometric modeling Kernel is a software component that provides solid modeling and surface modeling features to CAD applications. So you can see these are different types of objects which are drawn so you make it as a solid or you make it as a surface.

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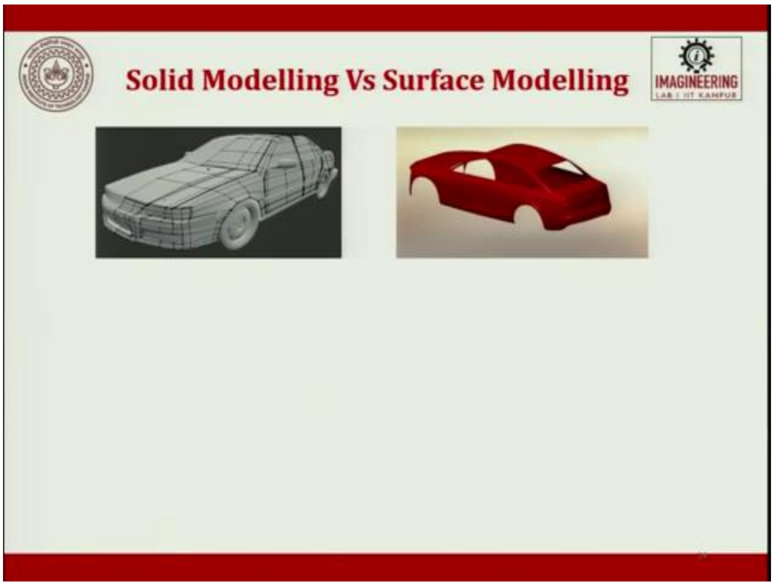

So here if you look at it, this is a solid modeling and this is surface modeling. For our application either you use solid modeling or you can use surface modeling. We put our most of that time we try to use solid modeling because we also have tried to calculate what is the volume of the material to be placed? But you can also do the entire thing with surface modeling.

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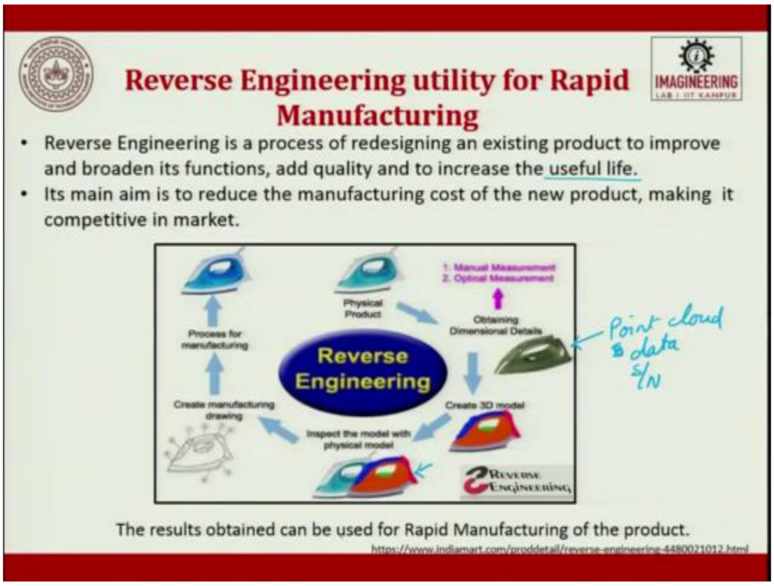

The next important thing, so we are going in the front route where we have points, point to lines, lines to surface, surface to solid we went. The other way is also possible, we try to do reverse engineering of the existing object and try to develop either the same or the negative of it. So reverse engineering utility for rapid manufacturing. Rapid manufacturing also use reverse engineering.

Reverse engineering is a process of re-designing an existing product to improve and broaden its function, add quality, and to increase the useful life. So reverse engineering is a process of re-designing. Reverse engineering is legal. If you want to understand the current state of the art and then if you are looking forward for an improvement, we do reverse engineering. So reverse engineering is legal.

You should not copy and produce the same what is available in the market. If you can improvise, if you can innovate, if you can change, modify, combine then reverse engineering is a very powerful tool which is used. Reverse engineering is a process of redesigning an existing product to improve and broaden its function, add quality, and to increase the useful life, okay.

So it main aim is to reduce the manufacturing cost of a new product making it competitive in the market, so this is a physical product so then what we do is we try to obtain the dimensions from the physical product. When we try to obtain the dimensions, what we get is a point cloud data.

After the point cloud data, we try to polish, because anyhow there will be certain places where the laser light will hit and it will get internally reflected, so you will have some noise signals. We will try to take signal to noise, we will try to take signal to noise and we try to remove the noise and we try to generate a surface, so surface or a solid model, we create a CAD model.

Then whatever we have created a CAD model, we try to look at the difference between the original and the reverse-engineered one, to inspect the model with the physical model. Then what we do is we create now it has become final, so now from here we try to create a manufacturing drawing, and based on the manufacturing drawing we try to process and produce the part.

So this entire cycle is called as reverse engineering. We start with the product, end with a product which is much more than the physical product is available. The results obtained can be used for rapid manufacturing of products.

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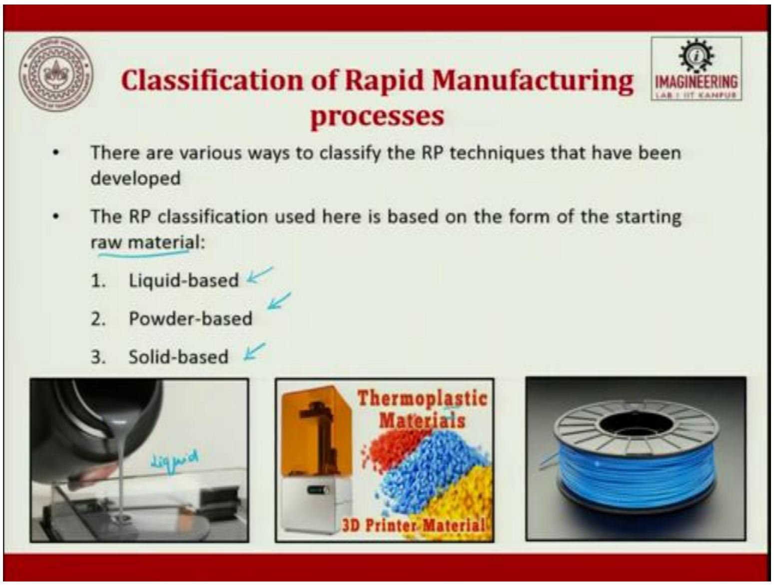

When we start going into rapid manufacturing process, there are several techniques used, basically, the rapid manufacturing or the rapid prototyping processes are classified based upon the starting material. There are several ways of classification. One way of classification is to start with the form of the material whatever is available, so there can be liquid-based, there can be powder-based and there can be solid-based.

So this is liquid-based, you can think of a silicon or an elastomer liquid-based, you can think of ABS and other plastics thermoplastics you are having and you can also think of solid which is in the wire form.

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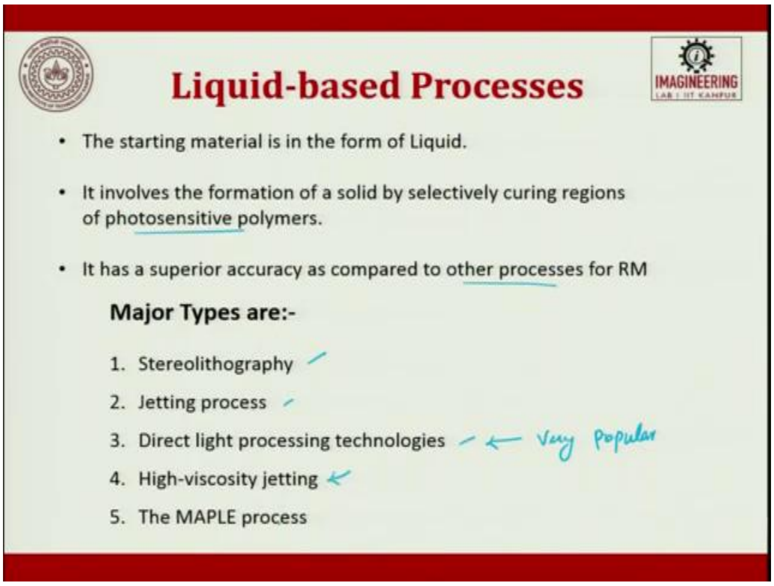

So the starting material is in the form of a liquid. It involves the formation of a solid by selecting curing regions of photosensitive polymer. So here what we are trying to say is we are trying to say we start with a polymer material which is liquid and what do I do is I use light to initiate the polymerization process.

I try to initiate the polymerization so the liquid gets converted into a solid and predominantly what we use here in this particular process we are talking about is a thermosetting process, right? So here we use a photosensitive polymer. It has a superior accuracy as compared to all other processes of rapid manufacturing.

The major process which come under this category is stereolithography, jet processing, direct light DLP process, direct light processing technology which is now becoming very-very popular, very popular. Direct light processing technology, then we have high viscosity jet then the MAPLE process.

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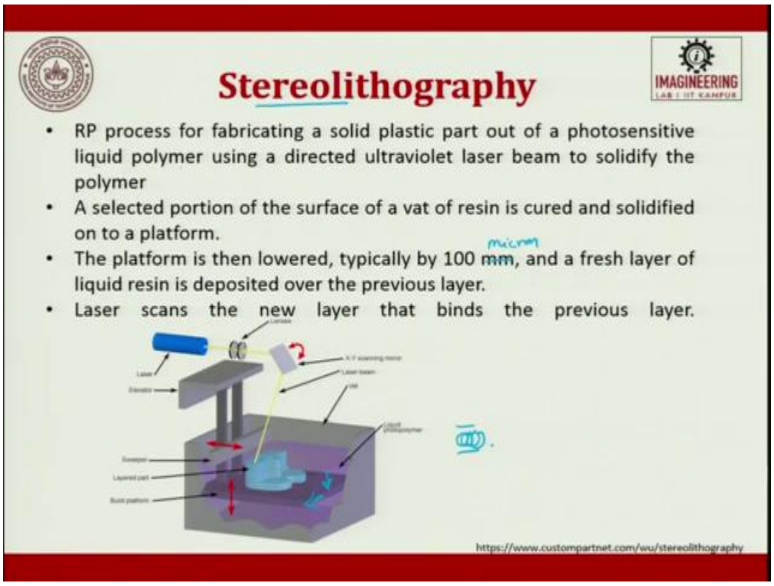

This is what a stereolithography process all about. RP process for fabricating a solid plastic part out of a photosensitive liquid polymer using a direct ultraviolet light, laser beam which tries to fall on the polymer and try to solidify. So it is one spot now overlapping of spots will be there, so now what will happen? It will try to produce a single layer.

A selected portion of the surface of a vat of resin is cured and solidified on to your platform. The platform is then lowered, so this is a platform, this is lowered by 100 millimeters or it is lowered by 100 microns it can be microns, it can be millimeter, a millimetre is large, so 100 microns and a fresh layer of liquid resin is deposited over the previous layer.

The laser scans the new layer that binds with the previous layer and in this manner, you use a stereolithography process to develop solid model.

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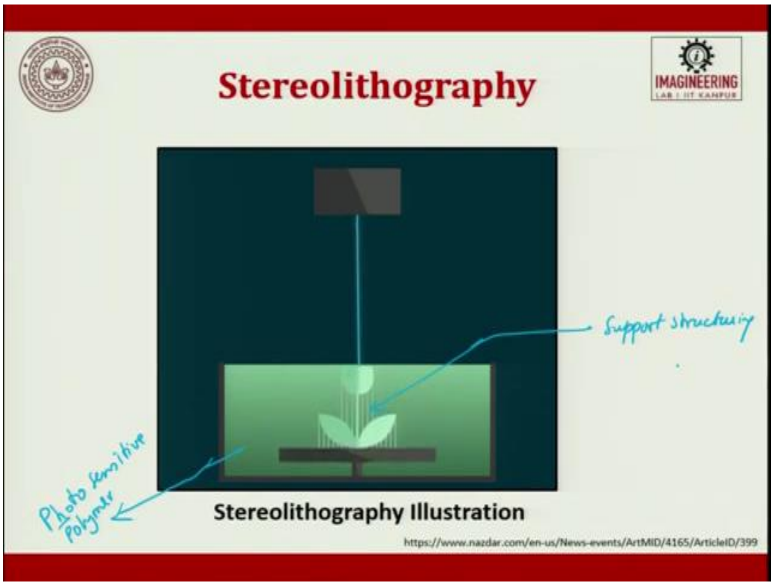

So this is how if you see the animation, it looks like. So here you see that there are straight lines which are there. So these straight lines are nothing but support structure. They will be removed, I said post-processing steps. So in the post-processing steps, all these supporting structures will be removed. So here is a laser and this is a photosensitive polymer. So when I say photo you can use light for curing it.

So here this is the object which is formed and here these lines which are there supporting the leaves and the flower are nothing but supporting structures. So these supporting structures will be removed. They will be, they are used here only at the time of developing they would like to do it and then they would like to cure.

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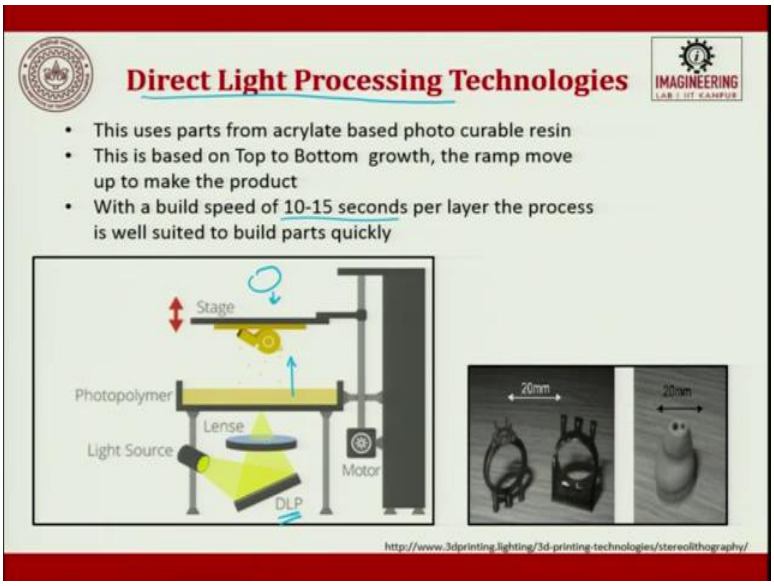

The next most popular process which is commonly used today is direct light processing technology. This uses parts of acrylate-based photocurable resin. So here what happens, till now it was all laser was on the top and the object it was projecting projected on to the vat or the photopolymer tank, it was just projected there. But here in DLP, it is going to be vice versa.

You have a laser, you have here mirror, DLP mirror, so you will have an array of 100 mirrors or 1000 mirrors, each mirror can be controlled. The laser light falls on the mirror and that passes through a lens and then that rises to heat the polymer tank at the backside. So now you see the object is getting developed against the gravity so any extra liquid material is there all droops down and you get the right product.

So direct light processing technology is the other technique which is used today. So here the building speed is also very fast as compared to other techniques. And here what happens is, rather than one spot moving, here the complete light gets projected and then you try to get it in a very fast manner. Thank you very much.