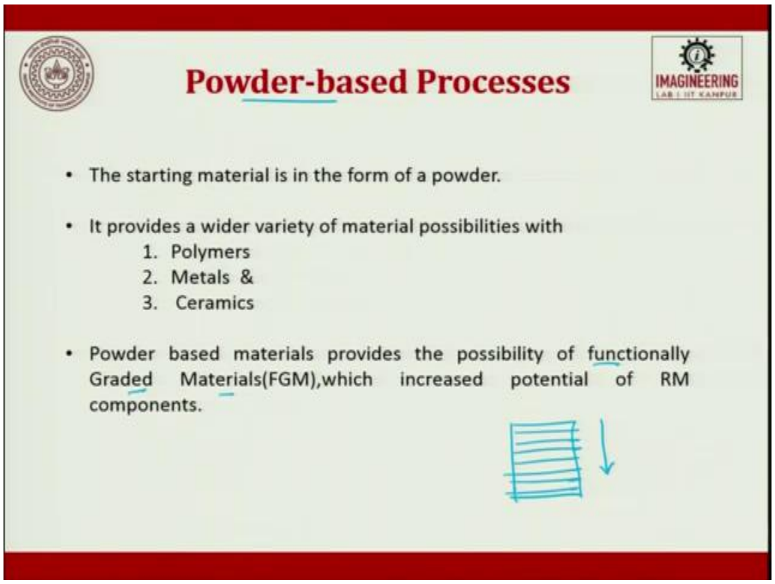
**Computer Integrated Manufacturing**
**Professor J. Ramkumar**
**Department of Mechanical Engineering, IIT Kanpur**
**Dr. Amandeep Singh Oberoi**
**Imagineering Laboratory**
**Indian Institute of Technology, Kanpur**
**Lecture 39**
**Rapid Manufacturing (Part 2 of 2)**

(Refer Slide Time: 00:16)



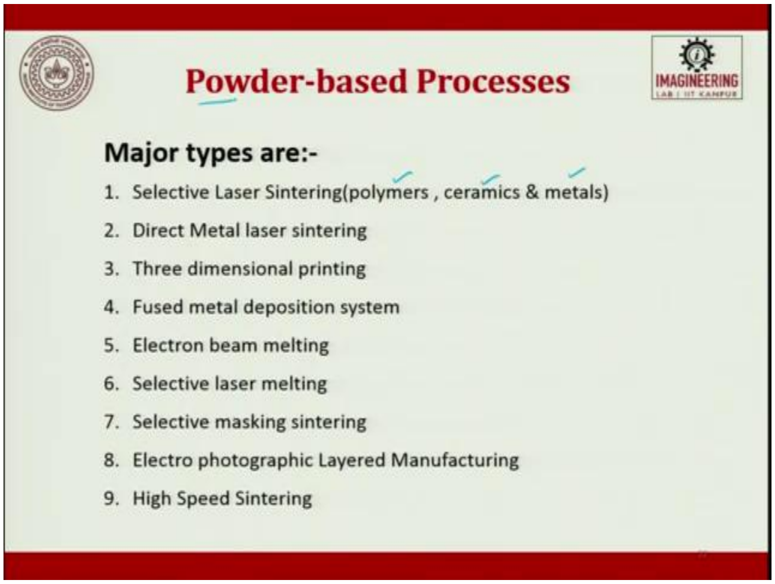

Next we will move to Powder-based Processes. See there are rapid manufacturing where in which you can make the mold out of polymer which is used for casting the output product. So, that is that is how the polymer process also falls in rapid manufacturing process. The other one is powder-based, the starting material here is in the form of a powder.

They are widely several types of classifications of these powders they are polymer-based, metal-based, and ceramic based. The powder-based material provides the possibility of functionally graded material which increases the potential of rapid manufacturing, what is functionally graded material?

Suppose I try to take a cube or I try to take a square and I try to change the physical property of this of the entire object in a very graded manner if I start doing it, so, here at the every layer there will be a compositional difference between the previous layer. So, this compositional difference can be to enhance strength to reduce weight and to enhance. So, that is what is called as functionally graded material.

The powder-based materials provide the possibility of functionally graded material, which is not possible in the liquid-based techniques, which increases the potential of rapid manufacturing component. So, today we are all looking forward for functionally graded material, your skin is a functionally graded material.

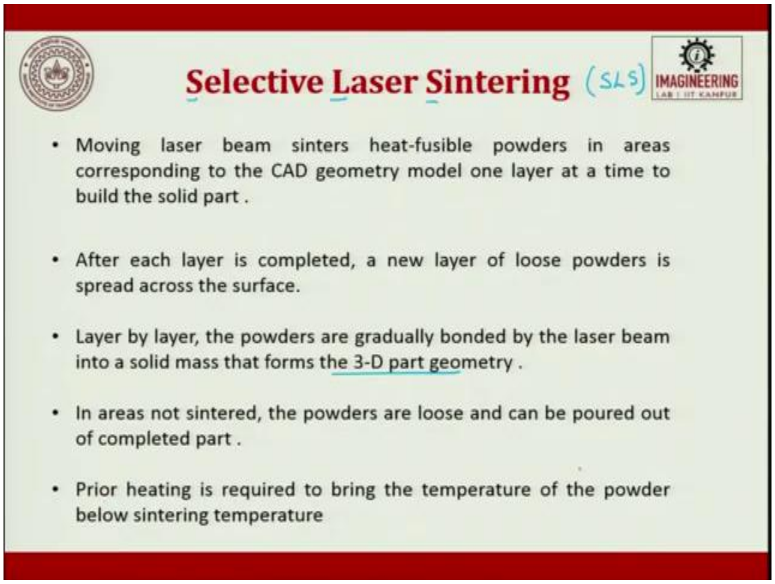
(Refer Slide Time: 02:02)




So, there are different types, which falls in the powder-based processing. The major types are going to be selective laser sintering which can be polymer, which can be ceramic, which can be metal-based.

The next one is direct metal laser sintering, third one is 3-dimensional printing, fourth one is fused metal deposition, fifth one is electron beam melting, sixth is selective laser melting, seventh is selective masking sintering, eight is electrophotographic layered manufacturing, ninth is high-speed sintering. So, these are all the techniques which come under powder-based processing under rapid manufacturing.

(Refer Slide Time: 02:48)



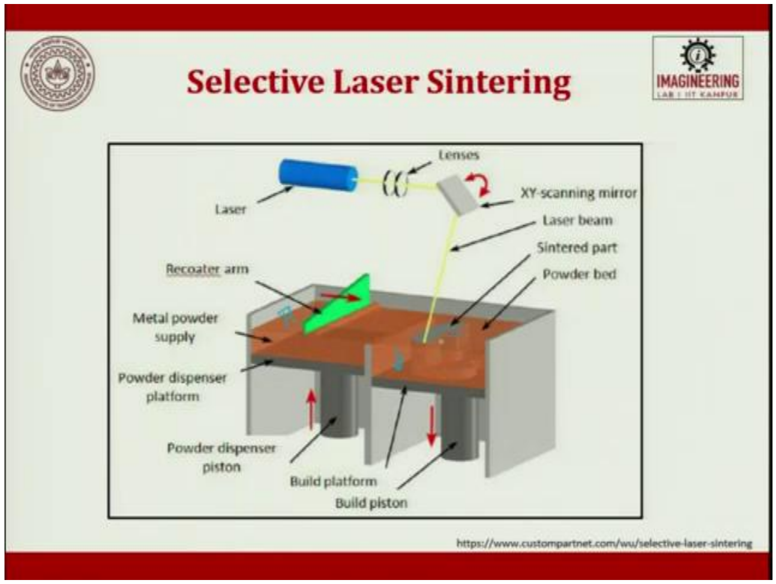

The most popular one amongst this is used exhaustively today is selective laser sintering, which is otherwise called as SLS. Moving laser beam sinters heat fused powders in areas corresponding to the CAD geometry model, one layer at a time to build the solid part after each layer is completed, a new layer of loose powder is spread across the surface.

So, one layer is there, laser just goes on top of it, tries to melt all these powders, melt in the sense surfacially. So, then they join with each other. So, it is not exactly melting, it is just joining all these metal powders. So, when you do it what happens the complete layer of information is done.

So, now they will try to move the platform down by one layer thickness whatever you have given in the program which is developed by CAD and then this the metal powder container will be moved up and then a roller will move and pick the material and spread it on top of the table, the layer by layer, the powders are gradually bounded by the laser beam into a solid mass that form the 3D part geometry.

In areas not sintered the powders are loose and can be poured out of the complete object. Say for example, what supporting structure we saw in stereolithography. So, that is only to support the structure. So, here what happens whatever powder which is not cured by the laser becomes available. So, on top of it, you start keep building it, in the areas not sintered the powders are loose and can be poured out or the complete part. Prior heating is required to bring the temperature of the powder below the sintering temperature.

(Refer Slide Time: 04:48)



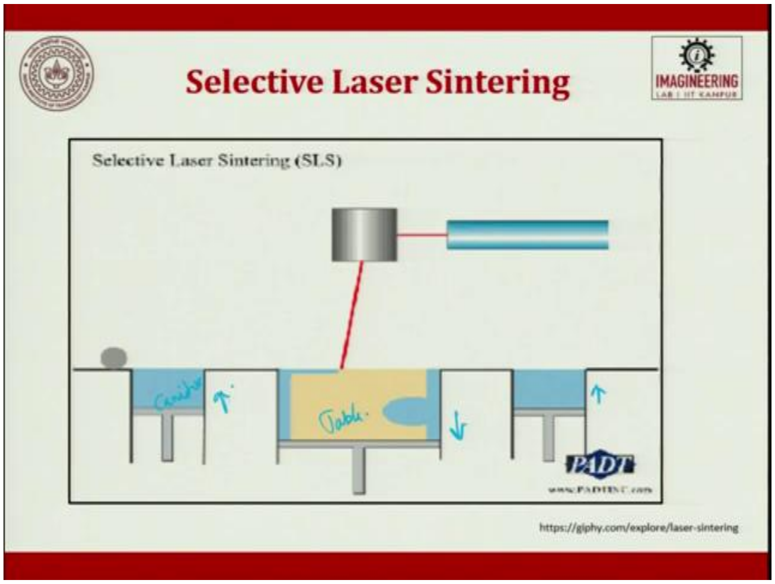

So, this is how the process happens. You have a series of lenses, so this lens hit at a Galvo stage. This Galvo stage tries to develop the complete layer in one shot without transferring powder to it okay. So, that job of scanning and then developing an object is done by the scanning mirror.

So, the laser again which is depending upon the raw material we are using it here you can choose different types of wavelength laser again you can think of using continuous laser, you can think of pulsed laser for a budget and then you start developing it.

So, sintered part is this. So, the powder bed is this, all this powder but whatever is not used or if the laser does not touch it, it does not get sintered So, you try to develop it and then once one layer is done, then this layer will sink down and this will go up and then there will be the blade will be used to transfer the material from the container to the table.

So, this is a metal powder instead of metal powder you can have ceramic powder, you can have polymer powder, and depending upon the wavelength and depending upon the requirements we can start developing it. So, this is the powder dispenser platform and this is also a powder dispenser platform, and then you have a build platform whatever is available. So, here and then we will have a piston, build piston to move, or to reduce the height of the object.

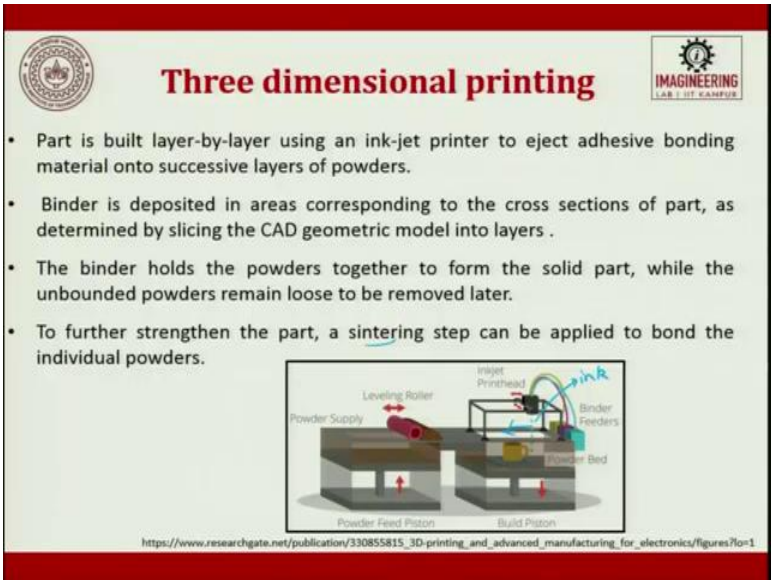
(Refer Slide Time: 06:24)

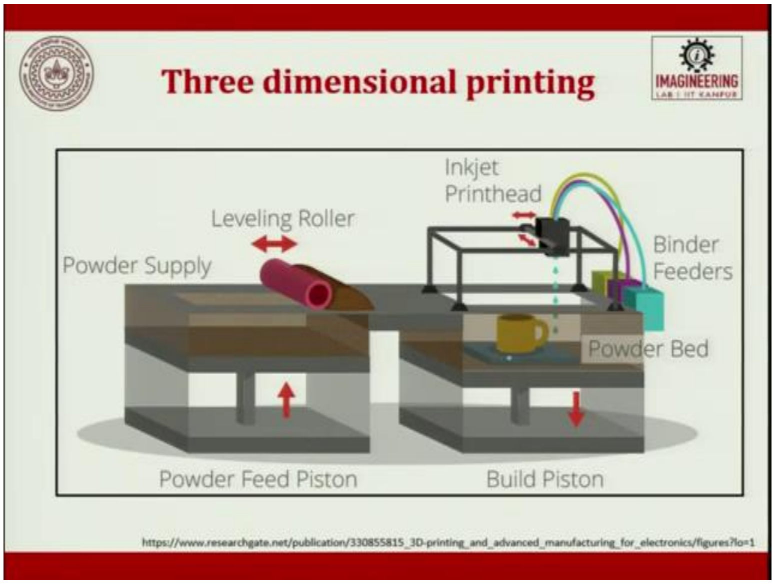



So, this is the animation of the process. So, you had the tank from this tank you can see the laser the powders were moved towards the table. So, this is a table, working table, this is the canister or can let people call it as a can. So, once this roller goes to the other extreme end you can see it will smear powder and go, and once it is done the laser gets activated and it tries to cure.

So by this way, this can go down, this will go up and up alternatively and try to generate functionally graded material.

(Refer Slide Time: 07:12)




The three-dimensional printing is the next area. So, we saw selective laser there, ceramic can be used, metal can be used, plastic can be used, elastomer also can be used. So the three-dimensional printing. So, this is another niche area which is coming out. So, here the part is built layer by layer using an inkjet printer.

So, you can see here inkjet, so this is the ink which is getting fallen on the table, which falls on the table. Okay, so part of the parts is built layer by layer using an inkjet printer to eject the adhesive bonding material on to the successful layers of the powder. The binder is deposited in areas corresponding to the cross-section of the part as determined by slicing the CAD geometry model into layer.

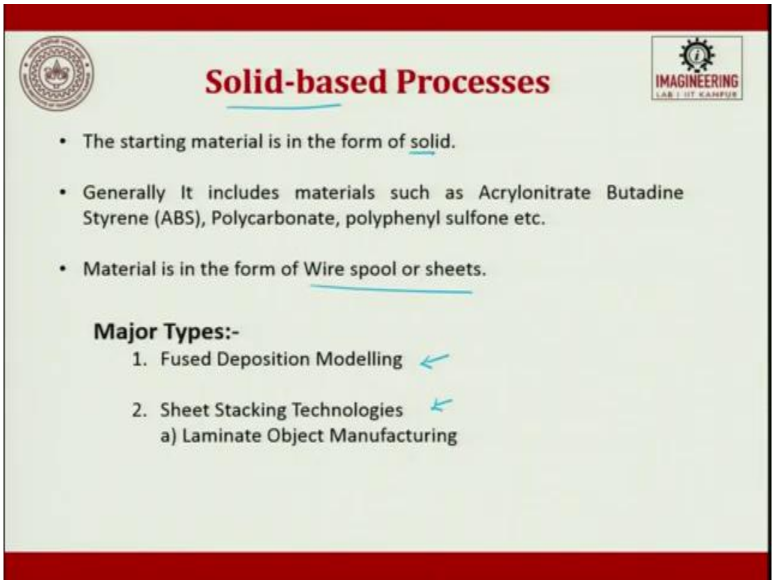
Binder is deposited in areas corresponding to the cross-section of part as determined by slicing the CAD geometric model into layers, the binder holds the binder. So, what comes out is not the laser, it is the binder, the binder holds the powder together to form a solid part while the unbounded powders remain loose and they can be reused or re-circulated.

To further strengthen the part a sintering step can be applied to bond the individual powders. Whatever gets done here is called as green stage product these green stage product will not have the strength. So, sometimes what people do is they immerse it inside a thinner and then they try to dry it that makes it scratch proof and also increases the strength of it.

If not, what you do is you try to do the complete product development, put it inside a furnace, and then do a sintering step. So, that this powder, the adhesive gets evaporated and the powder joints with each other gets consolidated to produce the required output.

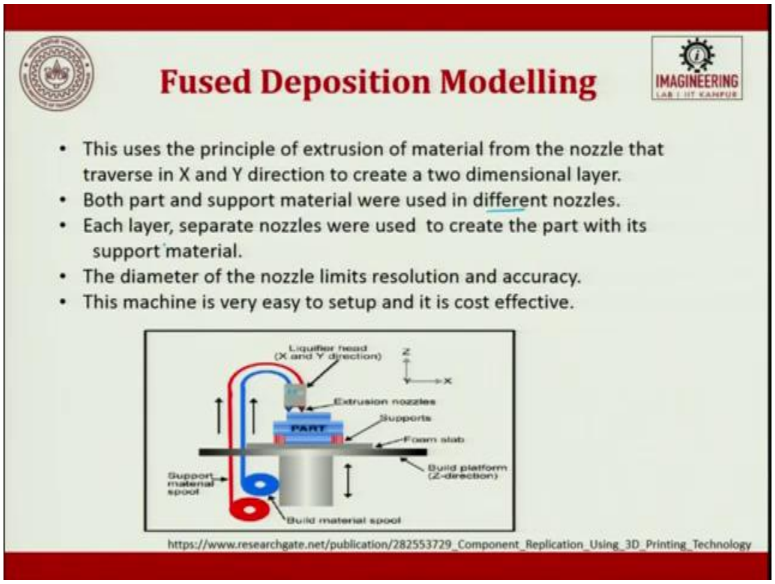
So, this is the 3-dimensional printing. So, the powder which is supplied a roller is trying to push the roller puts a layer on top of it and then you see the inkjet drooping from the top which will try to join those things and try to produce a complex 3-dimensional object.

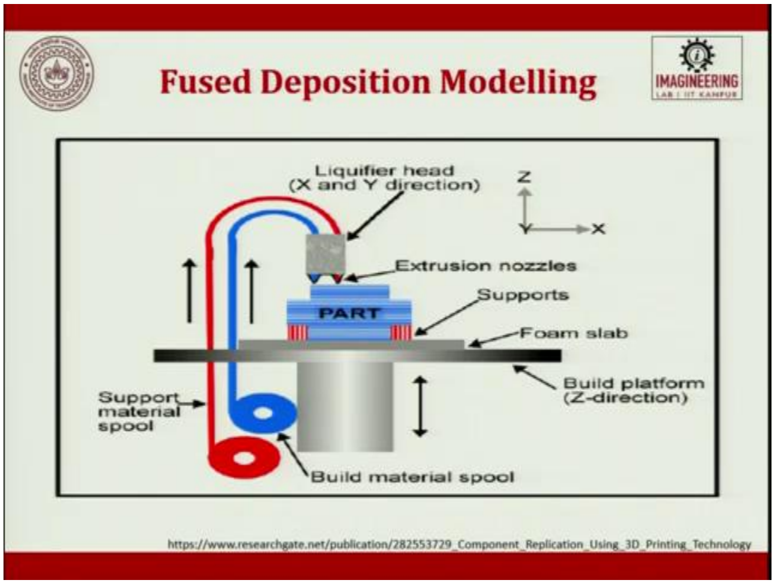
(Refer Slide Time: 09:40)




The last out of the three the last process is solid base process. The starting material is in the form of a solid. Generally, it includes material like ABS, polycarbonate, polyphenyl sulfone then you will also have a solid base you can also have wire, metal wires are also available. So, here the starting form is a wire spool or a sheet that will be the solid base processing. So, a metal deposition method and the sheet staking technology are the two most common technologies in the solid-based process.

(Refer Slide Time: 10:25)




So, this is the process for fused deposition modeling. The use, this uses the principle of extruding. So, here the wire is fed into through an extruder. So, then what happens there is a tension which is maintained by two rollers through which the wire gets fed inside.

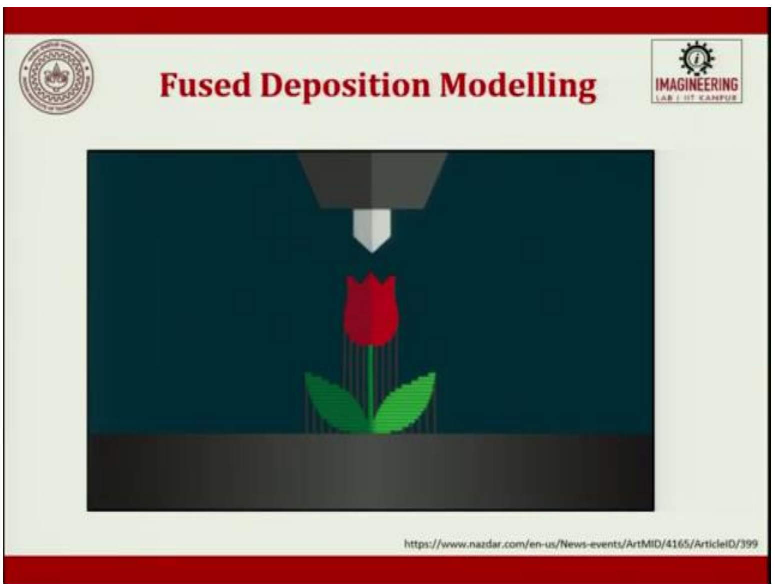
So, this tries to maintain a tension as well as it is also trying to heat in that dispenser liquefier head is nothing but you apply heat here and allow the wire to pass through to the heat so that you convert this into a viscoelastic state and, on a viscoelastic slate you do not have to spend a lot of energy to push the material.

This uses the principle of extrusion of material from the nozzle that transfers in x and y direction to create a 2-dimensional layer. So, x, y you keep moving you get one layer of information. So, you stack several of these layers together, you will try to get a 3-dimensional object, both part and the supporting material were used in different nozzles.

So, this can be blue, can be material which is required in the product and for which we need to have supporting that can be red. I am just taking it as an example. You can also have vice versa you can have multiple nozzles through which these wires are fed in.

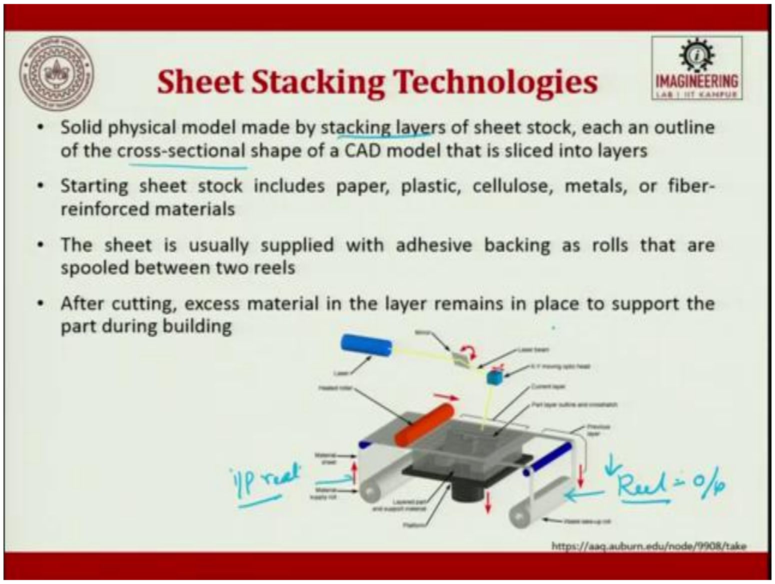
Okay, so each layer separate nozzles were used to create the part within its supporting material. The diameter of the nozzle limits the resolution and the accuracy, this machine is very easy to set up and it is cost-effective. So, this is how a fused deposition, the nozzle can move or the table can move depending upon the requirements.

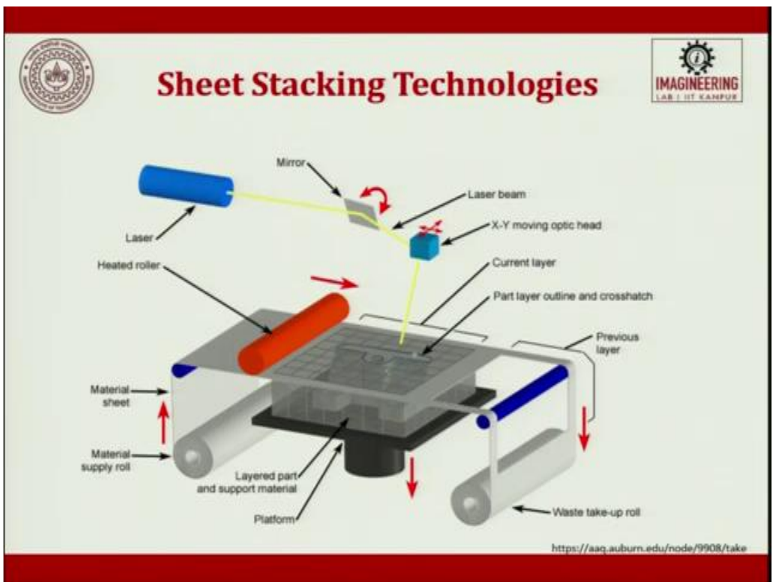
(Refer Slide Time: 12:19)




So, this is how a fused deposition modeling method works. So, you have material which is moved from the nozzle. So, these are the wires, green and red are the wires, which are passed through a nozzle and that nozzle tries to dictate what should be the laser thickness more and more layers lesser will be the inaccuracies or I would say very small layer thickness will lead you to better control over the result. But the only time it is going to take lot of time for you to make the product.

(Refer Slide Time: 13:03)



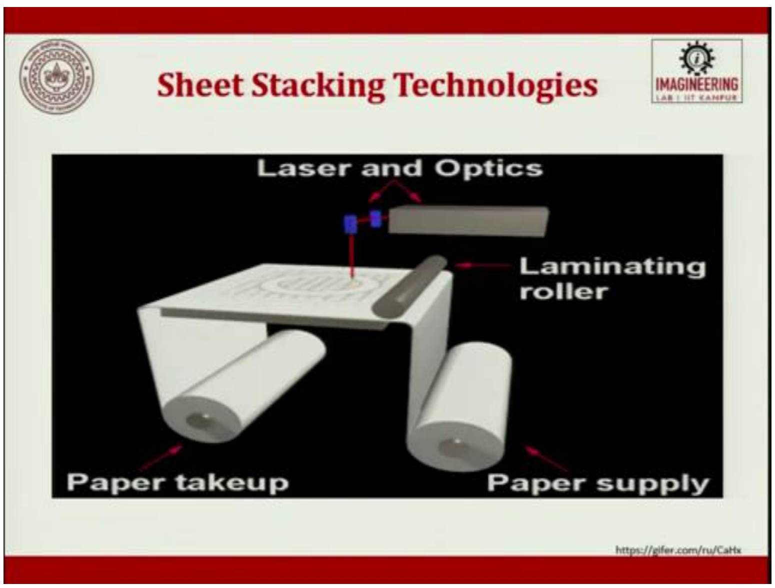

The next one in the solid is going to be sheet stacking technologies. So in sheet stacking technologies, the solid physical model made by stacking of sheet stock, each outline of the cross-section shape of the CAD model that is a slice into a layer. Okay, so I would repeat solid physical model made by stacking layers of sheet stock each an outline of the cross-sectional shape of a CAD model that is sliced into layer.

Starting sheet stock includes paper, plastic, cellulose, metals, or fiber-reinforced material, anything can be there. The sheet is usually supplied with adhesive backing as roles that are spooled between two reels, so this is the in-reel, this is an in-reel, this is an out-reel okay. So, this is a reel which is used and the material, starting material is fit here so it will have a plastic backing.

So this plastic backing what happens when the layer is moved on top of the table so the roller which is a heated roll which will try to move on top of this layer, and it will try to make it viscoelastic such that when the next layer comes on top of it, it gets harder and we try to do the cutting.

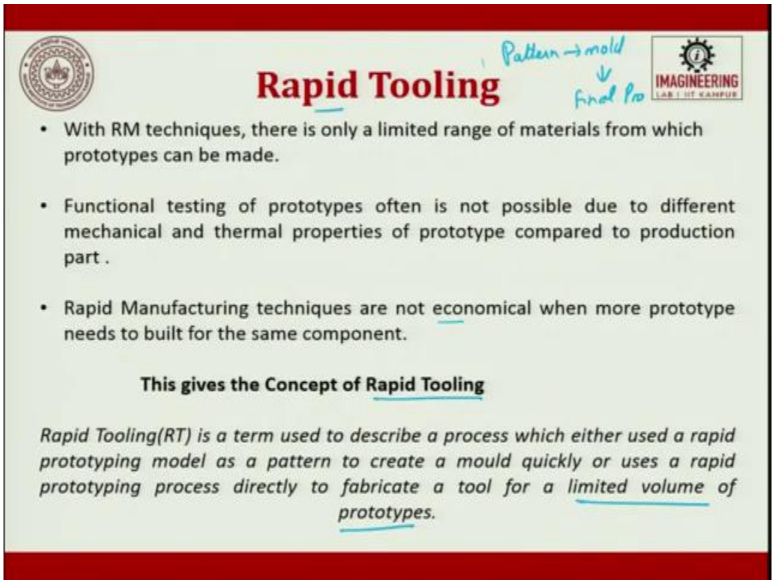
After cutting excess material in the layer, remains in place to support the part getting built. So, this is the sheet stacking technology, which was earlier popular, but now slowly, slowly, slowly it is getting phased off. So, you can see laser coming out through go hit at a Galvo, Galvo to x y stage mount. So here and then from there, it tries to hit on the table where you try to engrave the layer information to produce the output.

(Refer Slide Time: 15:31)




So, you can see here the zip file is given which will help to understand more the layer is there then the heated roller then it is in roll, out roll. So this is a paper supply there is a paper take-up.

(Refer Slide Time: 15:47)



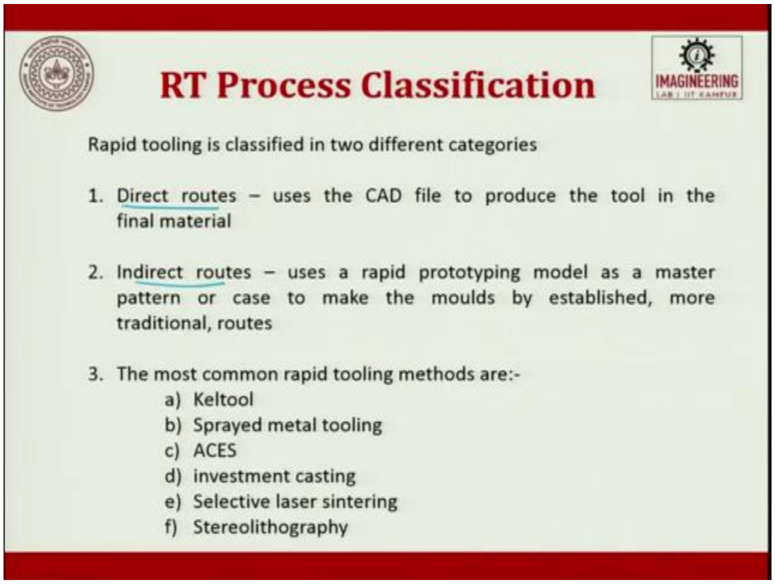

So now let us try to understand where this rapid manufacturing gets a name called as rapid tooling. With RM techniques there is only a limited range of material from which the prototypes can be made, functional testing of prototypes often is not possible due to different mechanical and thermal properties of prototype compare to the production part. Rapid manufacturing techniques are not economical when more prototypes need to be built for the same component.

If it is going to be a replica of the same rapid manufacturing is not the tool, you have to go for conventional path. If there is a customization happening to the component, then we look for the rapid manufacturing. This gives the concept of rapid tooling.

Rapid tooling is a term used to describe a process which either uses a rapid prototyping model as a pattern to create a mold quickly or uses a rapid prototyping process directly to fabricate a tool for a limited volume of prototyping. So, please keep that it began with limited volumes of prototyping, we use rapid tooling.

Rapid tooling is a term used to describe a process, which either uses a rapid prototyping model as a pattern to create a mold quickly. So, pattern leads to mold pattern leads to mold, mold leads to final product. So, if you are able to create patterns quickly then molds can be developed quickly if molds are developed, final products can be done so that is what is idea of this rapid tooling.

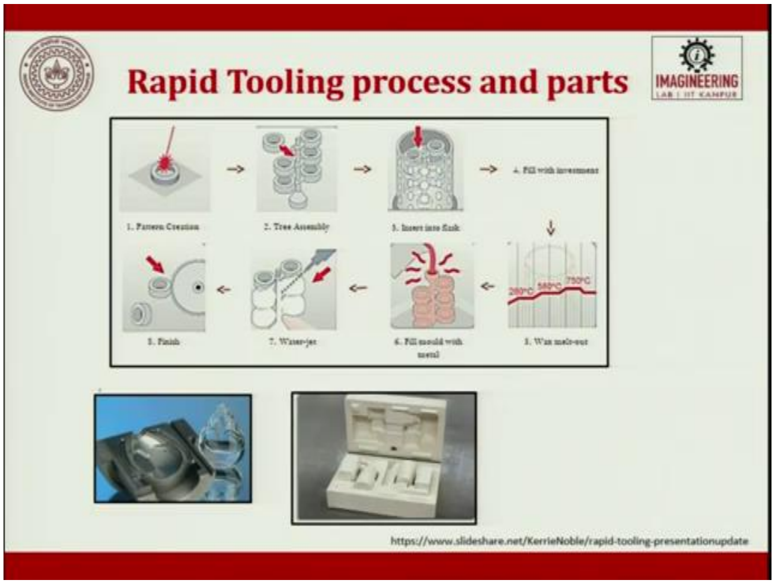
(Refer Slide Time: 17:41)




So rapid tooling process classification, there are two types which are done, one is called as direct routes and, the other one is called as indirect routes. The direct route uses the CAD file to produce the tool in the final material. Indirect routes are use a rapid prototyping model as a master pattern or case to make the mould by established more traditional routes.

The most commonly used rapid tooling methods are Keltool, sprayed metal tooling, ACES, investment casting, selective laser sintering and, stereolithography are some of the metals which are used.

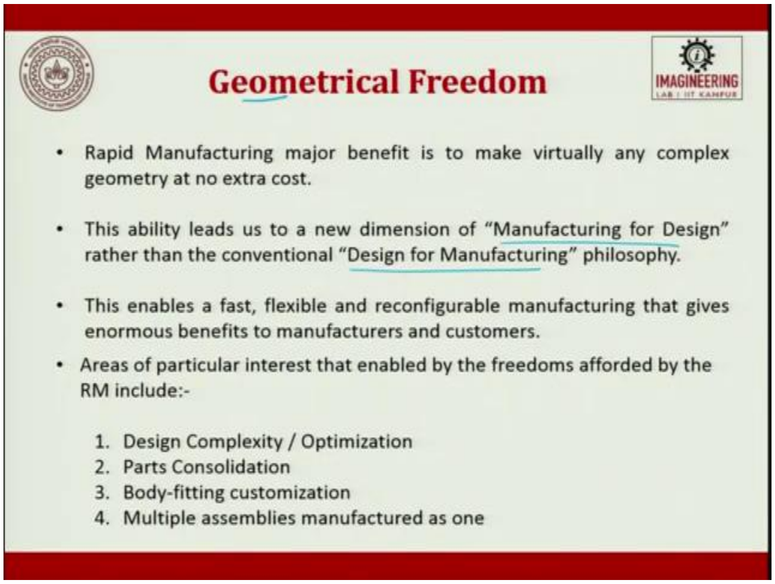
(Refer Slide Time: 18:25)




So, you see here rapid tooling process and how is it used to develop parts. So, the pattern creation will happen through a laser then the tree assembly is done. So, after the tree assembly, we try to insert it into here flash or into a container where there is a ceramic slurry, then, we try to fill with investment, then we try to melt the wax.

So, these are wax, once the wax is melt so the final mold what we get is, is obtained then with the obtained one we try to use other post-processing steps to break this dismantle and get the final product done. So a rapid tooling process here is used exhaustively for creating the patterns.

(Refer Slide Time: 19:14)

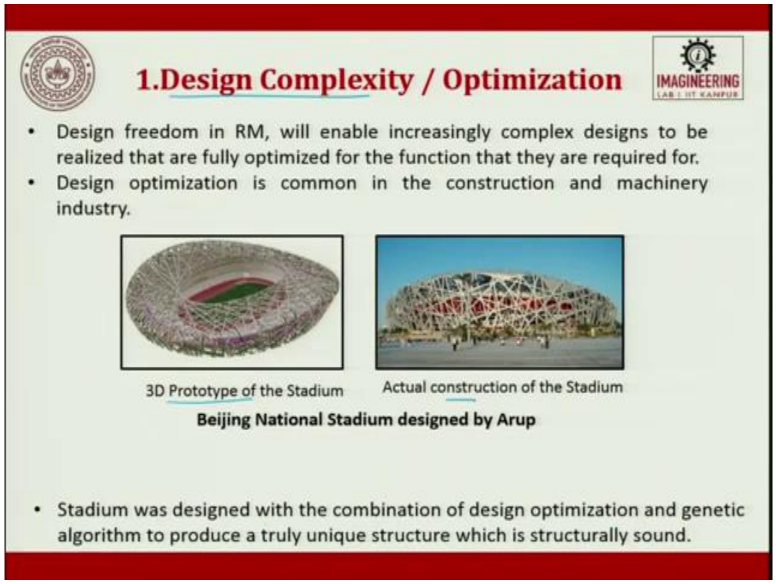



So, geometrical freedom is one another thing which is given in CAD. So, because it is given in CAD it is also involved, and given in rapid manufacturing, rapid manufacturing major benefit is to make virtually any complex geometry at no extra cost. This ability leads us to a new dimension of manufacturing for design rather than design for manufacturing.

So, you have understood the difference, manufacturing for design, and design for manufacturing. This ability leads us to a new dimension of manufacturing for design, rather than design for manufacturing which is a conventional philosophy, this enables a fast, flexible reconfigurable manufacturing that gives enormous benefit to manufacturer and customer.

Areas of particular interest that enabled by the freedoms afforded by the RM includes design complexity, optimization, part consolidation, you will have body fitting customization, multiple assemblies manufactured as one. So, all these things are some of the RM tools which are used.

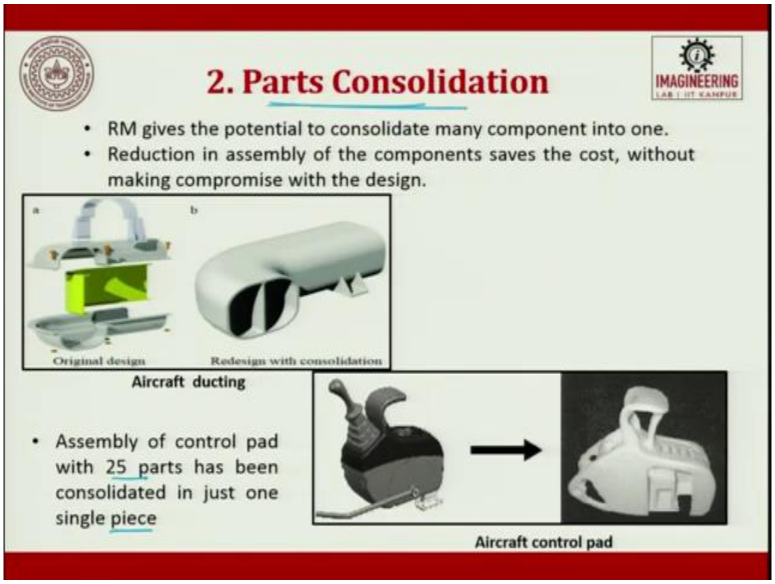
(Refer Slide Time: 20:42)




So, you look at this, you can see that, which for example, if you want to construct a complex city and you also want to try optimization here, rapid manufacturing is used to for better visualization, and then we try to construct the object the design freedom in RM will enable increasingly complex design to be realized, that are fully optimized for the function that are required for.

Fully optimized for the function which is required, one is to cover the other one used to give strength all these things, design optimization is common in construction and machinery industries. So, this is the 3D prototype of the stadium and this is the actual stadium which is constructed in China, Beijing. The stadium was designed with the combination of design optimization and generic algorithm to produce a truly unique structure which is structurally sound.

(Refer Slide Time: 21:45)




Second thing is the rapid manufacturing is used for part consolidation. Earlier rapid manufacturing you earlier we used to produce 6 parts and 8 parts that will be a lot of amount of material also can be reduced which is very much required for aerospace industry and automobile.

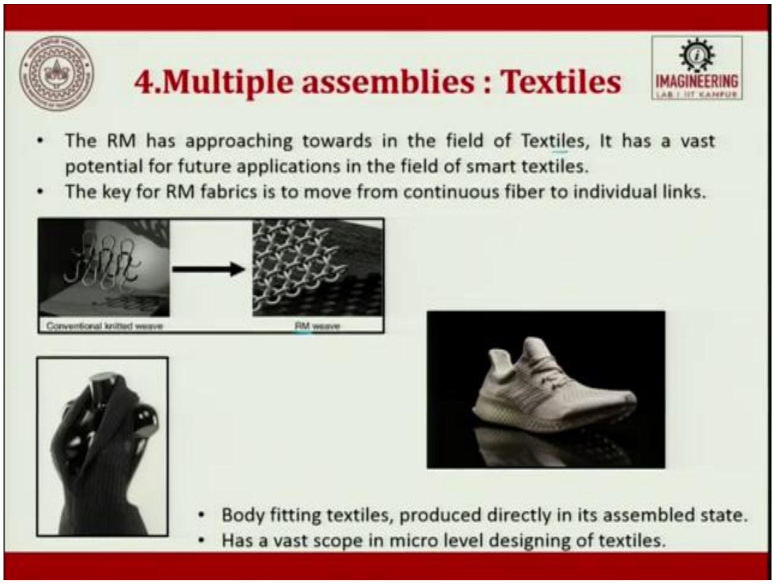
So, rapid manufacturing gives the potential to consolidate many components into one, because you are trying to build a complex thing, reduction in assembly of the components saves the cost without making compromise with the design. The assembly of control pads with 25 parts has been consolidated in just one single piece. So, 25 parts in one piece could happen because of additive manufacturing and rapid manufacturing methods.

(Refer Slide Time: 22:33)


Body fitting customization, many at times there are several chairs where we sit for the entire day and do our job. Many of these chairs are not customized. If it is not customized over a period of time it is going to give you some spinal problems. So conventional manufacturing especially body fitting customised products are not of the reach of the general public due to high cost.

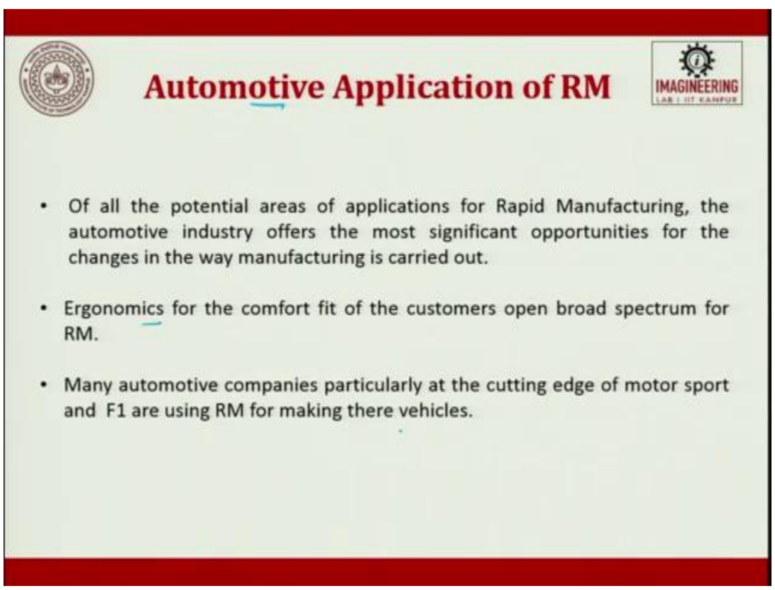
So, here the customer were forced to buy mass-produced goods only. But once the RM and reverse engineering of the product are established, now you will see mass customized chairs which are available in the market. The product now can be manufactured according to the best fit for the customer and the concept of mass customization is done.

(Refer Slide Time: 23:21)



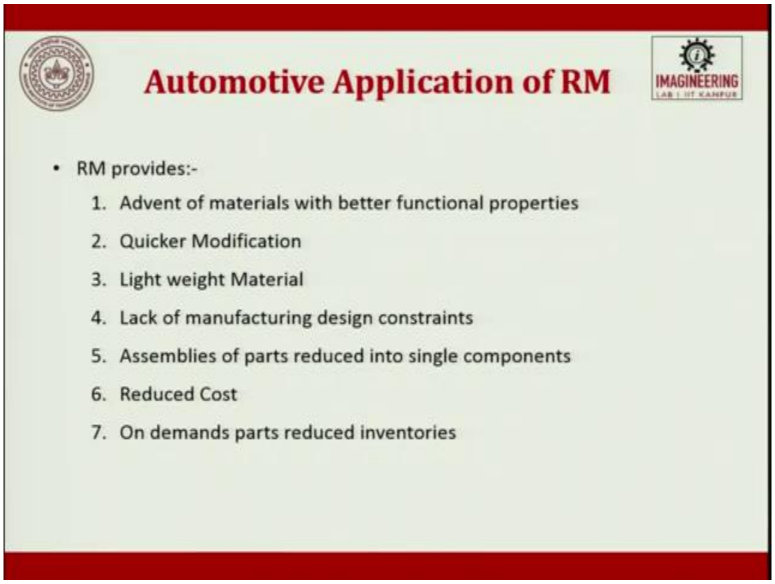

Multi-assembly in textiles, RM has approached towards textiles it has a vast potential for future applications. You can see here conventional knitting weaves are done, then RM weaves are done. Okay, the body fitting textile produced directly in its assembled state has a vast scope in micro-level designing of textiles.

(Refer Slide Time: 23:48)




The automobile application of RM of all the potential areas of application for rapid manufacturing, the automobile industry offers the most significant opportunity for the change in the manufacturing. Ergonomics for the comfort fit of the customer opened broad spectrum in rapid manufacturing. Many automotive companies particularly in the cutting edge of motor sport and F1 use RM for producing their vehicles.

(Refer Slide Time: 24:18)

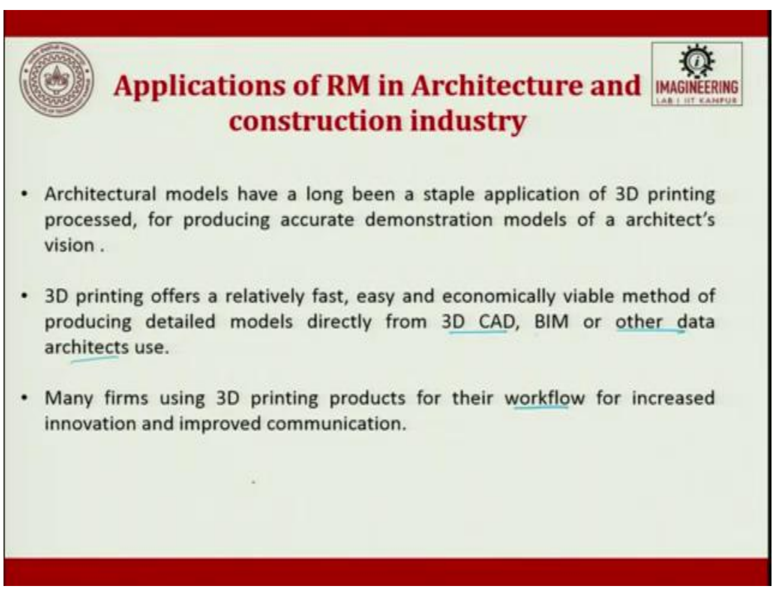



So automobile applications, so the advent of materials with better functional properties, quicker modification, lightweight material, lack of manufacturing design constraints, assemblies of parts reduced into single component, reduced cost, and on-demand parts reduces the inventory. These are some of the applications, which are now enjoyed in automotive industry as part of rapid manufacturing.

(Refer Slide Time: 24:47)


So, a 3D printed car and its parts, completely car where it is rapid manufactured towards customization. So this entire thing shows that.

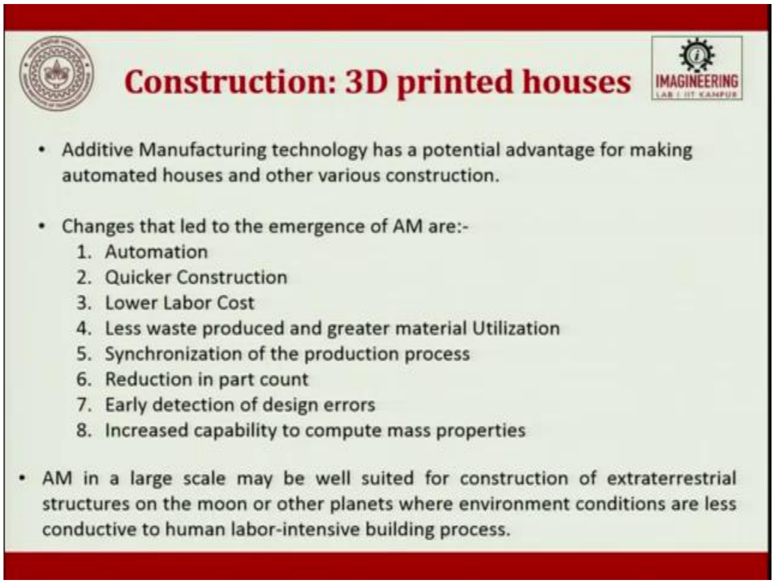
(Refer Slide Time: 24:58)




Application of RM, rapid manufacturing in architecture, and construction industry. We have already seen one example where a stadium was constructed keeping functionality as the optimum and then they have done it.

So the architects' models have a long been a staple application of 3D printing process for producing accurate demonstration models of an architect's vision. 3D printing offers a relatively fast, easy, and economically viable method of producing detailed models directly from 3D CAD to other data of architecture use. Many firms use 3D printing products for their workflow for increasing innovation and improve communication.

(Refer Slide Time: 25:50)



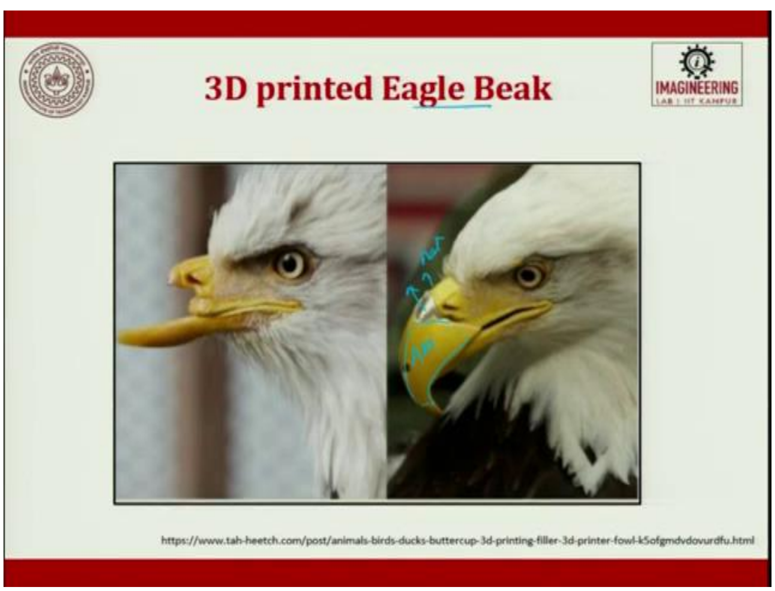

In construction industry, there 3D printed houses have come into existence where directly a houses is printed. So additive manufacturing technology has a potential advantage for making their automated house and other various construction the changes that lead to the emergence of AM are automation, quicker construction, cement materials, then labor lowering the labor cost, less wastage, synchronization of the production process, reduction in the past count, early detection of the design error and increasing capability to compute mass properties.

AM is a large scale, maybe well suited for construction of extraterrestrial structures on the moon or other planets where environmental conditions are less conducive to human labor-intensive building process. Today, 3D printing is used as desert layer for construction.

(Refer Slide Time: 26:53)

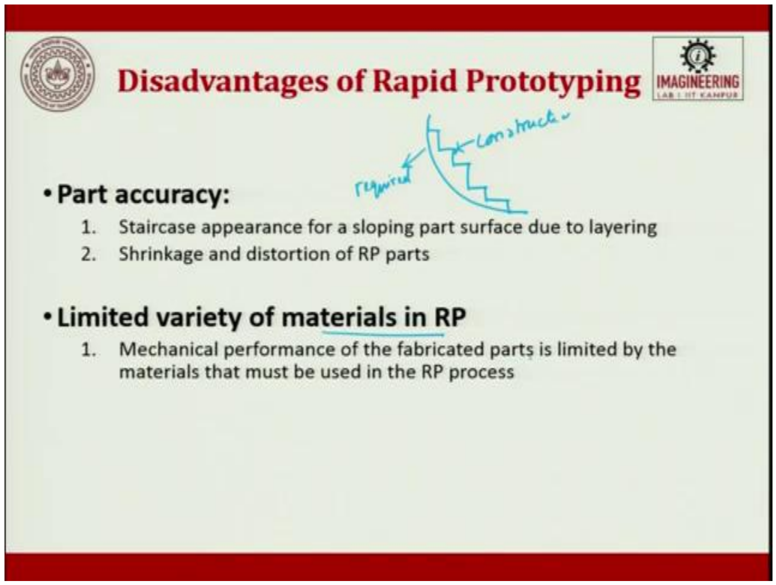

So, these are bridges which are constructed by RM process, rapid manufacturing process. They have done it and here is a tent house or a guest house or a farm house. So, this is completely constructed only by 3D printing or rapid manufacturing.

(Refer Slide Time: 27:11)




Even 3D printing can be used for Eagles beak which is broken, they could make a peak right and then insert with an insert which tries to merge the natural one and the additive manufactured one, and this the eagle is able to enjoy and keep continuing its life. So, here is an application where for nature is also 3D printing is used.

(Refer Slide Time: 27:44)

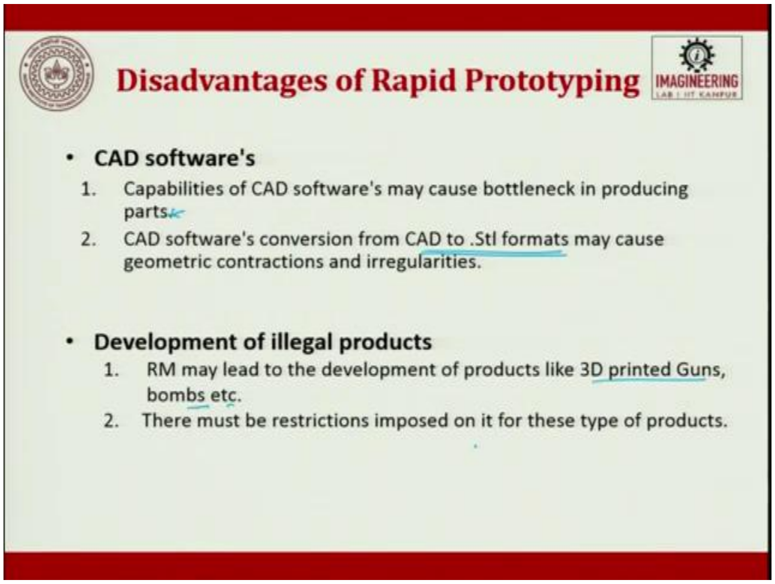



So, there are some disadvantages of rapid prototyping or rapid manufacturing. The part accuracy is very important. So part accuracy means when you have a curved surface, when we try to move along the x and y direction, you have this type of error. So, this is what is the required and this is what is the constructed, I am just zooming, okay.

So, you see here this error is because of the x and y moment and the Z moment. So, you have the staircase error, the staircase appears for a sloping parts surface due to layering, shrinkage and distortion of RP parts are very very important. So, when the product is getting developed, so, you have a lot of small-small distortions happening.

And there is a limited variety of materials are available in rapid manufacturing or rapid prototyping when we wanted to have mechanical parts of the, to be fabricated. It is limited by the material to be used in RP process.

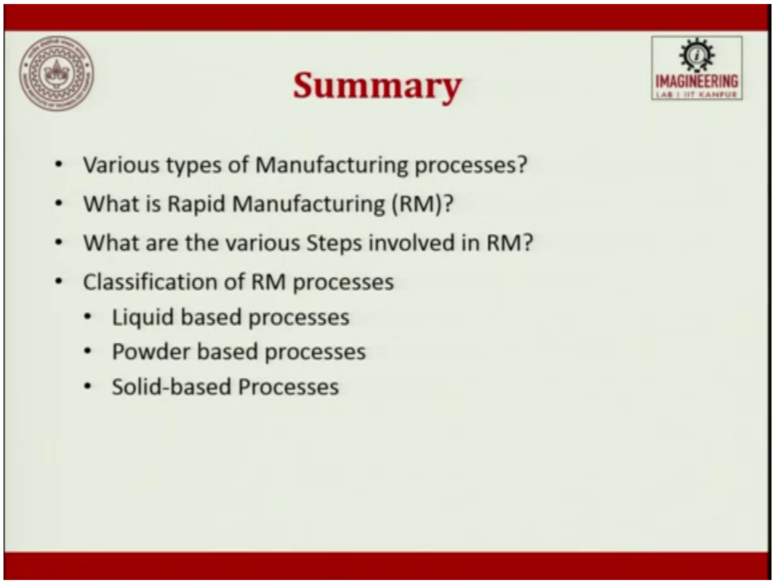
(Refer Slide Time: 28:51)




The CAD softwares are always a bottleneck, the capability of the CAD software may cost bottleneck in producing parts. So, the software converged from CAD to STL formats may cause geometric contradictions and irregularities. For example, when you make these facets there can be overlapping of 2-3 facets leading to an error.

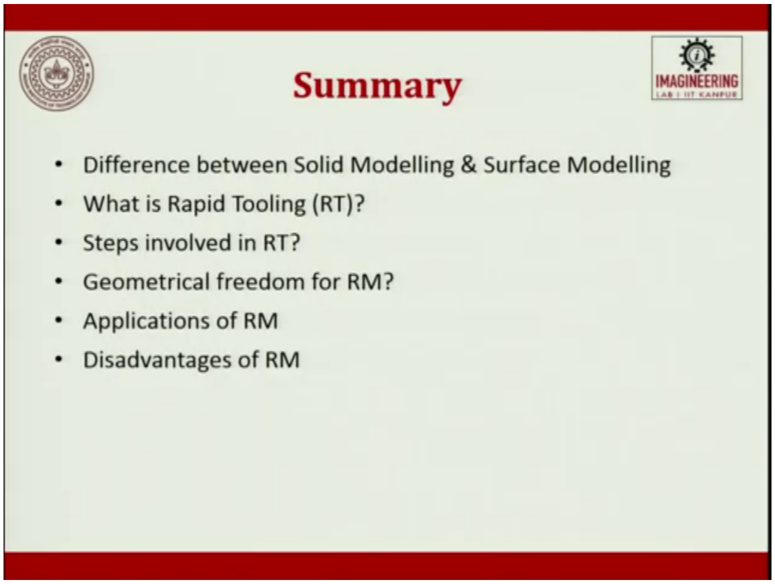
Then development of illegal products, RM my lead to the development of products like 3D printed guns and bombs, etc. So, this can lead very fast but you have to judiciously use, there must be restrictions imposed on this for doing such type of products.

(Refer Slide Time: 29:31)




Finally, to summarize, what we studied in this rapid manufacturing lecture is various types of manufacturing process, what is rapid manufacturing? What are the various steps involved in rapid manufacturing the classification based on the starting material, liquid form, powder form, and solid form?

(Refer Slide Time: 29:49)




Then we saw; What is the difference between a solid model and a surface model? Where are we using rapid tooling, the steps involved in rapid tooling, geometric free form of free Rapid manufacturing, applications of rapid manufacturing, and disadvantages of rapid manufacturing?

So, in this lecture what we saw is just icing on a cake. In this course we studied initially CAD, then we studied CNC, all these things are different-different verticals, we studied about PLC. So, all these things are put together in a hardware.

The CNC machine if you replace a CNC machine with the rapid prototyping machine a nozzle through a nozzle if you are able to pour or a laser head is attached, then a CNC machine will be typically an additive manufacturing machine. So, the CAD knowledge whatever you have is used to generate a solid model or a surface model.

So, after doing the solid and surface model tessellations, layer by layer all these things are software part. So, for this, if you want to enjoy, we should have a thorough CAD basics done. Then we went into the hardware part, hardware where the rapid manufacturing part is constructed and while doing the construction you might have some errors and these errors can be because of the staircase effect and material getting shrunk.

In order to camouflage these errors, we always do a secondary process operation to meet out to the requirements. The rapid manufacturing is used today in the aerospace industry exhaustively, dental industry exhaustively, automobile exhaustively, moon mission exhaustively, civil engineering constructions exhaustively.

So these are the 5 big areas where rapid manufacturing is used apart from your entertainment industry. So, all the major characters which you see in Hollywood and Bollywood, the characters, the mask, the shape, they are all made out of rapid manufacturing today or they will be made out of rapid tooling where they make the mold and then the silicon is casted and then placed on the character of the subject. So rapid manufacturing is the future and this is being talked at every place today. Thank you.