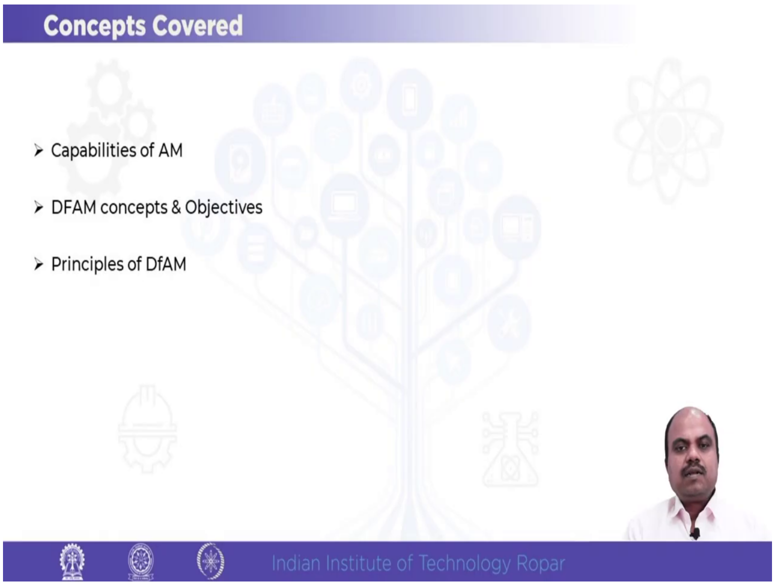
Product Engineering and Design Thinking
Prof. Prabir Sarkar
Department of Mechanical Engineering
Indian Institute of Technology, Ropar

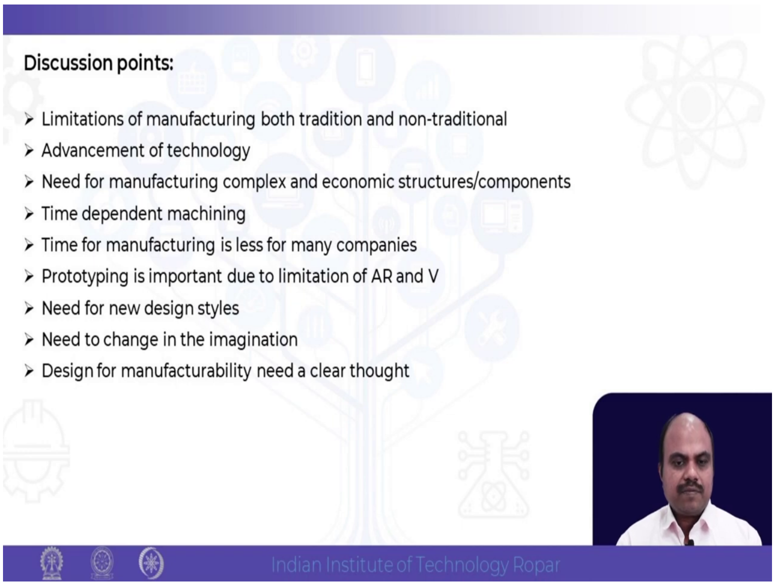
Module - 06
DFM, Rapid Prototyping and Affordability Engineering
Lecture - 27
Design for Additive Manufacturing

(Refer Slide Time: 00:28)



Design for Additive Manufacturing. There are certain points regarding the additive manufacturing process which we need to discuss.

(Refer Slide Time: 00:34)



The first thing is about limitations. The traditional manufacturing process have lot of limitations and this is applicable for both traditional and non-traditional. Traditional means the machining process which we generally use often for manufacturing like lathe, machine, billing machine and other things.

Non-traditional processes which are related to non-traditional machining processes like EBM, work cutting EBM, (Refer Time: 01:07) wire cutting machine, machines which are used like chemical machining, work cutting EDM and various others. Now, when the technology is advancing there are requirements from design point of view that we should make complicate shapes.

And, traditional machine processes may not be able to give us all the possibilities of making these shapes in an economic way. So, the need for making complex shapes which are economic it is right now, right now it is the time and the lot of designers who are moving towards designing products which are complex in design is more ergonomic.

So, it is not that this machine manufacturing processes both traditional and non-traditional it cannot make this kind of products they can. However, these are all a very expensive process if you wanted to go for making it. So, that way we need some other technologies and additive manufacturing is one of the way we can achieve this complexity making the complexity, making the products complex product is much more cheaper.

This traditional is machining process which means that which includes CNC machining. CNC machining it is much more accurate, but its talking lot of take it takes lot of time. So, it takes actually lot more time to make the product because we need to understand the product, make CNC code and put it in the CNC machine. And, even then depending upon the complexity of the product we need 5 axis, 7 axis CNC machines and this machining process is will not take lot of time.

So, time for machining nowadays is something which is very less because companies want to manufacture product faster. So, how do enable them to manufacture product faster especially for complex geometries because smaller geometries which are can be done mass produced like injection more using (Refer Time: 03:43) molding that is much more efficient if we can use mass manufacturing process like injection molding.

However, some of the component which are complicated shape and also batch produced, less number of components into a manufactured then additive manufacturing process is a better solution for this. When we have prototypes especially when you are designing prototypes is very important.

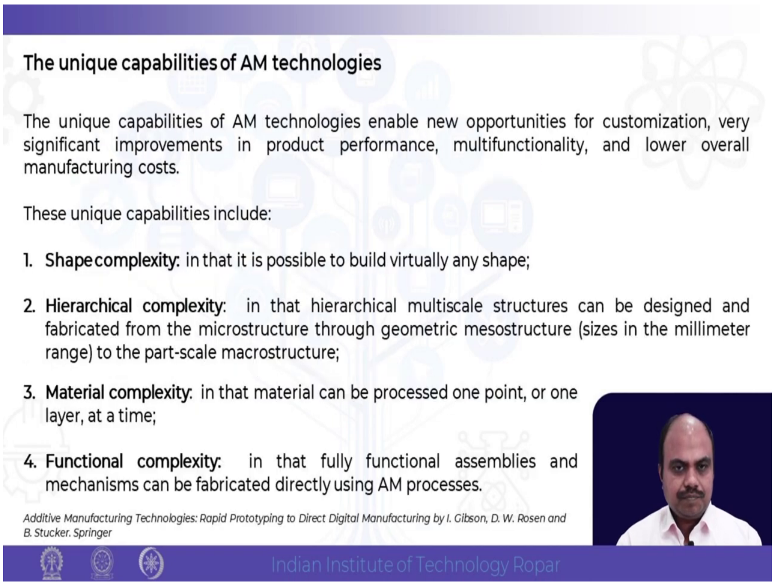
So, we need to have prototypes something like making the prototypes and filling it, testing it; this cannot be done directly using AR and VR, the Augmented Reality and Virtual Reality partially can be done, but not completely. That is the reason we need something which can be done or which can be felt physically which can be analyzed physically which can be maybe we can do some analysis of the strength another material properties and also, we can see how the product is on all physically.

That is the reason we need some kind of technology which can make and help us to make the product physically and additive manufacturing process is one such technology which can help us in making the product very fast. New design styles are coming when you support for that and when we have the additive manufacturing process, we need to change the way we are thinking previously.

Previously, we are thinking that when you designing, we need to think about manufacturing right, but in additive manufacturing process when you are thinking there are lot of limitations which are there in traditional manufacturing process are not there. So, we need to change the way we are thinking.

So, design for manufacturability need a clear thought, you need to change a shift and paradigm shift is required from the way we are thinking that is designing when we are designing a product which is traditionally been manufacturing traditional manufacturing process, now we are going for design for a design within additive manufacturing process.

(Refer Slide Time: 06:06)



So, the unique capabilities of additive manufacturing is to enable new opportunities for customization which is very significantly improve the product performance and multifunctional and lower the overall cost. There are certain unique capabilities of additive manufacturing process. One is shape complexity. Shape complexity means it can it is possible to make a really complicated shape using additive manufacturing process.

Hierarchical complexity. Now, previously we used to have same kind of material in general, but now in the hierarchical complexity there are multi scale structures which can be designed from the microstructure through the geometric mesostructure and the scale up is also possible, layered manufacturing is possible using multiple materials using it. So, all these possibilities are there when we are making using additive manufacturing process.

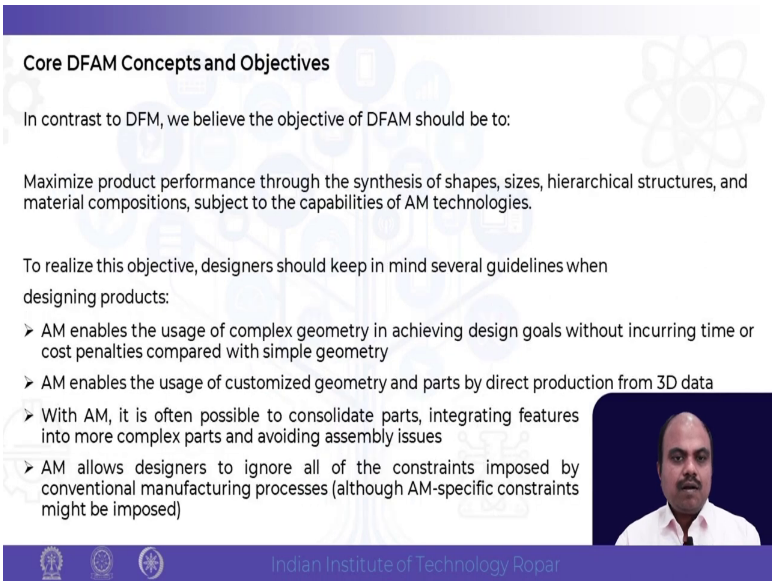
Next is material complexity. So, traditionally if you want to have multiple layered materials in a product is very difficult, but in manufacturing process with additive manufacturing process this is quite easy. Because, the same machine can be used to manufacture products using multiple different kinds of material and different layers of manufacturing process.

Functional complexity, previously we used to have a process product which is having just a component when you manufacturing and then of course, we are assembling multiple components in making a system work. But now we have completely freedom complete field lot of freedom is there where functional assemblies and mechanisms can be made. Compliant mechanisms can be made.

Mechanisms which is difficult to do manufacture using non-traditional machine process because very small and very thick materials component size can be manufactured in the same machine. So, if you want to go for micro manufacturing process, traditionally the machine is different.

For normal manufacturing process machine is different even though both are CNC, but in CNC in AM process that is additive manufacturing process all these possibilities are there where the same machine can be used for making very small structure, too large structure. So, in the same structure we can have multiple of them.

(Refer Slide Time: 08:59)



Now, in contrast to DFAM that is design for manufacturing, we design for manufacturing the normal design for manufacturing we are actually making a products. But, in design for additive manufacturing we are maximizing the product performance using synthesis of the shapes, sizes, hierarchical structure and then subject to capabilities of AM manufacturing process.

This is possible because we are making things which are easy to easy for the designers to think and manufacture, because they know now that lot of limitations are gone. They can make machines; they can make products which are much more complex. There are several guidelines which can be used, one is that complex geometry can be made.

Now, complex geometry can be made by using normal manufacturing process also, but in additive manufacturing process, the time required to make complex geometry is a simple geometry is almost similar. Because, it depends upon the amount of material amount of and then the shape overall shape, overall type of the material and the build volume.

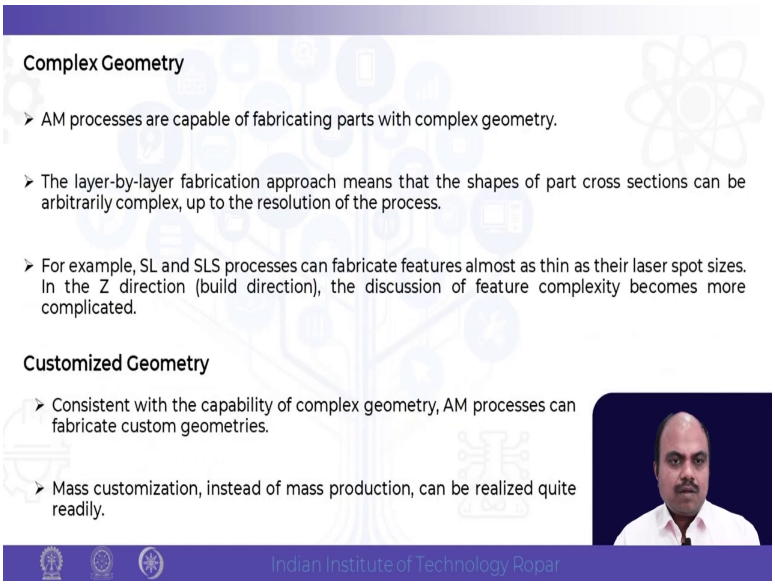
So, the difference will be very less if you want to make a simple product or complex products of the shaped same shape whereas, in the normal manufacturing process is not like that it is very different. And, additive manufacturing process is enables user of customized geometry for each and every component which you make, each and every component can be customized because 3D model may be different.

So, five different components we are making normal traditional manufacturing process. It is difficult because you need to change the coding efficiency or in normal manufacturing process, you need to know the a change the process. But, in additive manufacturing we just change the CAD model, put the find out they make the steel file which is different from different (Refer Time: 11:20) different product and then print it.

So, it is possible often to consolidate part we will see that, how multiple parts can be consolidated into one which means that when one product, one component may have been made using multiple part in using traditional manufacturing process because that was easier to make because casting was easier.

So, we cast different components, machine some portion of it, assemble it and then you make. But, in additive manufacturing process maybe all these components not equal just one simple contoured shape component may be enough. So, that can be done using additive manufacturing process. It also gives an opportunity to the designer that you can ignore all the constraints of the conventional manufacturing process and in additive manufacturing process the number of constraints which are very less.

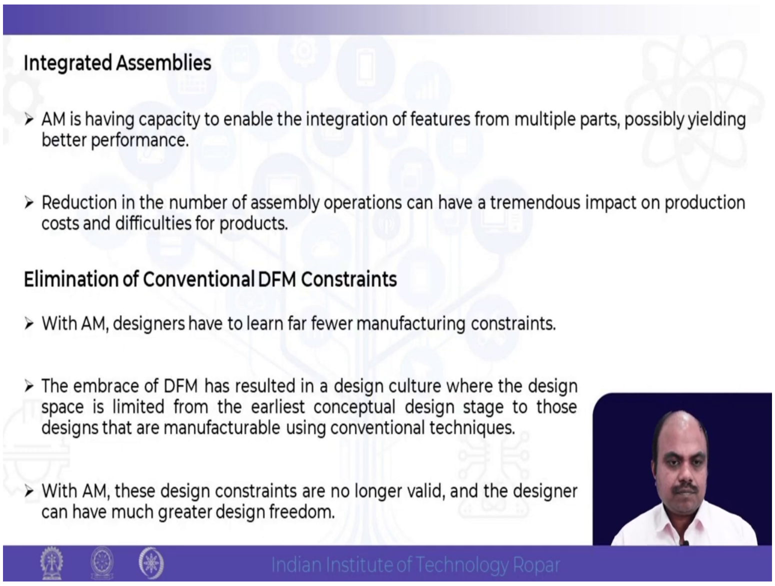
(Refer Slide Time: 12:28)



So, complex geometries we can make. So, layer by layered complex geometry we can make, but you should also understand that Z direction, the strength of the material in the additive manufacturing process is different in different directions depending upon the kind of component material machining process which we are following, that we should understand.

So, complex geometry process when we are making, we can make it in additive manufacturing process. Customized geometry that I already told that, we can change the design in very fast.

(Refer Slide Time: 13:10)



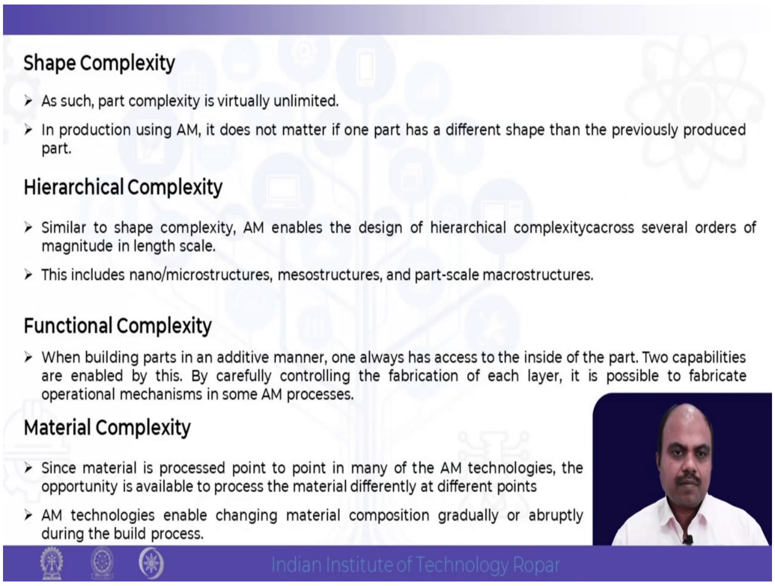
So, in integrated assemblies we can make where additive manufacturing process is actually enabling integration of features whereas, in traditional manufacturing process if you want to do it, you have to do it in different different components and assemble it. So, it is going to reduce the cost a lot.

Of course, mass manufacturing using additive manufacturing is something which is challenging yet still it is challenging. Now, traditionally this design for manufacturing has lot of constraints like you know rectangle slots if you want to make, you have to think how can I make.

So, when a designer is giving a rectangular slot in the design, you may have tried to avoid it, but in additive manufacturing those things are not there. So, there are much fewer constraints then the design culture whether space is limited that is also we need to the people have been thinking in different direction now. So, the design constraints which are there especially due to manufacturing all these things are gone.

Now, the designer is having lot of freedom to think that we can make complicated shape parts without affecting the cost of the product. So, this is going to change the way designers are thinking. So, design thinking when you are using design thinking, need additive manufacturing process with (Refer Time: 14:51) is going to change the way people are thinking products and how to design it, because the manufacturing constraints are all reduced now, many of them are reduced.

(Refer Slide Time: 15:04)



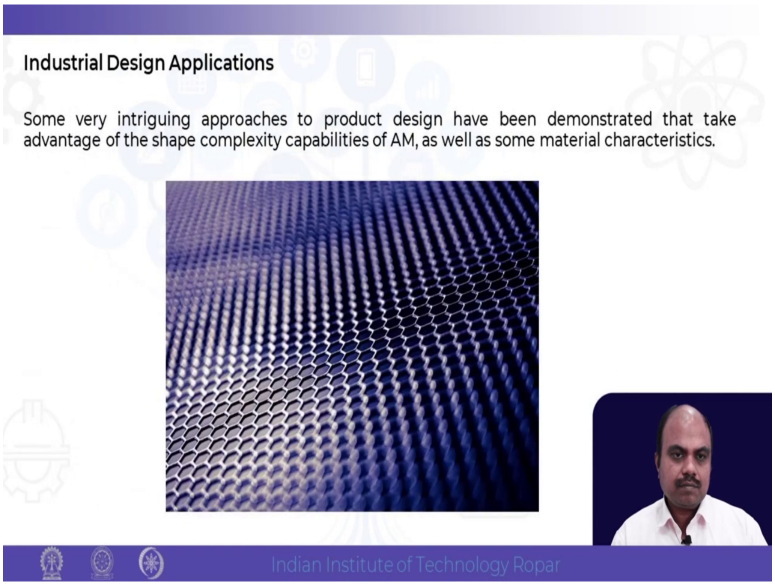
So, another thing is shape complexity we can have. So, all these things are possible using additive manufacturing process, higher little complexity we can have that is in terms of hierarchy we can make materials, hierarchy functional complexity. Material complexity all these things were possible in additive manufacturing process now.

(Refer Slide Time: 15:25)

So, now designers will have a possibility of exploring design freedom. Multiple parts are made together, it is much more simplified. So, we are seeing a world now where especially in the area of design and manufacturing things are much more simpler and customizable, economic etcetera. So, parts consolidation redesign.

So, especially this is important when there is low volume production is there if you want to have more parts, it is going to be expensive. So, parts consolidation something which is important to have. Hierarchical structures we can have.

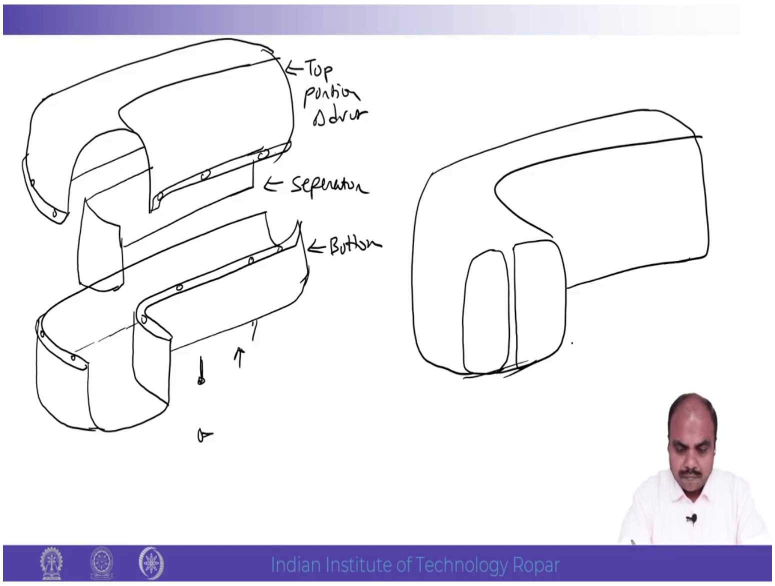
(Refer Slide Time: 16:15)



Industrial design application, the industrial design things are very different where we need products which are looking beautiful, attractive which are aesthetics which means that they are attractive and also ergonomics. It will be suitable for people who are going to use it and this is possible when we have additive manufacturing with us, ok.

Now, we will have two examples in which we would learn how part consolidation is going to be an important step in this additive manufacturing.

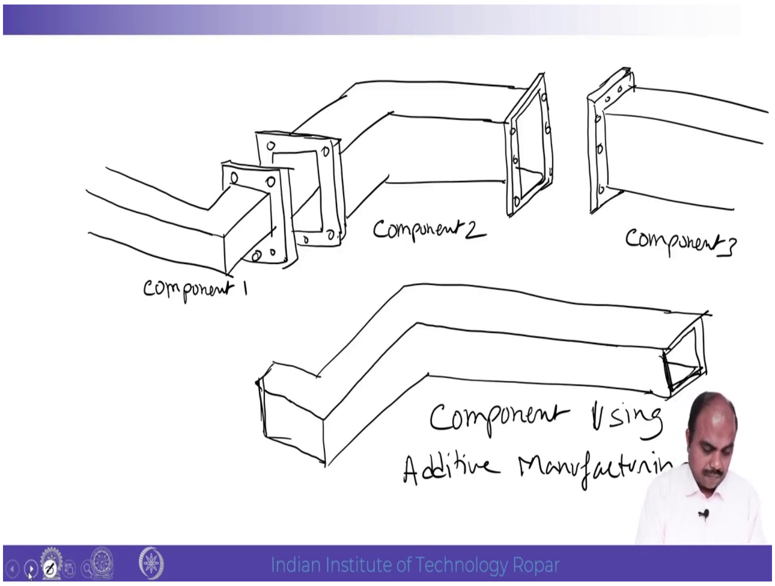
(Refer Slide Time: 17:19)



So, let me draw a example of it. So, let us imagine there is one part like this which is there. This is the valve 1, the down portion of the part. This is the other part which is there and it is having some kind of way to screw the part together. Inside there is another component which is going to be like this which is the separator duct this is. So, this is top portion of the duct and this is bottom and this is the separator.

Now, this is having lots of components. Imagine this is now we are going to make in additive manufacturing. So, we do not need to have these components. So, here you see lot of screws will be going up ok. So, all these required things are there. So, now instead of doing all these so, we can make a single component which is going to be consolidated one. So, let me draw that one first. So, in this one we will see another example.

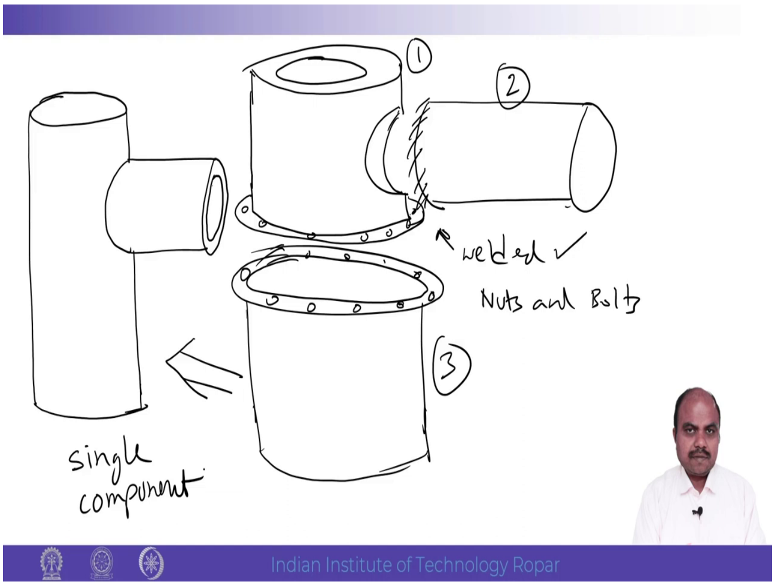
(Refer Slide Time: 20:41)



And take for example, that we are going to have this kind of component. Let us see this is water housing pipes and this is junctions. These are screwed with respect to each other. Here, third component is component 1, component 2 and this component 3. Now, instead of having so many components and having screws to join it, we can just use a single one and that is going to be like this something like this.

Because, we are using 3D printing so we do not have to really worry about this. So, we do not need any junctions and directly we will get the part like this. So, this is component. So, it is made with additive manufacturing. So, we get the single component like this. Now, we will have another example.

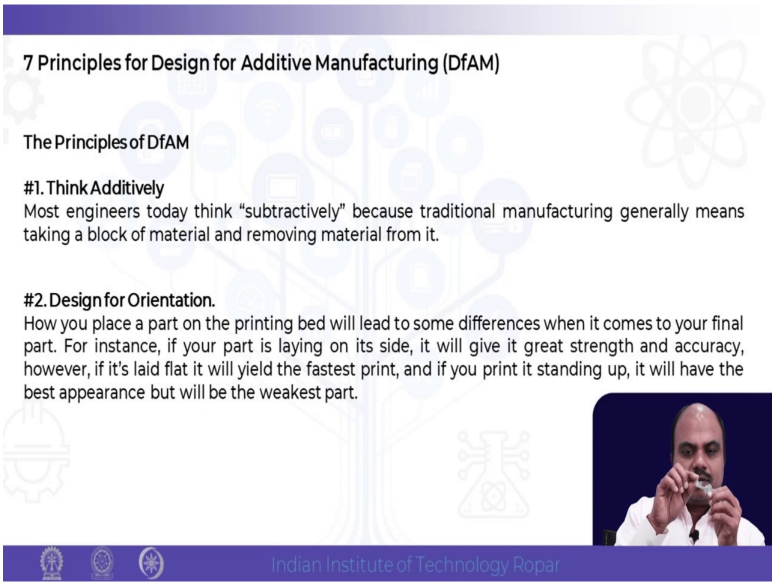
(Refer Slide Time: 24:00)



Imagine there is one component and it is having a hole here. So, down of it this is made using there is one another one similar to this. And, there is one another component is coming like this and this will be welded in this place. So, now instead of having this, this one what we can have? We can using additive manufacturing, we can have instead of all this one we can have single one.

So, we can see from here to here we have one component 1, component 2, component 3 plus welded. This is and then and then we have also nuts and bolts and all these things in this one we have single component. Yeah. So, I think you have now learnt how easy is to simplify the design now using additive manufacturing.

(Refer Slide Time: 26:42)



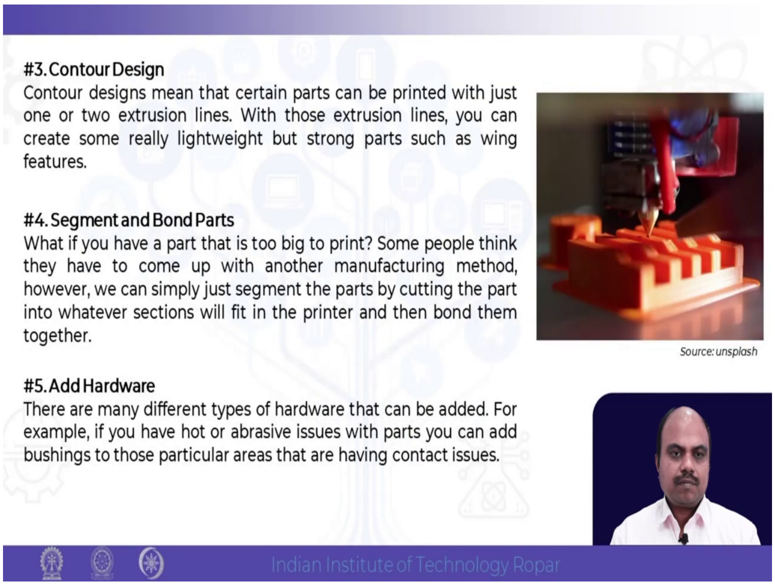
Now, 7 principles of additive manufacturing process. First is think additively. Previously, we should think subtractively which means that whenever a component is there, we used to think that how can I make this component. So, let us say I have this component, previously I should think that ok I have this rectangular bar and then I am going to use a method to cut.

And, then whatever is pending, whatever remaining it is a component which means that I need to use a wire cutting idiom maybe or a very small very accurate milling machine, micro (Refer Time: 27:25) micro milling. Now, in additive manufacturing all these things are not required, we have to just use the machine and print it because it is like addition to each other.

So, the first thing is think additively, change the way we are thinking. Design for orientation is because in additive manufacturing process, the orientation if you change; it is going to affect the quality of the product, it is going to affect the time of the manufacturing process and also is going to affect the cost of the manufacturing.

Because, if you change the orientation, the support material which are required during the manufacturing process it will be different. So, for some configuration you may not be requires support material, for some other configuration you may require. And, then where the strength is required which side which portion which direction the strength is required on that basis you have to orient the process.

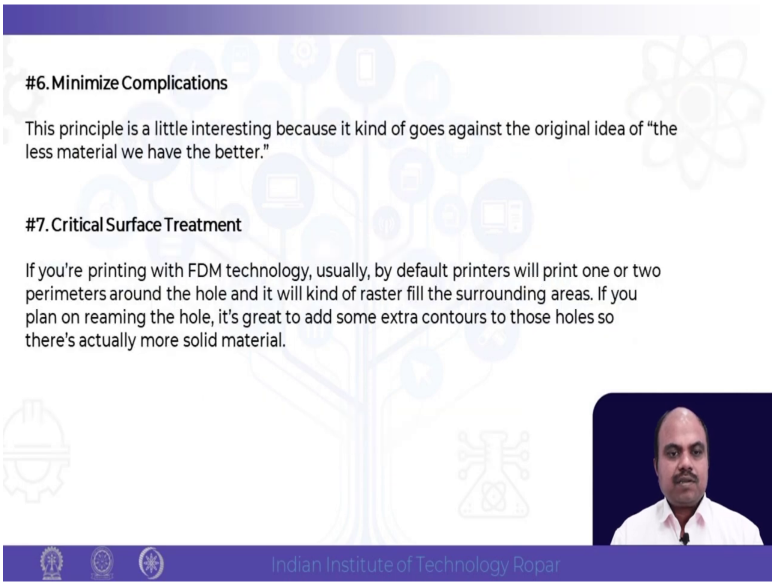
(Refer Slide Time: 28:30)



Contour design where it means that where we need to we can make contour design that certain portion can be printed with just one or two extrusion lines and with the extrusion lines you can really lightweight, but strong parts can be made. The segment and bonded parts. This is you know the another way we can have that if you have bigger product, how you can manufacture?

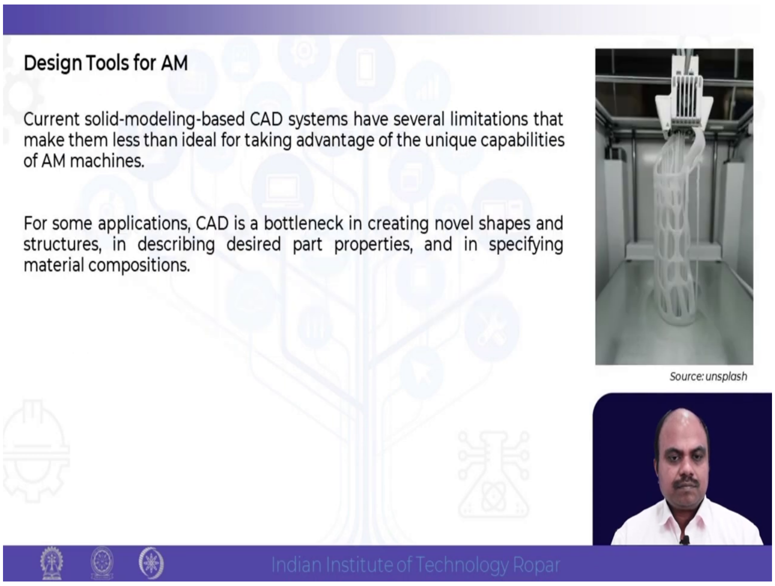
So, make small-small products small and then assemble it; so, that with bond bonded bond. So, that is possible in additive manufacturing process, in other manufacturing process difficult. You can add hardware, one can add hardware while manufacturing is going on, one can have add hardware. So, it will become a more directly a complex product directly can be made.

(Refer Slide Time: 29:33)



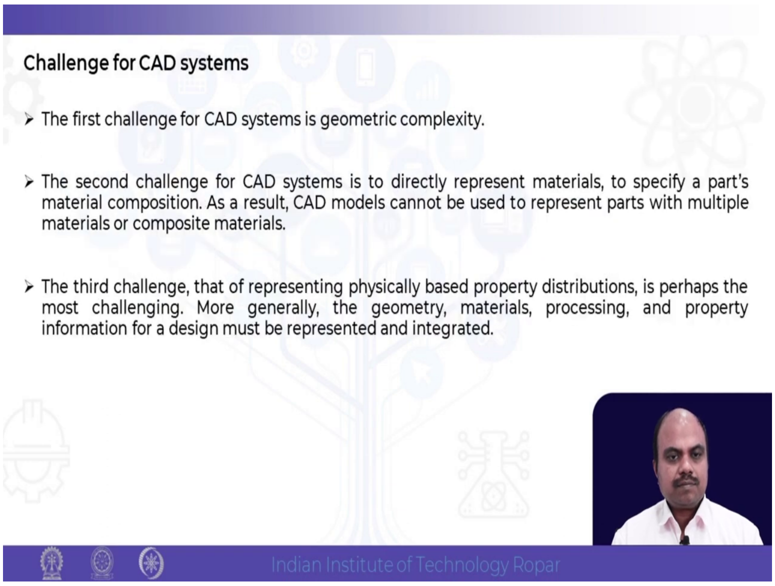
Minimize complexities means in this we can make the products much more simpler with less material and critical surface treatment that can also be done.

(Refer Slide Time: 29:49)



So, when we are talking about additive manufacturing process, you should also understand it is not just about some of the some limitations are there, the limitations with respect to CAD model also, CAD systems.

(Refer Slide Time: 30:03)

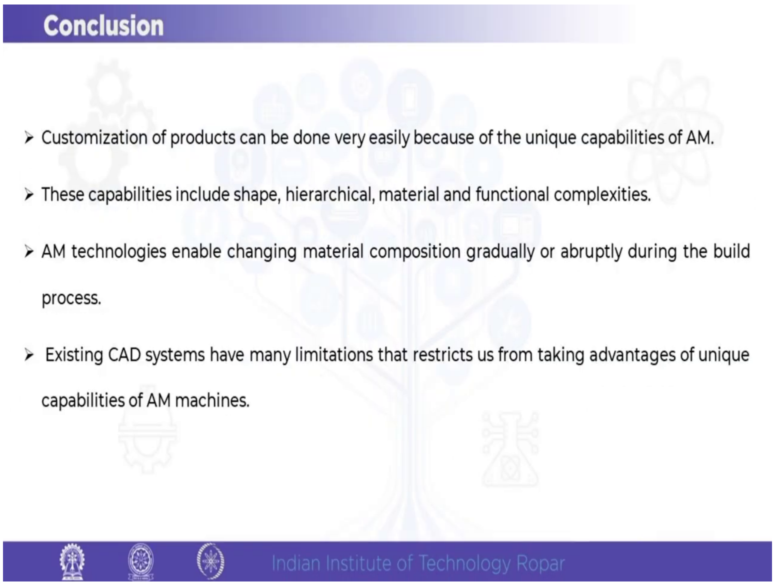


So, what are the limitations of CAD model, CAD systems? CAD system which is there (Refer Time: 30:09) ideas, Unigraphics, UX, NX, SOLIDWORKS, CATIA, Rhino. There are so many softwares which are available. However, many other software are not really designed to take care of the additive manufacturing process, because in a CAD CAD software many of you would have used it, that if you want to make really complicated shape, this is sometime is difficult using CAD, CAD model. It will take lot of time.

Second is the material which are there in the CAD system, if you want to make a CAD model with multiple materials or composite materials is difficult. Nowadays, recently people the CAD softwares are adding this facility, but if you think that there are where variation in the material across the product surface. If you want to make that kind of material, if you want to make you want to model that kind of material in the CAD system that is something which is still a difficult.

And, if the complexity is a high, analysis is going to take lot of time that is another problem and third channel is representing physically based property distribution. And so, if you have a property distribution of a product across component from one place can be varying and different components having same components having different material is made ok; then how do man model it, that is something in difficult. There lot of challenges there involved in this one.

(Refer Slide Time: 31:58)



Thank you.