Product Engineering and Design Thinking
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Module - 06
DFM, Rapid Prototyping and Affordability Engineering
Lecture - 26
Introduction to Additive Manufacturing

Today we will be learning about Additive Manufacturing. Additive manufacturing is a new revolution in manufacturing driven by cutting-edge technologies and breakthrough innovations, additive manufacturing is reimagining production processes, and redefining sustainable manufacturing.

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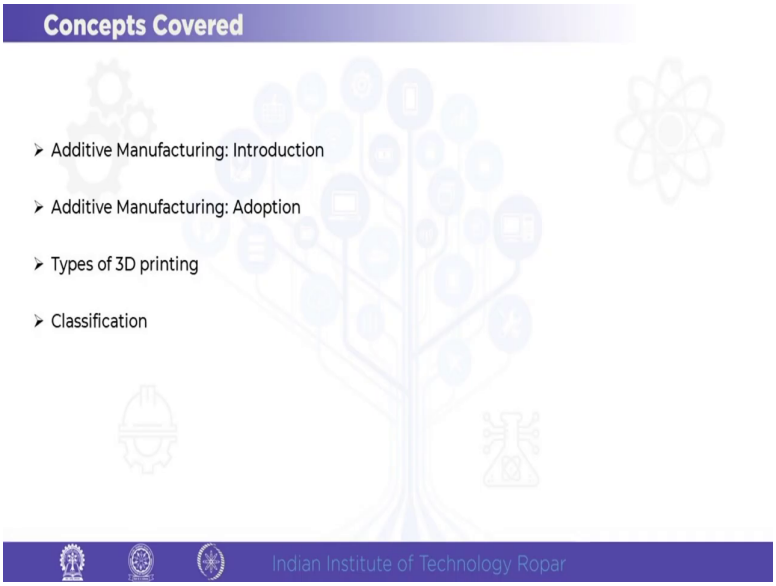

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Additive manufacturing is currently more than 2.2 billion industry wide, industry wide ways, world wise wide. And if you see the machine, there are lot of machines which have been currently sold across US and globally in India also large number of machines are being sold by various companies. The data which I am having is from 2012, it is that time lower cost machine was 35,000 was sold and in US and especially in other places and US also the bigger machines were only 6,000.

But now things have changed. Now, what we have is with 20.50 CAGR, global additive manufacturing, it is supposed to be a worth of 34,846 million by 2028.

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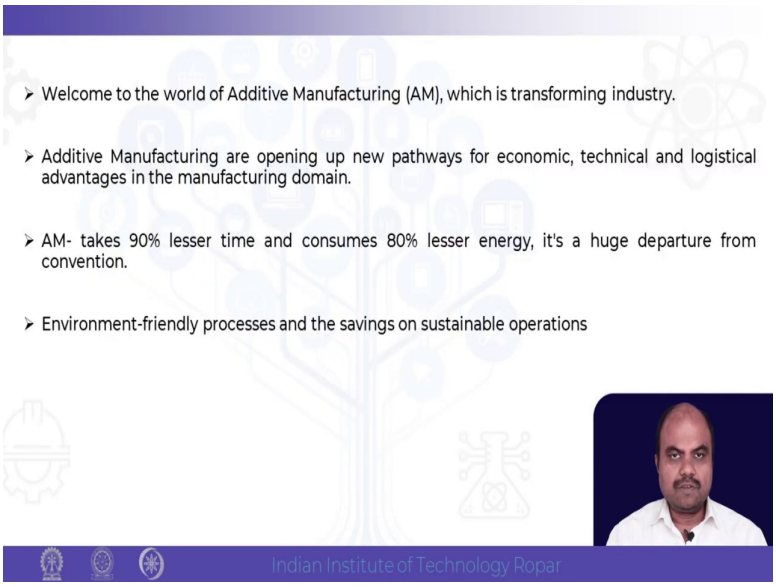

So, welcome to the world of additive manufacturing, which is transforming in India manufacturing process and world wise manufacturing process is a very big way. It is opening a new pathways to economic, technical and logistic advantages in the manufacturing domain.

Additive manufacturing takes less than 60 percent of the time and consumes 80 percent lesser energy. It is huge departure from conventional manufacturing process, traditional process that is both traditional and untraditional processes. It is also environmental friendly, because in normal manufacturing process it is a removal technique right. So, there is a block, he removes some portion of the block and after removing whatever is there that portions that portion is basically a component.

So, we have to think what is exactly happening to this portion which is being removed that is sometime waste, sometime we are recycling, sometime we are doing other things, but that is

going to in that is lot of energy required for recycling where is the additive manufacturing things are very different. We are directly printing only those portions which are required as a component and of course, little bit of support material is also added.

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So, while conventional and subtractive manufacturing process 3D object by machining out additive manufacturing is properly known as 3D printing it is also known as 3D printing. It makes layer by layer manufacturing and builds product in a minutes and also smaller sizes and bigger sizes components are also made can be made using additive manufacturing. So, very small at micro level printing is also possible whereas, even a civil systems bigger projects using additive manufacturing is also possible.

So, additive manufacturing a rapid prototyping or 3D printing it is a it print faster significantly reduces time to market very fast whenever you want to print something you take

it make the CAD model and convert to a STL file and give it to the computer and the from computer is going to give it to the 3D printing machine.

So, the time for design to manufacturing is very less and this speed up the overall innovation. So, new technology new product if you design you have to wait for long time to actually realize it, very fast we can design and produce part very and less time. So, it is huge benefit any sustainability also resource consumption is less and then cutting gas emissions are reduced and applications are limit less. It is various models we can fabricate and using various application in various industries.

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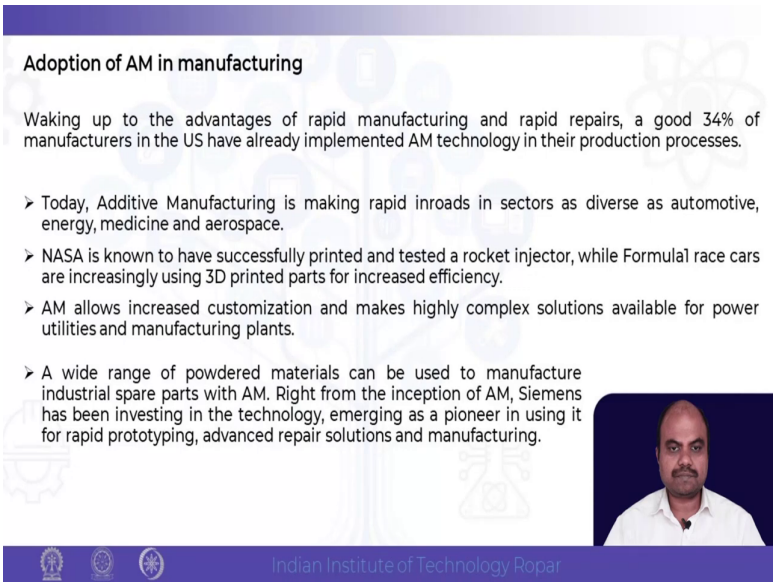

So, whenever we see is adding up it is a 34 percent almost 34 percent of the US manufacturers already adopted additive manufacturing in their manufacturing plants and manufacturing systems. It is not required that we have to remove the additive manufacturing

process, additive manufacturing process can replace some portions or some processes. However, it could be it should be actually as a and addition to the manufacturing technologies and the machines which company is already having.

So, the added advantage which companies can use it and make it use for multiple applications. So, applications are diverse from automobiles energy, medicine, aerospace, so many applications. NASA has successfully used a rocket injectors and a in a formula car 3 manufacturing product has also being used.

A wide range of materials can be covered which is which can be used for industrial application and also for other applications. Repair, previously repair was a big problem because the component has to be taken out or it has to be replaced. But now with additive manufacturing process the component needed to be thrown out it could be repaired easily. There are so many techniques which are available in additive manufacturing that can be used for repairing of components.

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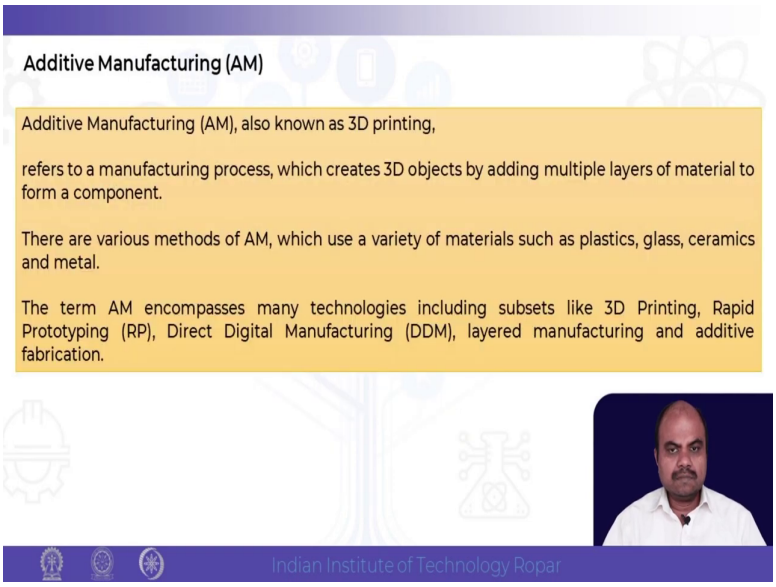

So, additive manufacturing is also known as 3D printing. It is refers to a manufacturing process which creates 3D object using multiple layers of products to form a component. There are various materials various methods are there for additive manufacturing and various materials can also be used like glass plastic ceramics metals.

There are also other technologies like 3D printing rapid prototyping, direct digital manufacturing, layered manufacturing and additive fabrication. All of them have similar kind of terms which are being used to depict the additive manufacturing setup processes.

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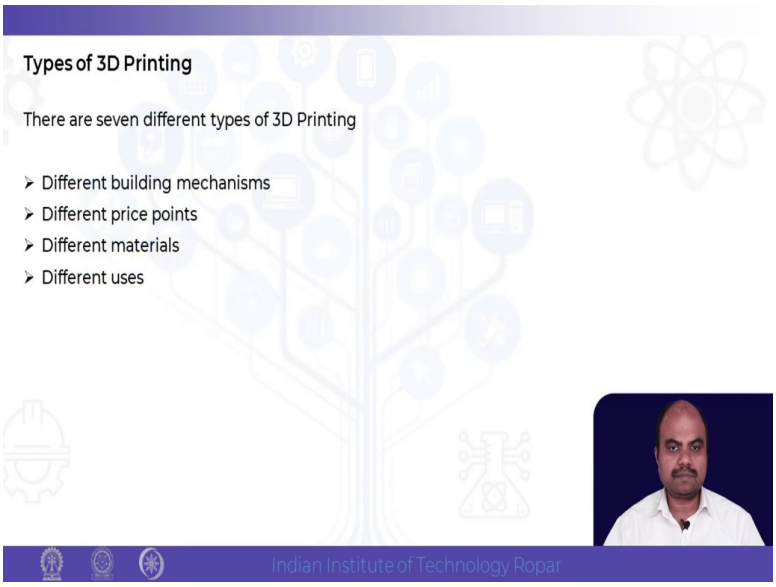

As far as standard there are actually there are various additive manufacturing processes, but there are 7 major additive manufacturing processes which we are going to learn soon. And why this difference is in terms of building mechanisms, price point materials usage there are so little bit of difference is there in all these some of them are quite different with respect to each other.

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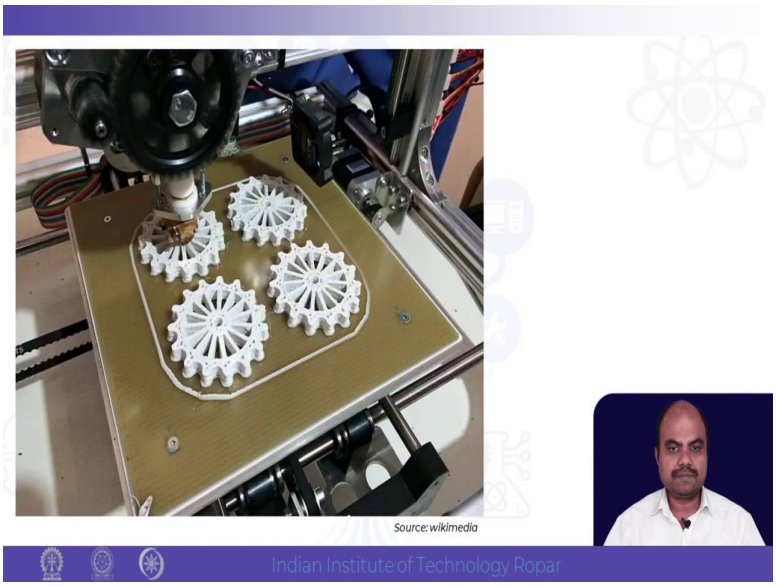

So, in this image which you can see here additive manufacturing machine is used to make as a very intricate setup plastic components.

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So, why additive manufacturing's are manufacturing used? It used for prototyping, it used for low volume manufacturing, tooling; tooling means previously especially if you see the tooling or plastic bottles or anything which you want to make dyes are very expensive you have to make 5 axis 6 axis 7 axis milling machine, CNC milling machine to make a dye and it takes lot of time also.

Now, many of the tooling can be done in additive manufacturing process metal additive manufacturing process and of course, post processing required, but that is much less time consuming compared to the post processing or the total time required for manufacturing. Consumer products can also be made; customization is very much possible with additive manufacturing because previously we used to have one design which is being made multiple times.

Now, if additive manufacturing used, we can use the same means every time we have to print. So, you can customize easily. Art production can be, AM can be used for art production also and see how it looks. Design checking you can make more type prototype and check whether the design is ok or not, but apart from the same prototype can be also analyzed.

For education AM is used for medical lot of applications are there many places AM used.

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So, now categorization of additive manufacturing process here you see one image of metal additive manufacturing machine.

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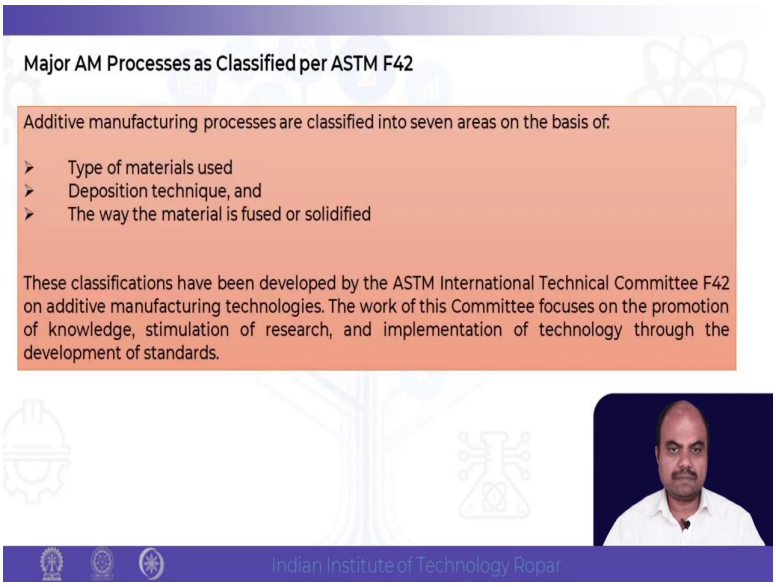

So, as far ASTM F42 additive manufacturing classified into seven major categories. The difference in this are basically material used deposition techniques which is used in the machines and the way the material is being fused or solidified.

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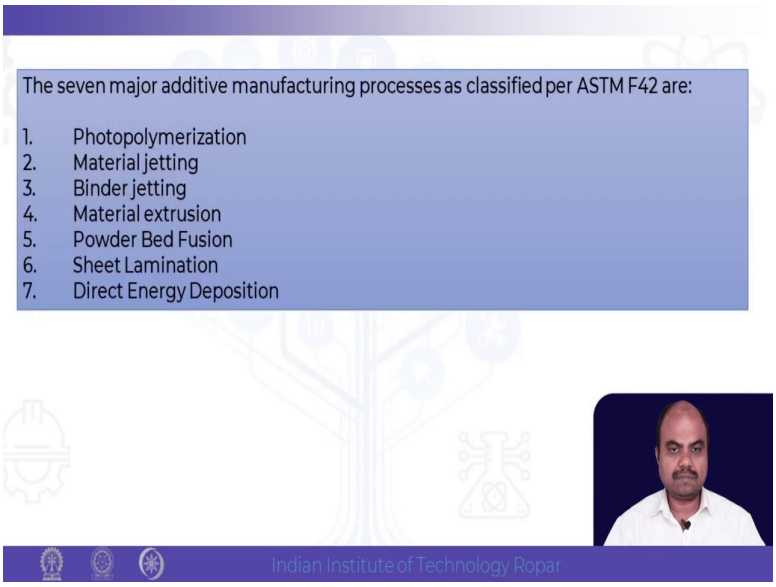

So, what are the seven additive manufacturing processes according to ASTM F42? One is photopolymerization, second is material jetting, third is binder jetting, forth is material extrusion, fifth is powder bed fusion, 6th is sheet lamination, 7th is direct energy deposition. Now, we are going to learn more into in depth.

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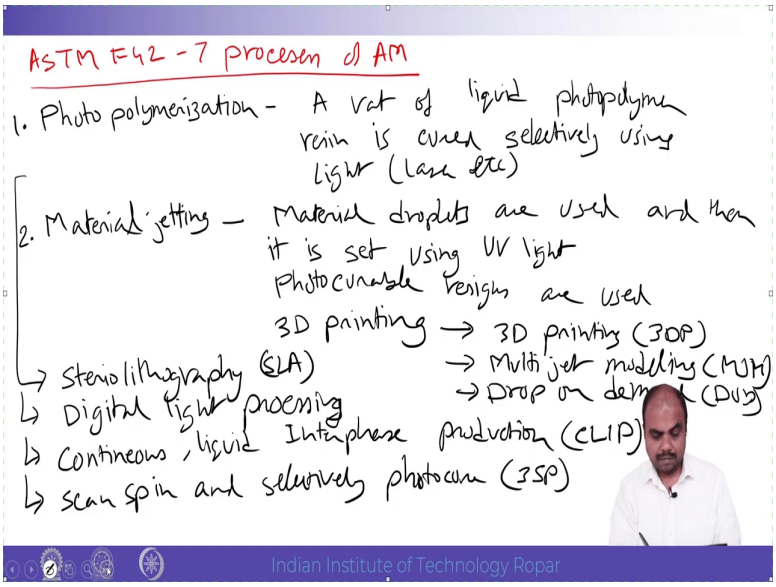

According to ASTM F42 there are 7 techniques, 7 processes basically. Let me take a different color. One is photopolymerization; in this basically a vat of liquid photo polymer resin is cured through selective exposure of the light. A resin is cured selectively using light laser TC etcetera.

The next one is material jetting; second one in this material droplets are used and then it is basically set using UV light. So, here also photo curable resins are used. This is actually originally this was termed as 3D printing. So, there are names also multiple names which are there for this photopolymerization.

So, some of the names are stereolithography, SLA it is also called digital light processing these are very similar technologies, but this is not same this is little different from each other.

And then clip technology that is continuous liquid interface production clip that is also falling under this system.

Then scan spin and selective photo cure. These again these are names are why because these companies are making technologies which are falling under the main photopolymerization technique. And the name is different and also some technologies also different like clip technology is much faster, little bit less accurate, but very fast, but this is under falling under photopolymerization.

Under material jetting there are also various technologies one is 3D printing, multi jet modeling, JM there are also drop on demand. Now, we will go to the next technology that is binder jetting.

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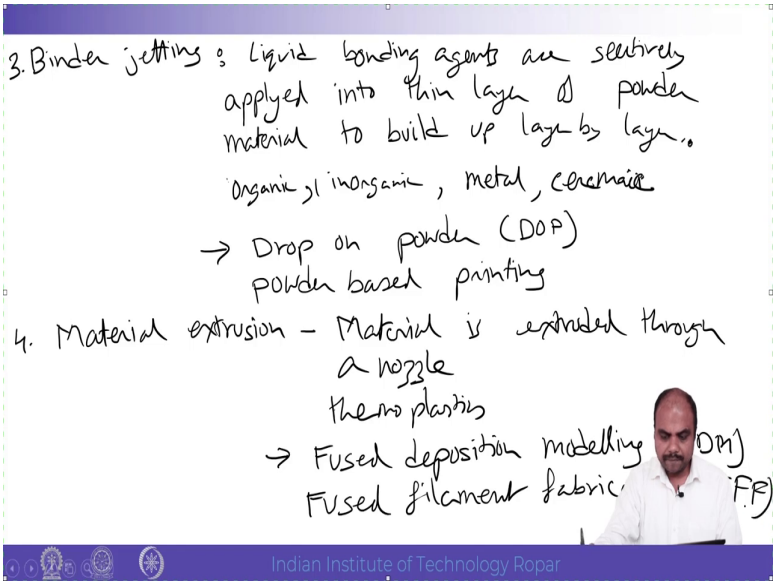

Third one in this the technology is that liquid binding agents are selectively applied on thin layers of powder material to build up layer by layer. That is liquid bonding agents are selectively applied into thin layer of powder material to build up layer processes. Layer by layer manufacturing layer by layer.

So, here electricity is not used because is not required. So, in this one and materials can be organic inorganic, it could be metal also metal ceramics etcetera. The other names for this is Drop On Powder DOP, powder based printing. The next one is coming is material extrusion.

In this the material is extruded through nozzle. And it is made into multiple layers the engineeringly thermoplasts thermoplastics are used. So, this is one of the most widely used technique for this one and FDM is one of the machine and various companies they have actually made this machine as they are selling in the market in a very cheaper price. The technology is which are coming is fused deposition modelling, FDM and fused filament fabrication that is FFF.

The next one that is powder based fusion 5th one.

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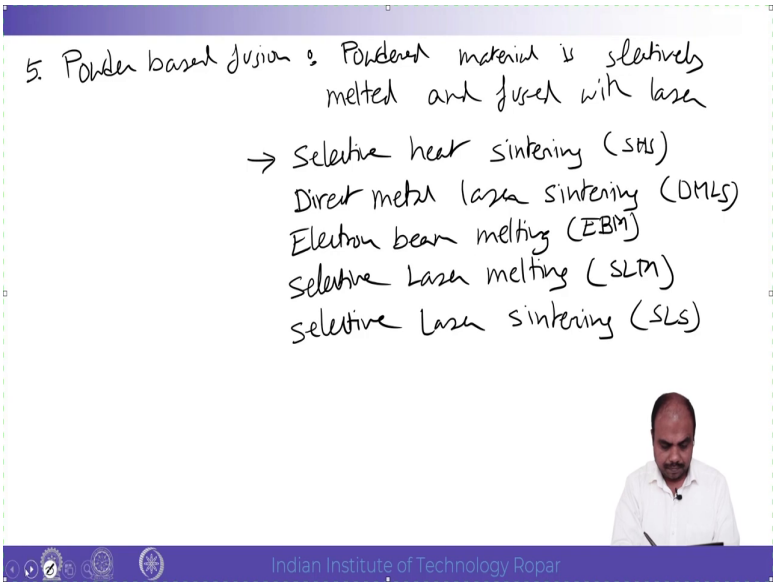

In this the technology is that powder material selectively basically consolidated and they have been melt together using a heat source like which was laser. So, here powder melted. So, here this is widely used technique for especially for metal.

The technology which are coming under this one is selective heat sintering, direct metal laser sintering, electron beam melting, selective laser melting SLM. As selective laser sintering this is one of the widely popular name which you have many of you may have heard about this.

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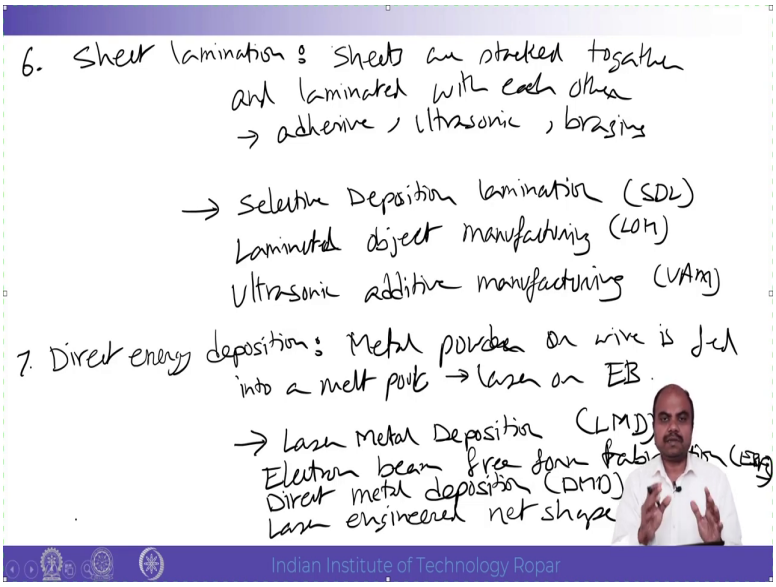

Sixth one is about sheet lamination. In this technique sheet soft materials are being stacked and laminated together to form the object and it could be the method for sticking making the object it could be adhesive, ultrasonic welding or even brazing. This could be using a receive; it could be used ultrasonic or brazing.

So, here the technology which are under this is selective deposition lamination. That is SDL laminated object manufacturing this many of you would have heard one of the popular method and ultrasonic additive manufacturing. Last one which we are discussing is the direct energy deposition. In this basically powder metal or wire is being fed into the metal pool which the generate say surface and basically this is basically it is the it is very it is made into liquid format almost and then the laser is being laser or electron beam is used.

So, the metal powder or wire is fed into a melt to a melt pool and we are using laser or electron beam. Technologies under this one is our laser metal deposition. Electron beam free form fabrication direct metal deposition and laser engineered net shape. So, now we have seen all these 7 techniques and what are the other names which are being followed which are there for this technique.

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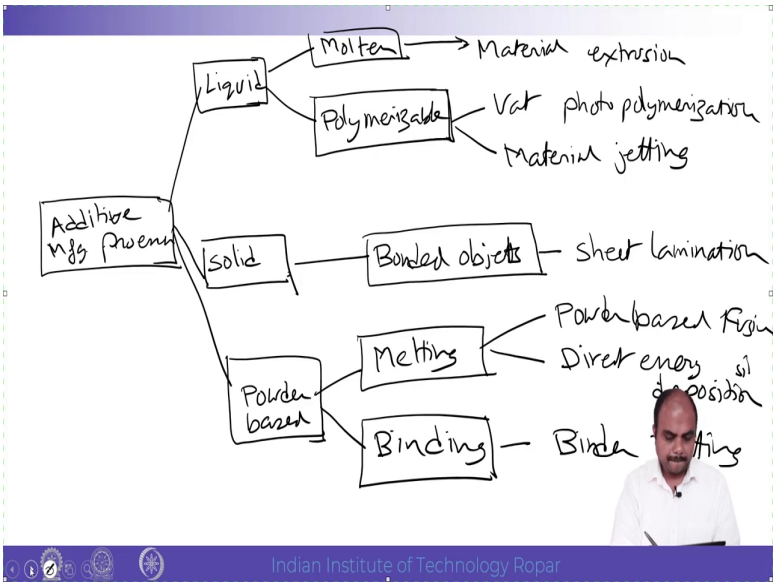

Now, we will see the how the categorization can be done. So, additive manufacturing process it could be either liquid based solid based or powder based right. Powder so, under liquid phase it could be one is molten next possibility is polymerizable, if it is molten, it could be material extrusion, if it is polymerizable one option is vat photopolymerization, second possibility is the material jetting. If it is solid then of course, bonded objects and as we have already learnt solid means sheet lamination.

Now, powder based it could be one is melting. If it is melting one could be powder based fusion. Next possibility is the direct energy deposition or it could be binding also if it is binding then binder jetting. So, now we have seen 7 technologies which are there how this can be categorized with respect to each other.

As far as materials are concerned there are so, many materials which are possible to be used in additive manufacture. As one of the metals are materials are metallic materials.

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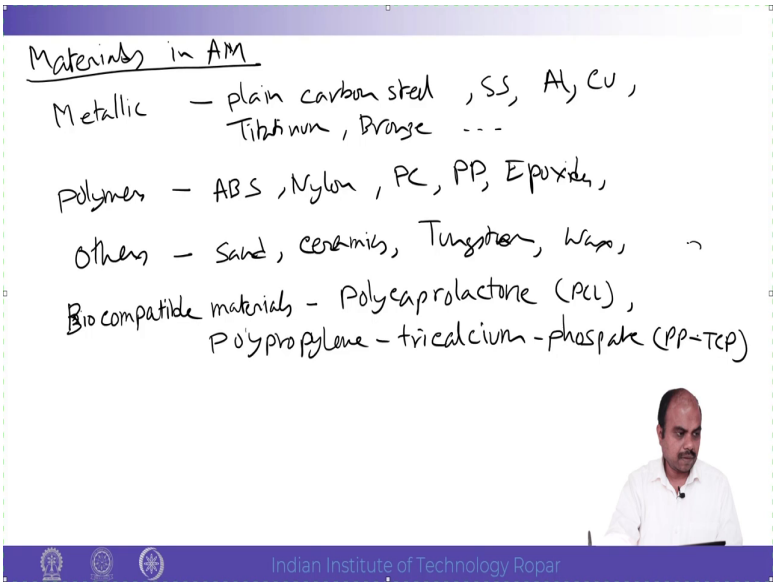

That is you can use plain carbon steel, stainless steel, aluminium, copper, ok then titanium, bronze, nickel and various others.

For polymers that is plastics we can use ABS, acrylonitrile butadiene, styrene, nylon, polycarbonate, polypropylene, epoxides, glass filled, polyamide, wind form, polyester,

polystyrene so, many other materials can be used. There are also others which are not coming under this is we can use sand, we can use ceramics, we can use tungsten, we can use wax, we can use starch, we can use plaster, similarly.

So, many materials we can use biocompatible materials. There are various biocompatible materials which can be used some of the names and write PCL. And there are several other others also. So, now we have to learn little bit of the genetic way of additive manufacturing.

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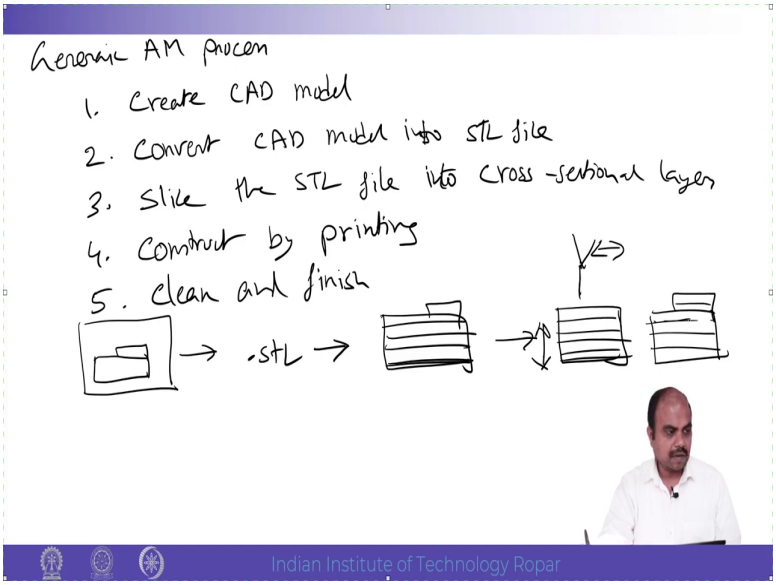

One is first is create CAD model. The next two convert the CAD model into STL file. Third one is slice the STL file into cross sections.

Then construct the model by printing using a machine and fifth one clean and finish post posing if required. So, if I explain little bit, first is you make a CAD model using any CAD

software and then convert into dot STL file, stereolithography file it is also standard tessellation library language. And dot STL file is basically in computer CAD and this is dot STL file can be used to print 3D object and this 3D object can be printed using the machine and then this slicing.

So, if this is the object it has to be sliced and this slicing is generally done by the software which is already being given by the manufacturing of this machine. There are various reason for it like how the quality of the product then accuracy and all these thing depends upon this. So, how much or how many cross sections you need to have it depends upon some of the factors related to this machine.

And then once we have this, so, this once we have this one the next one is we want to print it of course, so then orientation is of course, important and the support material required we can we need to add support material also. So, then machine will be actually going to print.

And then layer by layer the machine is going to print the product and after that once it is printing is done maybe post processing required with some marks will be there on the surface the quality has to be improved and these things are required for this.

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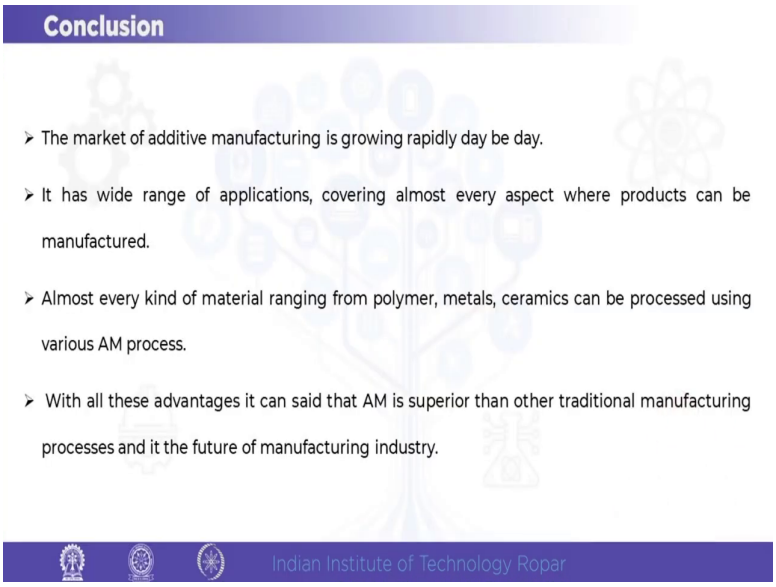

Thank you.