Rapid Manufacturing

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Lecture – 01
Introduction to Rapid Manufacturing (Part 1 of 3)

Welcome friends, welcome to the course of Introduction to Rapid Manufacturing. This course we will go through the topics given here.

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So, rapid manufacturing is a word or is a coined word which is gaining lot of momentum in the recent times. Today, when there is lot of requirement for customization and now I have to rephrase this term also now today people talk about mass customization. For example, I would like to have a spoon which could cater my requirement; I would like to have a shoe which can cater my requirement.

Please understand a shoe my requirement; a spoon my requirement. I would like to have a camera which could fulfil my requirement. I would like to have a car which could fulfil my requirement. See I have brought four examples in front of you and I said all these things a spoon for me; a camera for me; a car for me; a shoe for me. When I take the first example a spoon, when we look at spoons there is something called as teaspoon and

slightly you go up you have a spoon which is normally we use it in parties and other things. Many a times these spoons are not customized for my requirement; that means, to say for my hand and the other thing is the weight of the spoon.

So, because of that many a times I spill my food right the spoon what I have is not customized for my requirement and when I talk about shoe all of all of us the population is boxed under sizes like 6, 7, 8, 9 and 10, 11, 12 maybe this is in terms of Indian standards; if you go for or American standards they talk about in terms of inches and sometimes they talk about in terms of centimetres. We are boxed in each of the requirement.

When I buy a shoe of size number 10 or 11 for example, I only have the option of deciding whether it is a party issue or a sport shoe. If there is a sport shoe I just pick then I have what are the options left is the colour I have that is all. But when my friend also goes he also is buying the same shoe what happens to my body to mass index, where is it getting integrated with the shoe? If I have a size between 6 and 7 or 9 and 10, 9 and a half then how is my shoe going to take care of it?

I do not have customisation I accept what is available. Many a times when you buy shoe and when you are trying to play games football, you can see some of the child children when they are kicking their shoe the football the shoe just flies off because it did not fix it properly to his foot. So, because of this what happens? He gets into knee problem over a period of time. Then let us take at an example of camera. Almost all the cameras which are available in the market today are for right handers. Many of the products which are available in the market are for right handers.

If you are a left hander all you have to do is swap that button from the right hand side to the left hand side. So, we do not have that customization. Today there is a statistics which says about 8 percent of the total world population are left handers when exa[ct]- when the chairs are made for the examination, we always try to make it more friendly towards the right hander and not towards the left. So, here again the problem of customization is not coming into effect.

The last one let us try to look at a car which is available in the market which is prepared or done for assuming a standard height for a driver let it be male or female. When there is a small variation in your height, weight or in your body to mass index or your shape of

the body there is no provision in the car to customize it such that you can have a comfortable journey for a longer time and you also have a complete view both in your right hand side and left hand side. So, now, I have put in front of you four examples the first one was very low cost, next one was slightly higher today you have shoes for 1000, 2000 and 5000 rupees or 10000 rupees.

Then I gave you an example of a camera and the last one I give an example of a car. We are paying a huge money for all these products, but these products are not customized to my requirement. So, now, there comes a challenge what is the challenge? Why is it not done why is it not done. Because the users are not captured and then the product is not made. So, now, comes a relook into your definition we are not supposed to produce more in terms of batches, but produce less, but make it more mass customized.

This is what is going to be the future manufacturing; future manufacturing is going to be more towards mass customization. When we talk about mass customization we cannot sacrifice time, we cannot sacrifice cost. So, we are still supposed to work to the expectation of the customer both in terms of economy and in terms of time delivery. So, in this scenario we are pushed from mass production to batch production to mass customised production. So, this mass customised production is termed or is redrafted and given a terminology called as rapid manufacturing

What is rapid manufacturing? We try to take the customer feedback or requirements converted it into a digital form; and that digital form is given directly to the machine the parts are produced and directly moved towards an application. So, we are not going to go into a field called as prototyping, we make a prototype for that prototype then we make tools and from that tools we try to go for the final product. So, rapid manufacturing is more towards mass customization where cost is not to be compromised, but things have to be produced to the customers satisfaction with the highest integrity, that is rapid manufacturing.

For this topic we and we are supposed to go through rapid prototyping and we will see reverse engineering some termino some technologies and rapid manufacturing we will see in totality. So, this course is a futuristic course it is open for undergraduates and postgraduates practicing engineers can also enjoy this course. So, along with me in this

course I have Amandeep Singh who will share the lectures with me and we hope that we try to make an impact and add a new knowledge to your understanding.

So, I would now try to tell you an example which we are recently working at IIT Kanpur. We had a patient who came to us and said that he has lost his ear in an accident. All he wants to do is, because of this losing of his ear in an accident he has stopped moving outside world. So, he has got himself confined within a space and now he realized that that is not the future. So, he came down to us at IIT Kanpur and he said can you make another ear for me of course, it involves lot of medical involvement, but all we agreed to him is that ok let me let us try working along with a partner with some doctor practicing doctor and we will try to do the engineering requirements.

So, we worked with him. So, what we did was we copied his left ear and he has lost his right ear, we copied his left ear and we did reverse engineering then we developed it by cad model, then we did some patch work here and there and then what we did was, we tried to make a prototype of it then we try to make a mold out of it and from that mold we made a final component and then we have today given it to him and said that please use this ear. So, it is made out of silicon it gives it has the same flexibility and we have also tried to do justice for the texture and now with the help of the doctors what we have done is, we have also allowed him to just keep at his the location of the ear; from a very far off distance it looks like he has a true ear.

So, this could happen only because of rapid manufacturing and the involvement of additive manufacturing. So, this is what we are trying to cover in this course. The example I have told you we are still working on it, it has to be placed we are trying to apply some magnets this and that. So, there is a long way to go, but partially we have addressed the problem and we are able to help him at least now the patient is able to fix his ears at the location and then keep going. It has it is not been integrated as part of his body, but he just keeps it as an insert to his body. So, this is rapid manufacturing ok.

So, in this lecture 1, we will try to see additive manufacturing we would see a rapid prototyping then we will see functional prototyping then we will see rapid manufacturing then rapid tooling and finally, direct and indirect manufacturing.

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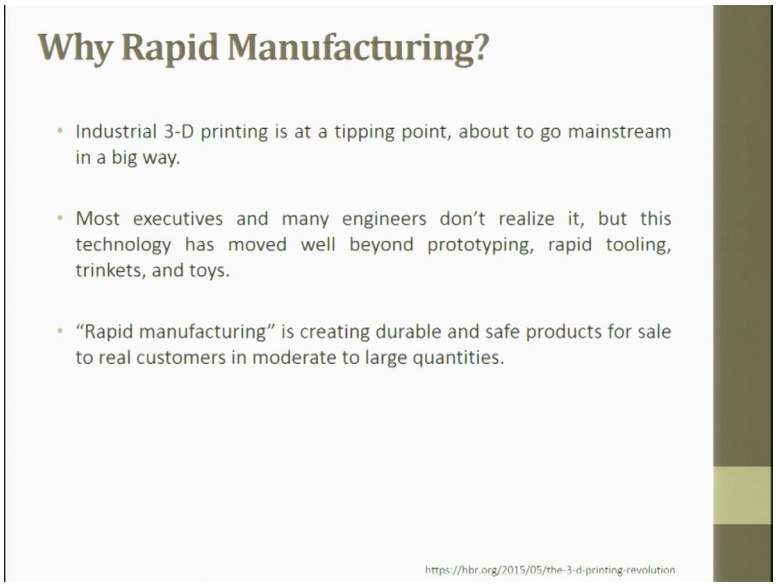

When we talk about rapid manufacturing the industrial 3D printer is at the tipping point, about to go mainstream in a big way. So, earlier additive manufacturing was thought of only from the prototyping point of view, today what has happened? The power source whatever you apply, the raw material whatever we use are now moving towards the real-time requirements, which was earlier thought about in plastic now it is changed into metal.

So, earlier we used to make only polymer based prototyping, today we are making metal based prototyping moment we make a prototype we are now pushing it little bit more to a live requirement itself. So, that is why industrial 3D printing is at the tipping point about to go mainstream in a big way. Main most executives and many engineers do not realize it, but this technology has moved well beyond prototyping, rapid tooling and toys. Rapid manufacturing is creating durable and safe products for sale to real customers in moderate to large quantities ok. So, this is where the terminology mass customization I talked about is getting integrated. So, rapid manufacturing is creating durable and safe products for sale to real customers in moderate, this moderate can be 1 to 10, 200, 500 whatever it is in moderate to large quantities ok.

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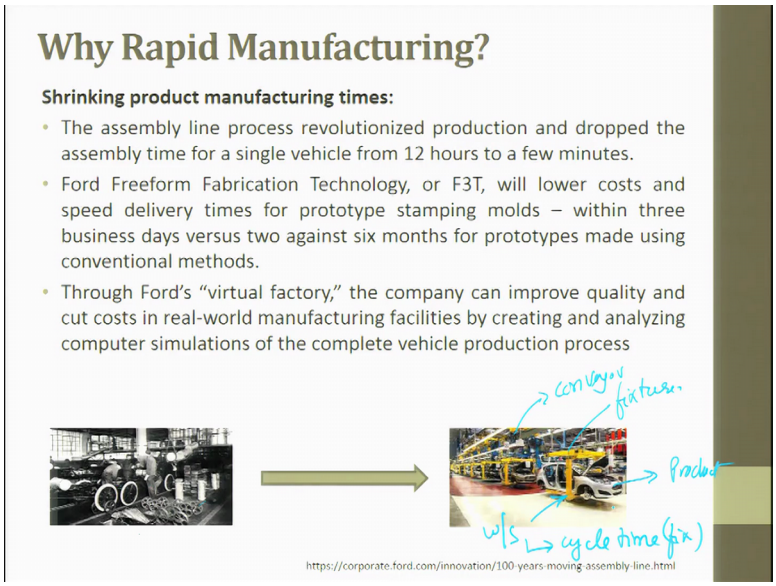

Today the major challenge is shrinking product manufacturing time. Earlier we used to talk about, for if a company decides to make a car if a big giant company decides to make a car, they say we will in the next 5 years we will come out with a new car, next 10 years we will come out with a new car, but today it has come down to next 6 months we will come out with a new car. So, what has happened? The product life cycle time has shrunk down; the manufacturing time has shrunk down drastically ok. The assembly line processes revolutionized production and dropped the assembly time for a single vehicle from 12 hours to few minutes.

Today we talk about product delivery in minutes. We talk about pizza getting delivered at our residence in 30 minutes. So, look at the amount of readiness which this product has in these stores. So, here the product is all in semi cook state or in a very raw state, then it is all getting assembled it is passed through an assembly line where it is in terms of pizza it is a furnace. So, it is passed through the oven, and then you get out after 10 minutes or 20 minutes or 3 minutes you get a pizza right. So, now, they are talking about doing product delivering products in 30 minutes. Today we are not talking about product production, we are talking about product delivery. I produce and keep it in a warehouse does not matter because the customer is not happy, if I produce and deliver it to a customer he is very happy. So, today the manufacturing industry is working towards delivery that is produce or make to delivery rather than make to produce and keep it in a stores.

Ford freeform fabrication technology or F 3 T will lower cost and speed the delivery time for prototype stamping molds, where in 3 business days versus just against 6 months of prototyping may be used in the conventional machine. Since we are moving from rapid prototyping to rapid manufacturing in between tooling segment is now slowly thought of why do not we withdraw. So, here it is very clear within 3 business days 3 business days 3 working days they are able to make a mold which earlier took them 6 months. So, what is this all talking about? This is all talking about how quickly I can change my product, produce a product, and try to customize the product to their requirement.

Through fords virtual factory, the company can improve quality and cut cost in real world manufacturing facilities by creating and analyzing computer simulations of the complete vehicle production process. Today we have virtual labs we have we call it as smart factories or virtual factories we are able to simulate every condition which is there in real time. See where the bottlenecks are understand where the product is going to fail by our simulation try to reinforce the product wherever it is required and correspondingly try to change the manufacturing route, assembly route and produce the part whatever we want.

So, this virtual factory is also part of rapid manufacturing. So, you can see here the ford example which was earlier you have a person trying to handle where there is not much of conveyor from there it is changed to a way where in which there is a fixture, there is a conveyor fixture, there is a conveyor which moves from place to place and here is your product ok.

So, the product moves and since it is an assembly line and it is continuously moving the assembly happening workstation, the time is also the cycle time is also fixed. It is also fixed the cycle time is fixed the product is produced the conveyor belt is moving and this is a fixture to hold it. Earlier the vehicle was moving where there was man involved, but it had the cycle time was large, but now it has shrunk down drastically.

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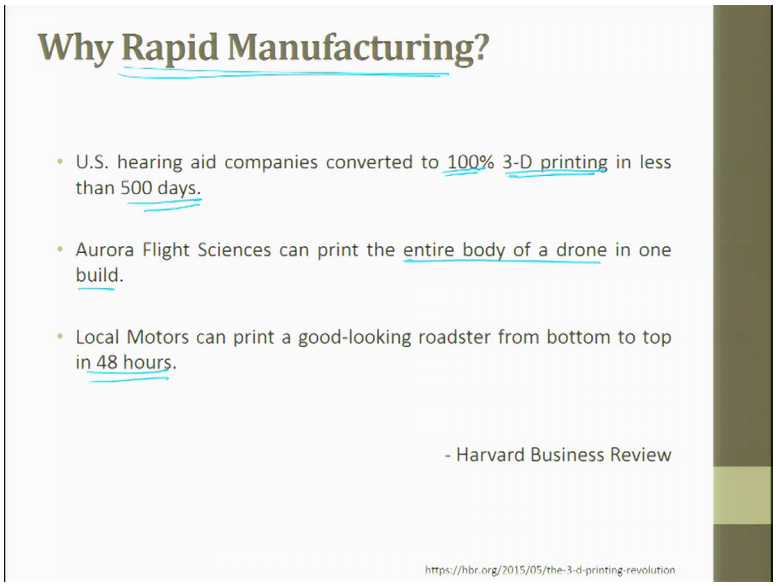

U S Hearing Aid Company converted to 100 percent 3D printing in less than 500 day. So, today hearing aids are made by rapid manufacturing. Today many products which are made for human centric or human friendly they are all done digitized for example, they are first scanned what is the requirement, converted into a digital form, the product is made such that it can get adhered fixed in the required space.

Aurora Flight Signs can print the entire body of your drone in one build. Today people have also realized that if you want to make a 3D product it is good we start making a 2 D one and 2 D one it is very quickly you can cut through laser or any engraving tool you cut it and then you break the 2 D things assemble it you get the 3D part ok. So, aurora flight science can print the entire body of a drone in one build. Local motors can print a good looking roadster from bottom to top in 48 hours. So, these are all some of the products which have been made under rapid manufacturing.

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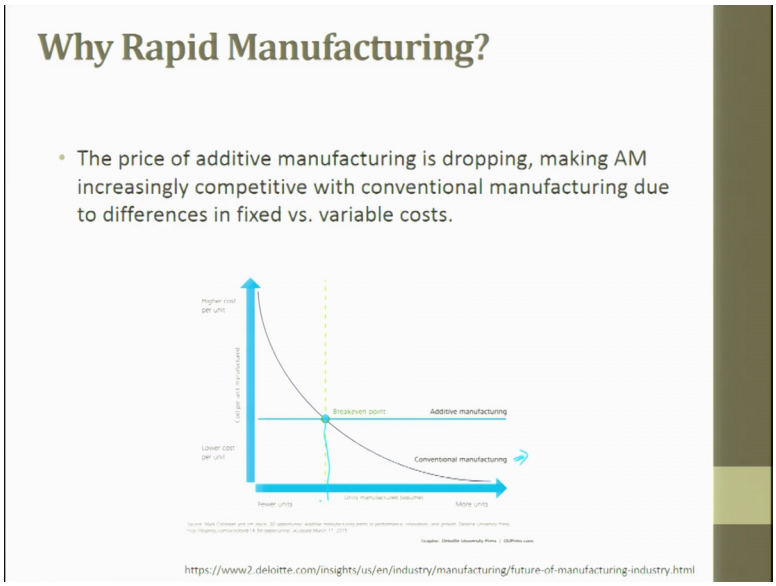

When we talk about rapid manufacturing in terms of units and cost, the price of additive manufacturing is dropping in terms of technology awareness raw material cost third party involvement in supplying the machine parts. So, the price of additive manufacturing is dropping, making additive manufacturing increasingly competitive with conventional manufacturing due to the difference in fixed cost versus variable cost.

So, this is the conventional cost, this is the additive manufacturing. So, you can see here the cost is drooping down at one point where the breakeven is there. So, you can see if we are able to produce so much in quantity, the cost then additive manufacturing will be economical as compared to that of your conventional machine ok.

So, this shows the higher cost, lower cost, the cost per unit manufacturing and here it says unit manufacturing in terms of volume ok. Of course, when more the volumes are there conventional is the best method of making it. So, conventional methods are the best and especially sheet metal or metal forming operations are the best it nothing can be economical than that. But, if the quantities are literal you cannot use the same metal forming techniques here because the die cost is pretty expensive ok. So, this is what is the breaking point, where in which tries to talk about additive manufacturing and conventional cost in terms of units.

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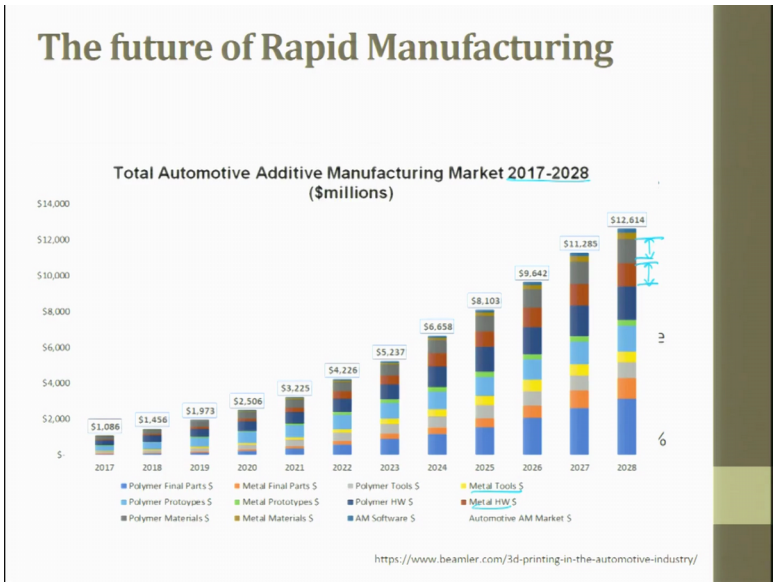

So, the future of rapid manufacturing when we talk about automotive; total automotive additive manufacturing market which is projected for from 2017 to 2028 in terms of millions, you can see here these are polymer parts, polymer prototype, polymer material you can see polymer tools, metal prototyping you can also see metal tools and metal hardwares. So, you can see them how drastically their numbers are getting increased over the years you see this it is increasing. And if you see polymer material this is also increasing ok. So, this is a very interesting graph which talks about what will be the future of rapid manufacturing.

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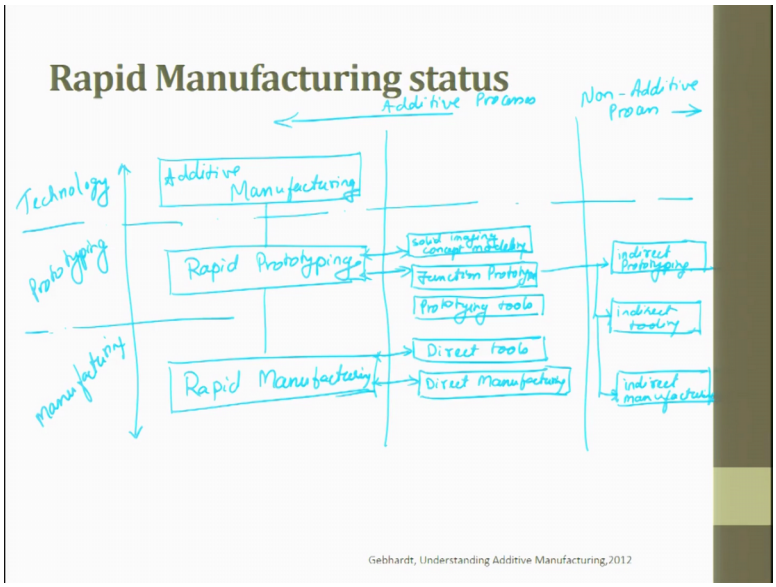

Let us see the rapid manufacturing status ok. So, I would like to draw block diagrams this is additive manufacturing, this is rapid prototyping and this is rapid manufacturing. This in turn, this is solid imaging and concept modelling and the next one is functional prototype we will see what is functional prototype little later. I am just giving you the overview how does it go about. We have prototyping tools then we have direct tools I have direct manufacturing ok. So, I will divide it into segments, this is called as this is called as technology, this is called as this is called as prototyping and this is called as manufacturing and I will again divide this. So, that it becomes easy for understanding. So, this portion is additive manufacturing additive processes and here we have non additive processes ok.

So, this from here I would like to go for indirect prototyping and then we have indirect tooling and then we have indirect manufacturing ok. This is the current rapid manufacturing status and if you look at it this is where technology, prototyping and manufacturing is there. We have additive manufacturing, then we have rapid prototyping, then we have rapid manufacturing ok. So, these are the arrows. So, we will try to see what is a rapid manufacturing as and when the course goes by.

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So, the major modules which we are going to cover in this is going to be introduction to rapid manufacturing, then we will talk about product engineering

we will talk little bit about CAD which is Computer Aided Design slash CAE which is Computer Aided Engineering then we will study about CAM, CAM Computer Aided Manufacturing and Computer Integrated Manufacturing. CAD is only the drawing, a drawing with simulation and optimization is CAE and which when it gets transferred for manufacturing it is called a CAM and CAM with the office automation in an industry is called as Computer Integrated Manufacturing. Then we will try to see design for modularity, this modular design makes the manufacturing today more comfortable and easy for rapid manufacturing. We will talk about reverse engineering we will talk about rapid manufacturing processes and technology, then we will talk about rapid manufacturing digital factories.

We will also talk finally, about competitiveness in rapid manufacturing. This course is reinforced with lab demonstration self-completion tasks, reading material and weekly quiz and many of the quizzes will be for your understanding and some quizzes can be for you for submission. And I will try to give you an exercise just from the live examples which you can think of and start solving that assignment. You do not have to submit it for correction or evaluation it is only for your understanding.

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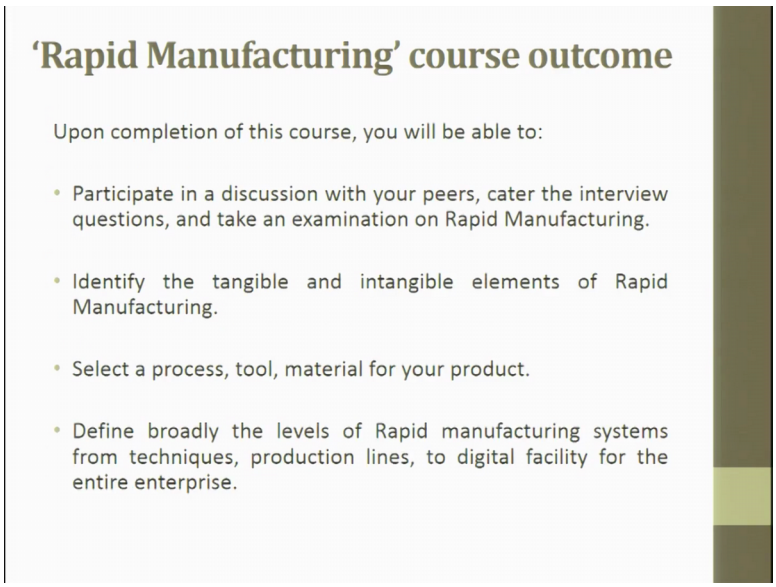

Upon completion of this course, you will be able to participate in a discussion with your peers, cater the interview questions and take an examination on rapid manufacturing.

Identifying the tangible and intangible elements of rapid manufacturing, will also be the outcome of this course. Select a process, tool, material for your product, define broadly the level of rapid manufacturing systems from techniques, production lines, to digital facilities for the entire enterprise. So, all these things are expected outcome of this course.

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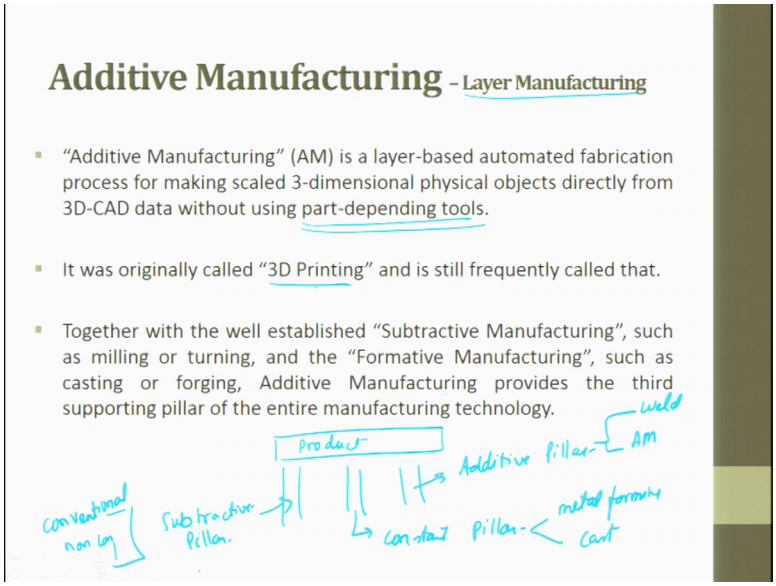

The first one is additive manufacturing. So, we will start with additive manufacturing which is otherwise called as layered manufacturing. Additive manufacturing is a layered based automated fabrication process for making scale 3 dimensional physical objects directly from a 3D cad data without using part depending tools this is very very important. Rapid manufacturing is I would like to build the 3 dimensional objects from fundamentally 2 dimensional layers. I make layer by layer by layer, I stitch those layer by layer by layer and make it into a 3 D physical object.

And this object is made without involving any tools. It was originally called as 3D printing and is still frequently called that, together with the well-established subtractive manufacturing such as milling or turning and the formability manufacturing such as casting and forging, additive manufacturing provides the third supporting pillar of the entire manufacturing technology. So, what we are trying to say is here is a product, here are 3 pillars, one is subtractive pillar, the other one is constant volume pillar subtractive pillar constant volume pillar and this is additive pillar. So, constant you have metal

forming and you have casting, here you have joining and additive manufacturing. Subtractive you have the conventional and the non-conventional machining processes. So, 3D printing is something which is which is very much talked about today.

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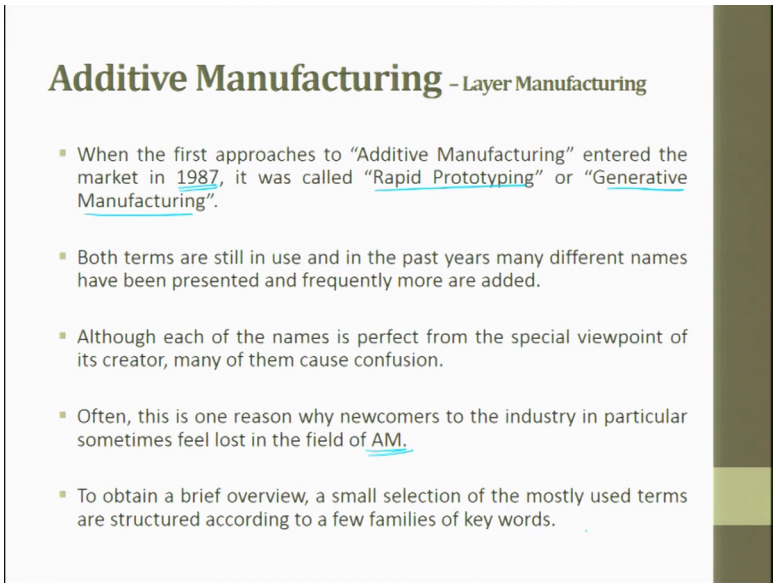

When the first approaches to additive manufacturing entered the market in 1987, it is very new it was called as rapid prototyping or it was called as generative manufacturing.

Generative manufacturing, rapid manufacturing, rapid prototyping, layered prototyping, freeform manufacturing all these words and terminologies are interchanged and later you will realize that 3D printing is a word, which is different from what we are talking about in rapid prototyping. Both terms are still in use and in the past years many different names have been presented and frequently more are added ok. Layered manufacturing is a very standard terminology which is used which falls under additive manufacturing. Although each of the name is perfect from the special viewpoint of its creator many of these causes confusion ok. Often this is one reason why newcomers to the industry in particular sometimes feel lost in the field of additive manufacturing.

To obtain a brief overview a small selection of the mostly used terms are structured according to a few families of keywords.

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Often used terms include rapid, rapid manufacturing, rapid technology, rapid prototyping, rapid tooling. Additive: additive manufacturing, additive layer manufacturing, additive digital manufacturing. These are the 3 terminologies which are used very exhaustively. So, this is also commonly used and this is also commonly used.

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Layer: layer based manufacturing, layer oriented manufacturing, layer manufacturing. These are terminologies which are interchanged which are used in terms of layer.

Then the next one is digital fabrication and they also call it as digital mock up. So, these are the terminologies which are used under this. Then direct people use direct manufacturing and also direct tooling. These are terminologies which are used as part of additive manufacturing and these are the terminologies which are used commonly.

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Then at last 3D, we use 3D printing and 3D modelling. So, these are the terminologies which are often used rapid manufacturing, rapid technology, rapid prototyping, rapid tooling. When it comes to additive, it is additive manufacturing, additive layer manufacturing, additive digital manufacturing it is almost the same. Layered based manufacturing, layered oriented manufacturing, layer manufacturing it is almost the same.

Digital fabrication, digital mock-up it is also used digital they both are the same and direct manufacturing, direct tooling these are the terminologies which are used apart from 3D printing and 3D modelling.

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As additive manufacturing is a comparably young technology as compared to the other two pillars whatever we have said there were almost no efforts for standardization for many years, other than some preliminary work done in Germany in early 1990s. The standardization of this has not still happened. Because of the non-standardization these processes are not very much accepted in real time.

Now, there is a lot of initiative which is going towards standardization of additive manufactured parts. In 2007, a special recommendation dedicated to rapid prototyping VDI 3404 was created under the supervision of German society for Mechanical Engineers. In 2009, the American society for mechanical engineers in cooperation with the American society for Testing and Materials started the development of their own standards. Like what we have ISI, ISO, BSI, JSI these are standards. So, like that people thought there is a need to initiate this rapid prototyping standards tool because people did not realize in the initial days that this can be used for rapid manufacturing, they realized it only for prototyping. But now since there is lot of need and requirements have arised now standardization as of this rapid prototyping has also started.

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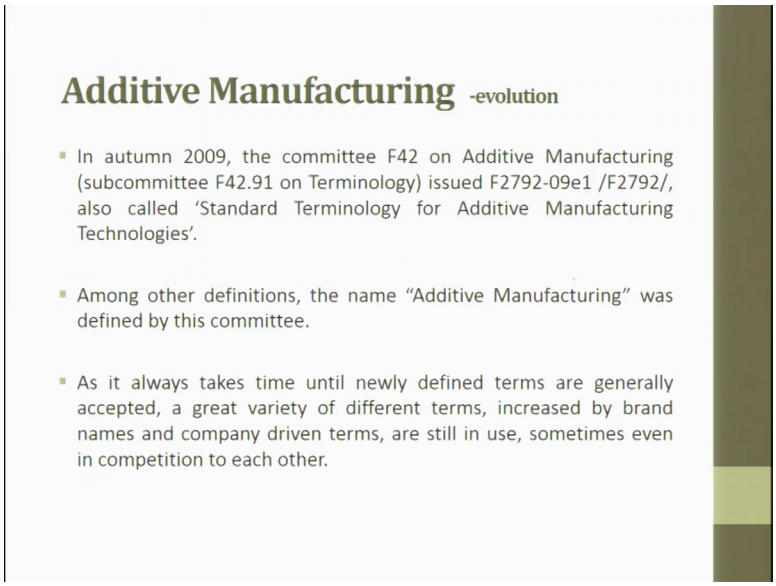

In autumn 2009, the committee F42 on Additive Manufacturing issued F2792 dash 09e1 slash F2792 slash and called it as a Standard Terminology for Additive Manufacturing Technologies they release a standard. Among other definitions the name Additive Manufacturing was defined by this committee. As it always takes time until newly defined terms are generally accepted, a great variety of different terms increased by brand names and company driven terms are still in use, sometimes even in competition to each other.

For a simple example what we realize is we always say let us take a xerox copy of your document. Xerox was the company which made this photocopying technology or the photocopying device. Actual process is photocopying, but we go ahead calling the process in terms of the company name that is what is even still happening in rapid prototyping or in rapid manufacturing or in additive manufacturing terminologies.

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The principles of layered based technology; the term additive manufacturing like generative manufacturing covers any imaginable way of adding materials in order to create a 3 dimensional physical part. This is done from the data what is received or accepted from the virtual form. The technical realization of additive manufacturing is based solely on layers and therefore, it is called as layer based technology or layer oriented technology or even layer technology. Consequently today the terms additive manufacturing, generative manufacturing and layered based technologies are sometimes used synonymously. In the future as new additive technologies may become available they will need to be classified within the current structure of rapid manufacturing definition.

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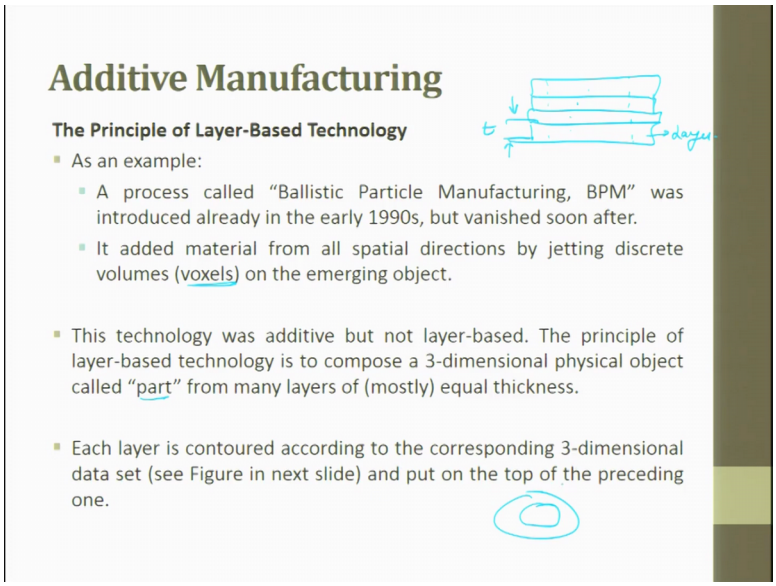

As an example the process called ballistic particle manufacturing BPM was introduced already in the early 1990s, but vanished soon after. It added material from all spatial directions by jetting discrete volume of the emerging object. This technology was additive, but not layer based understand the difference this was particle by particle was impinged. The principle of the layer based technology is to compose a 3-dimensional physical object called part from many layers of mostly equal thickness.

Today we also talk about variable thickness, but primarily the machine is expected to do a standard thickness only. Each layer is contoured according to the corresponding 3 dimensional data set and put on to the top of the preceding one so; that means, to say I place one layer, I place the next layer, I place the third layer I go on to the fourth layer. So, I place layer by layer this is the layer we are talking about, this is the thickness we are talking about and this is placed on top of the other. So, this is placed this is placed, this is placed. So, each layer is contoured according this is only the side view suppose if I wanted to look the plan view, you can have something like this on this ok. So, each layer is contoured according to the corresponding 3 dimensional data set and put on to the top of the preceding one.

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So, this is how the layer looks like. So, here the principles of layer based technology is explained. You can see here a plywood a thin wood sheet is carved layer by layer and it is fixed one upon each other to get a final product like this. The principle of layer based technology contoured layer left 3 dimensional made from stacking these layers one upon each other we get the 3 dimensional part layer to part 2D layer to 3D part.

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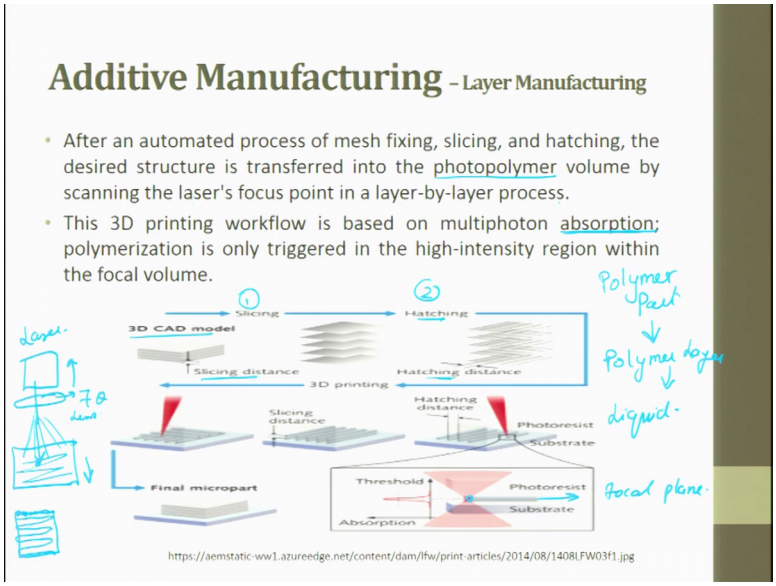

So, additive manufacturing if you see, it follows the schematic which is given here. After an automated process of mesh fixing, slicing and hatching the desired structure is

transferred into the here I have taken one particular material called as photo polymer, you can take any material into the material volume, by scanning the laser focus point in a layer by layer process we are trying to develop it.

The 3D printing workflow is based on multiple photon absorption, polymerization is only triggered in the high intensity region within the focal volume. So, what we are trying to say is, we are trying to say, we are trying to develop a polymer part right. This polymer part is developed from polymer layer. The layer whatever is getting the getting made the starting material is here liquid. So, now, what do I do is, I have here laser which comes down and then I have a tank in which photo polymer is filled.

So, this fellow tries to hit at a spot and this part alone because of the absorption phenomena, it absorbs the UV light and gets cured. If I can move several dots can be created and if I can make it into a hatch pattern then it forms a complete layer. So, one layer is formed, then either I move the liquid polymer tank down or I move the laser little up you try to get it. And interestingly you will have something called as f theta lens which is used. So, this can scan and browse through a large area to create one layer of information.

So, when you give you a CAD data, this CAD data is first sliced. So, this is what I said it is hatched. So, we are doing reverse of it polymer part, polymer layer, then in the liquid. So, liquid so, first what we do is layer slicing is done then the slicing is broken into hatching this is what is a hatching. There are several patterns of doing hatching this hatching pattern where we can optimize the hatching pattern with respect to time, with respect to strength we can do whatever we want. Polymerization is only to trigger the high intensity region within the focal volume. So, what is a focal volume? This is what it is. So, you can see here slice, this is the slice distance and inside a slice we have hatch patterns between the hatches, between the hatches it is called as hatching distance ok.

And then what happens? You will try to make a single layer. So, this is what is the slice distance, hatch distance you keep doing it and when the laser tries to hit at the surface, I try to play with changing the focal plane. So, moment I change the focal plane, the curing can happen at the surface, in between the surface, below the surface at whatever z direction I want; that means, to say I can keep adding the layer by layer within the polymer tank itself. So, this is what is adsorption, threshold and here is what is photo

polymerization happening. This process is typically for a photo polymer, photo polymer which is used as a liquid; where in which we use UV laser to cure the photo polymer first in dot form, then in line form, then in layer form, then layer stitching of layer you get a 3 dimensional object ok.

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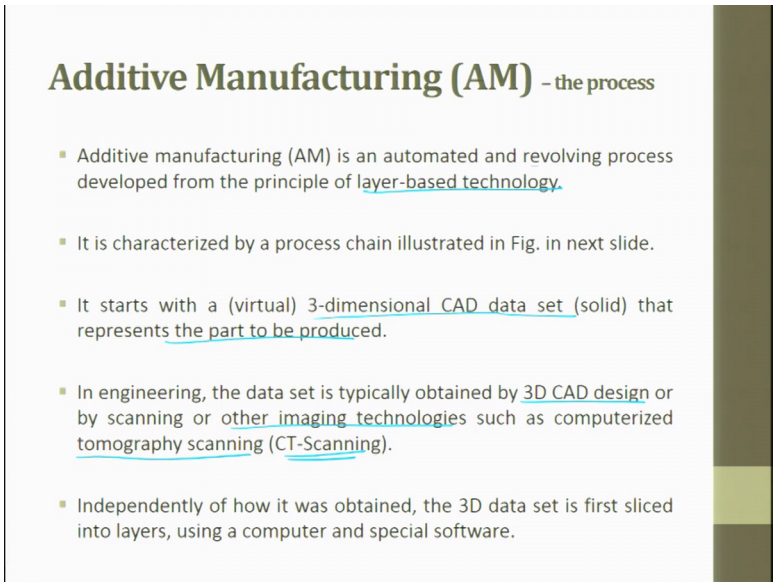

So, this is what is explained in this figure. So, additive manufacturing is an automated and revolving process developed from the principle of layer based technology. It is characterized by a process chain illustrated in the figure which is explained in the next slide. It starts from a 3D CAD dataset that represents the part to be produced. In engineer the data set is typically obtained by 3D CAD design or by scanning or other imaging technologies such as computerized tomography scanning, CT-Scanning is also used for developing the data independent of how it is obtained a 3D data set is first sliced into layer using a computer and a special software.

Thank you very much.