Rapid Manufacturing

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Lecture – 2
Introduction to Rapid Manufacturing (Part 2 of 3)

Welcome, to the course on Rapid Manufacturing.

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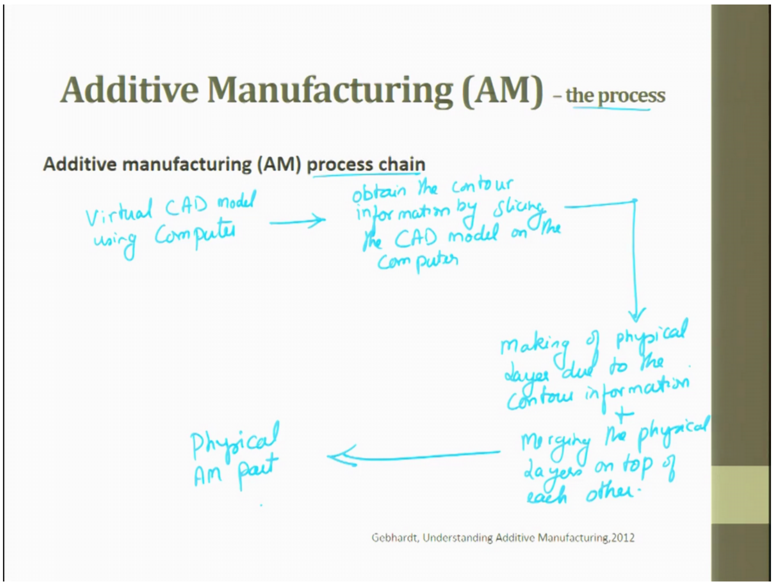

So, additive manufacturing the process; so, we will try to see here the process chain. So, in the process chain the first step is virtual CAD, CAD model which we generate using computer and then after that we try to obtain the contour information by slicing the CAD model on the computer. This is what we do and then what we do is we try to make physical. So, making of physical layer due to the contour information plus we try to merging the physical layers on top of each other. Then finally, what we get is a physical additive manufacture part, ok.

So, this is the process chain first we do CAD, from CAD what do we do is we try to get the sliced information. When we try to get the slice information we also try to get the hatching and then the information is transferred to a machine, this machine is used to develop from the first it develops dot, dot to hatch, hatch to layer, layer on top of layer it finally, forms a 3D part.

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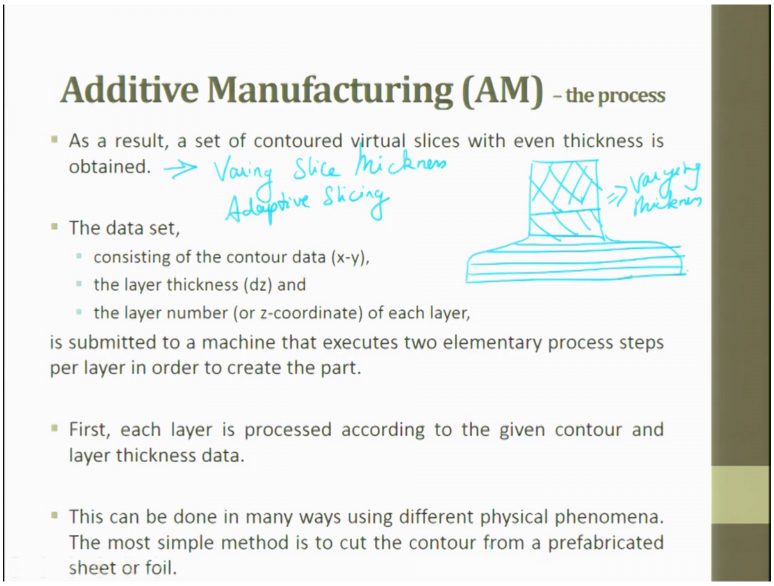

So, as a result a set of contour virtual slices with even thickness is obtained. Today, this also has changed. You can have varying slice thickness. Machines have been developed where in which you can have not even you can also have varying slice thickness. For example; if you have a geometry like this you can chose up to here as one layer, then this layer and then suppose, if you have here change in geometry like this. So, this slice layer can be here then it can be here, then it can be small, small, small, small such that the change in geometry is accommodated and then you get. So, this is varying thickness. If there is no change in geometry you can use the larger thickness. So, that is what is today's technology called as adaptive slicing.

Earlier it was slicing of the same thickness you draw an object you slice it the algorithm was like that. Now, you have adaptive slicing such that strength, roughness can be optimised and you get the better output. The data set which is consisting of the contour data are going to be x-y then the layer thickness dz and the layer number of each layer will be there. These are the data sets which will be used while reconstructing the object; is submitted to a machine that executes two elementary process steps per layer in order to create the part. So, that means, to say it first moves an x-y then you moves in z.

First, each layer is proposed is processed according to the given contour and a layer thickness data. So, this is what we have already discussed. This can be done in many ways by using different physical phenomena. The most simple method is to cut the contour from a prefabricated sheet or foil. So, that is how it is executed layer by layer, slicing.

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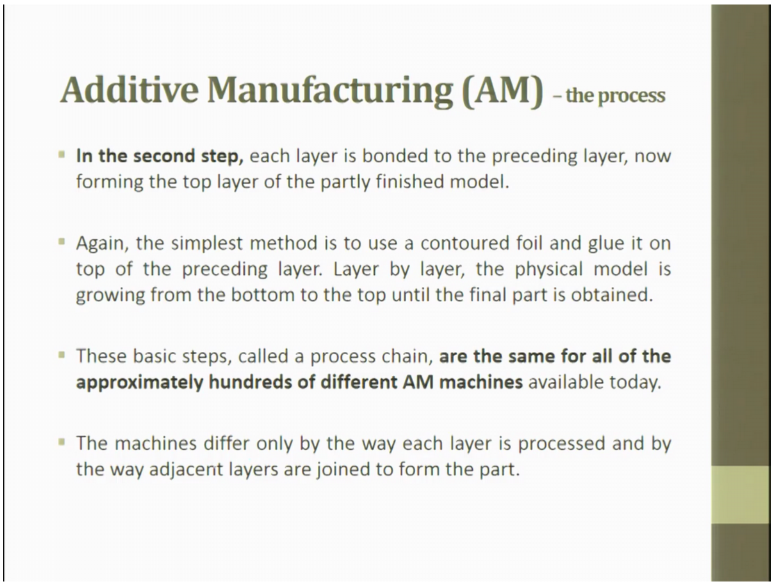

In the second step, each layer is bonded to the preceding layer, now forming the top layer of the partly finished mode. Again, the simplest method is to use a contour foil and glue it on top of the preceding layer. Layer by layer, the physical model is growing from the bottom to the top until the final part is obtained.

The basic steps, called a process chain, are the same for all of the approximately hundreds of different AM machines available today. You take any machine it will develop only like this. The machines differ only by the way each layer is processed. So, the starting material if it is liquid it you can use laser, if it is a wire you can use passing through a hot nozzle, if it is a powder you can glue that powder and by the way adjacent layers are joined to form a part.

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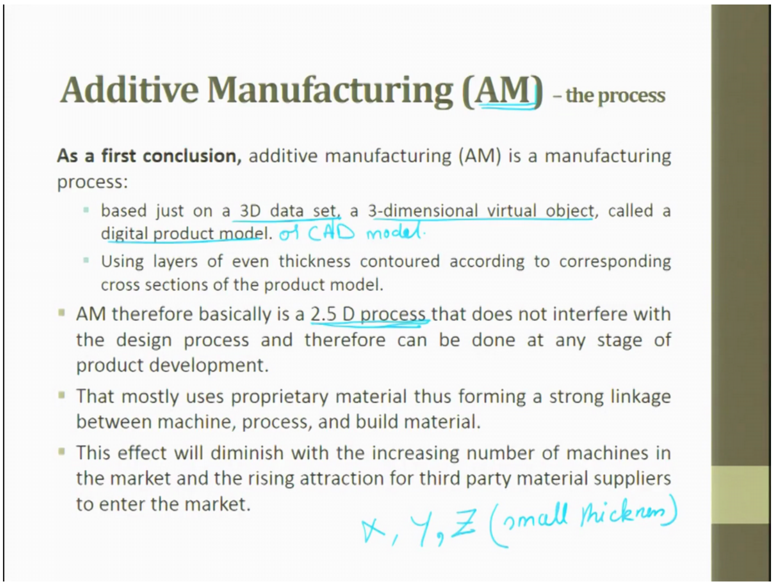

As a first conclusion additive manufacturing is the manufacturing process based just on the 3D set, 3-dimensional visual objects called as digital product model. This is otherwise called as CAD model, CAD model; so, digital product model. Using layers of even thickness contour according to the corresponding cross section of the product level. So, the conclusion is in additive manufacturing we always prefer to have even thickness.

AM therefore, basically is a 2.5 D process. Why is it 2.5 D? X comma Y is 2D and Z; Z will always be small thickness as compared to X and Y. So, that is why it is called as 2 and a half D process, ok. The similar thing is also used in CMC machines. We say it is a 2 and half access CMC machines where X, Y can vary while the process is going on, but Z cannot be varied. So, those processes are called as 2.5 D CMC machine and here in rapid prototyping since the layer thickness is uniform it is not changing in the X, Y plane, it is called as 2.5 D process that does not interfere with the design process and therefore, can be done at any stage of the product development.

That mostly uses proprietary materials thus, forms a strong linkage between machine process and building material. This proprietary material today companies have come forward and may keeping cost into a predominant effect they have made it into third party suppliers also; that means, to say company which produces additive manufacturing for that the raw material can be bought from any customer where the company tries to specify. So, because of that opening it out there is a competition between these company, so, material cost has come down drastically

So, proprietary materials which was earlier, now slowly slowly this is also getting change. I am walking you through the academic what is available in a book and the latest research what is going on. So, when I said varying thickness please understand that is still in the research state and there are few companies which have started claiming that in their products they do varying thickness and that too varying thickness not in one layer. In one layer they cannot change the thickness between layers they can change and in the same way proprietary materials now it has been opened out for third party supplier.

This effect will diminish with increasing number of machines in the market and the rising attraction of third party material suppliers enter into the market. So, this is what I was trying to tell you.

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Most of the peoples interest in additive manufacturing preferably wanted to know how they can use this new technology and what kind of new and different products they can develop using it. This is what people always will try to think of I have a machine what I can do from that machine. So, for example, people make wonderful carving out craft from the existing lathe machine. So, the creativity when it is added to the machining operation it tries to come up with new products. So, today people are looking at additive manufacturing and then they are looking at what can it do, what new-new things it can do, what all different products I can develop.

In addition, it is advantageous to use the right term during the discussion in the product development team. Many thinks that each of their different AM processes is exclusively linked to a certain application in the sense that a certain AM process can only be used for one or a small range of application while the other processes is solely suitable for another application. So, this is a thinking which people had, but today what is happening is slowly this is also getting removed out.

Today, we have polymer material which is the starting material for additive manufacturing, it has blended polymer, it has impregnated polymer. So, impregnated it has metal impregnation in a polymer. So, many things are coming up today. So, earlier it was said for these particular application please use this process, but today slowly that is also getting moved out. Additive manufacturing that rapid prototyping is now getting more and more generalised. This opinion encourages people to study all different process first and to care about a suitable application afterwards.

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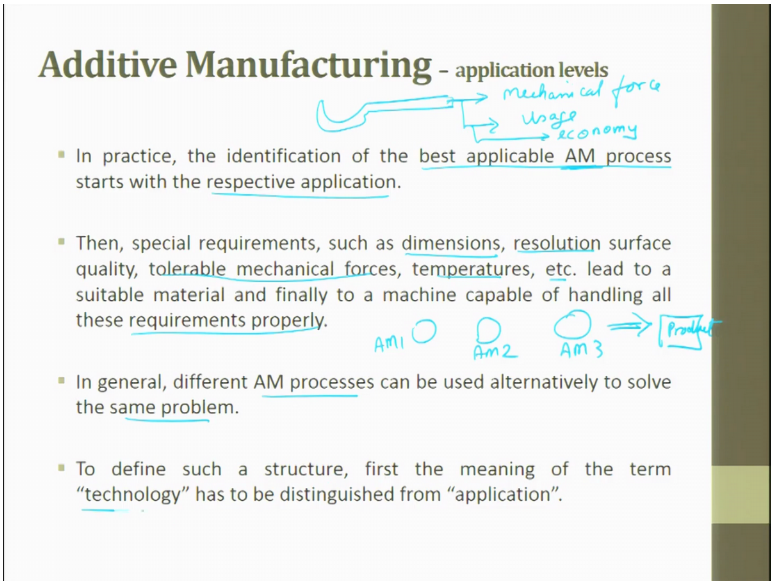

In practice identification of the best applicable AM process starts with the respective application. So, that is what it goes. For example, if you wanted to have a spoon to be made, ok; a spoon to be made, you should first understand what are all it is mechanical forces which are getting acted, then you try to see it is usage then you try to see it is economy and then you decide which additive manufacturing process to choose. So, for every product we have to choose a proper cost effective performance based additive manufacturing process.

Then, special requirements, such as dimension, resolution, surface quality, tolerances, temperature etcetera lead to the suitability of the material. For example, once you start working on powder based materials your resolution of the part you get is very high, the tolerances are very tight. If we use wire you might not get the same tolerance, and second thing tolerance is also directly proportion to the wire whatever raw material form and dimensions or shape. So, this special requirements such as, dimension, resolution surface quality, tolerable mechanical force, temperature, etcetera lead to a suitable material and finally, to a machine capable of handling all these requirements properly.

In general, different additive manufacturing process can use alternative to solve the same problem. So, what we are trying to say is you have AM 1, AM 1, you have AM 2, you have AM 3 machines or processes. So, all the three processes can lead to one output product, ok. To define such as structure first the meaning of the term technology has to be distinguished from application.

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As, technology is defined as a science of technical process and describes the scientific approach, application means how to use the technology to benefit from it, which is also called the practical approach. So, this is the definition for technology

To obtain a better overview, different classes of application, so called application levels are defined to apply this technology. The definition are widely accepted, but not standardized yet and despite all standardization efforts sometimes there is always a different terms in usage.

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So, AM technology is characterized by two main application levels; one is rapid prototyping, the other one is rapid manufacturing. As can be seen in the illustration AM technology is characterized by two main application levels rapid prototyping and rapid manufacturing. Rapid prototyping describes all applications that lead to prototypes. Samples, models, mock-ups, while rapid manufacturing is used when final parts or even products are made.

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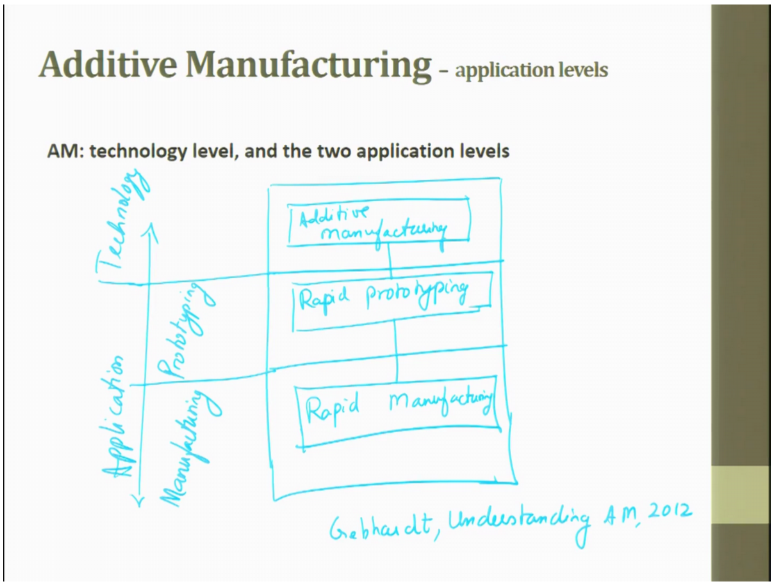

So, AM technology level and the two application levels. So, let me draw the same schematic diagram which we used earlier, now we will try to have a deeper insight. So, this is going to be additive manufacturing. The next one is going to be rapid prototyping, rapid manufacturing. So, here we have prototyping, here we have manufacturing, this is technology. So, this schematic diagram is given by Gebhardt from the book, Understanding.

So, this we saw earlier. So, this is additive manufacturing which is a technology then rapid prototyping rapid manufacturing this is the manufacturing which is there in levels.

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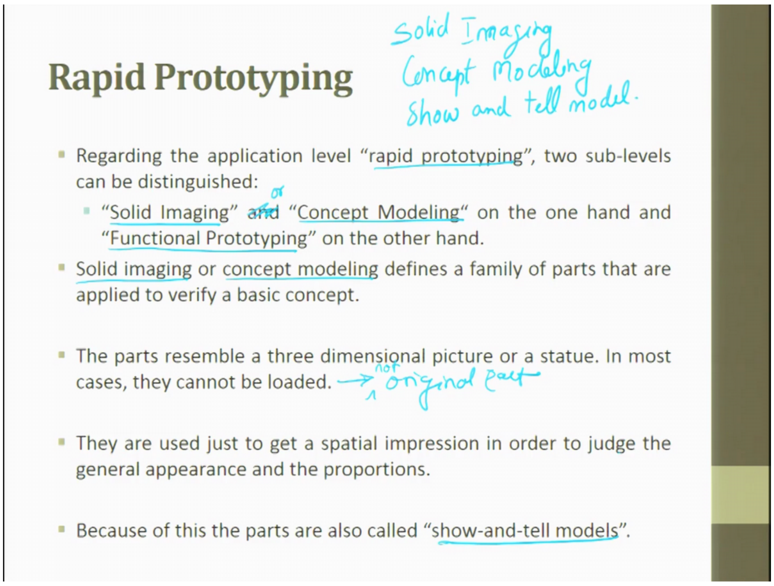

Regarding the application level rapid prototyping has two sub-levels which can be distinguished one is solid imaging and concept modelling on the one hand and functional prototype on the other hand. So, solid imaging and concept modelling on one hand, and functional prototyping on the other hand; solid imaging or concept modelling defines a family of parts that are applied to verify a basic concept. Please understand, solid imaging or concept modelling defines a family of parts that are applied to verify a basic concept.

The parts resemble a 3-dimensional picture or a statue. In most cases they cannot be loaded. So, because it is not the original part; it is not it is not the original part not original part, it is only for prototyping. So, this has to be or. They are used just to get a spatial impression in order to judge the general appearance and the proportions because of this the parts are also called as show-and-tell models. So, please understand this is solid imaging concept modelling and show and tell models, all are almost the same. So, it cannot be used for any functional application.

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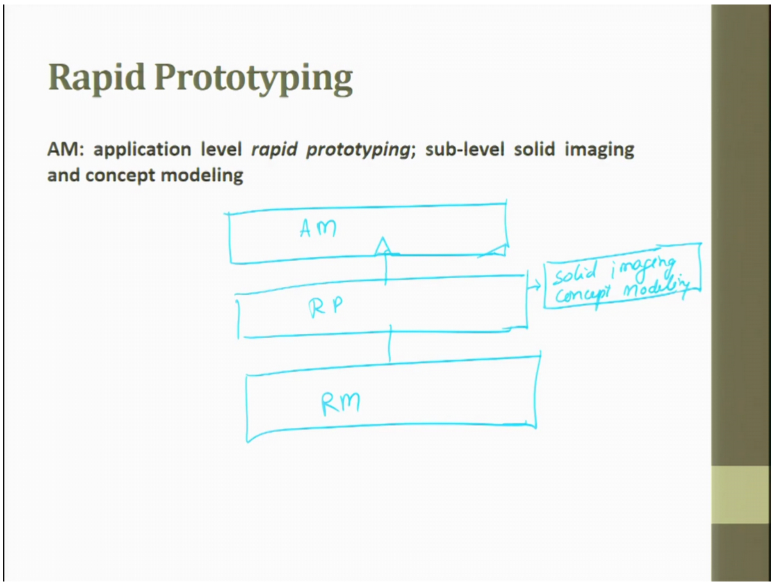

So, AM application level rapid prototyping; sub level solid imaging and concept modelling. So, here if you see that the same image whatever we have discussed earlier which is nothing, but additive manufacturing rapid prototyping and rapid manufacturing, you have here this is: what is a level which is called as solid imaging concept modelling.

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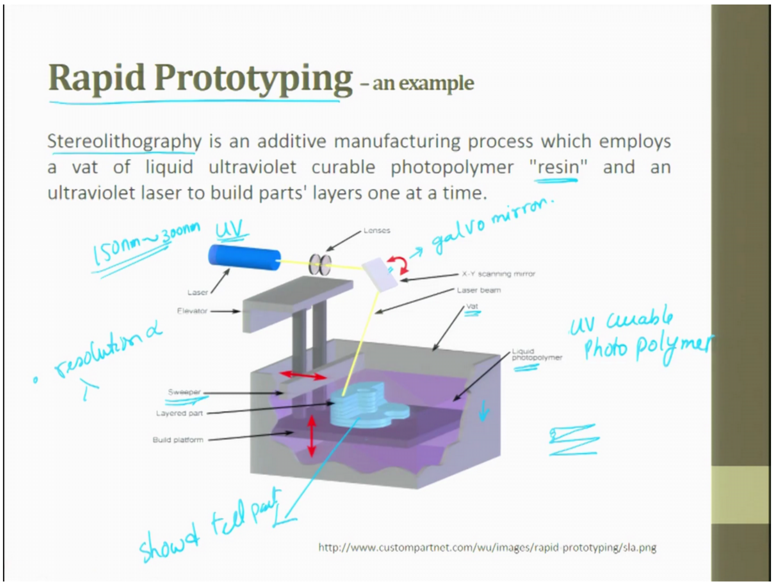

So, we are just taking an example of a process which is very much popular in rapid prototyping which is called as stereolithography. Initially it was very popular, then slowly slowly because of it is cost per part is. So, expensive this technology is over taken by many other technologies, but today once again stereolithography has come into action when you want to make miniaturized and very small parts. So, stereolithography is a additive manufacturing process which employs a vat. So, this is a vat. So, the entire box which is there that is called as the vat is which employs vat of liquid of liquid ultraviolet curable photopolymer. This is the polymer which is placed. This polymer is placed in a tank which is called as vat with the polymer is otherwise called as resin.

And a UV laser is used to build the part layer by layer one at a time. Liquid photopolymer is nothing, but UV curable photopolymer and then what I use is, I use a laser which is UV. What is UV? Anything less from 150 nanometre to somewhere close to 300 nanometre, ok; so, this is UV. So, we use this UV laser to hit at a galvo, this is called as a galvo mirror.

So, this advantage of this galvo mirror is you are not mechanically moving any part. This galvo what it does is it just sweeps and tries to take the information from the laser and it starts curing layer by layer and once one layer is done this table either can shrink down or can go down or shrink it can go down or the laser can go up. Generally, what happens the vat tries to move down, ok. Once, one layer of information is there. One layer of information everything is getting transferred from the laser through the lens to the galvo mirror and from the galvo mirror it is hit at a surface and it is cured.

So, here first it is done spot then it is done here raster then it is done a layer ok. So, here is the sweeper. So, what happens is once the vat sinks down by a layer, in order to maintain uniform thickness access resin is removed by using the sweeper. So, this is the part which is already made because of UV curing and this is the platform on which the part is getting build, ok. And, why the from the by looking at the wavelength itself you can decide that it the resolutions are very good; resolution is directly proportion to the wavelength.

So, if the wavelength is small so, the resolution of the feature whatever is getting build is high and on top of it you have this lenses to modify the beam, beam quality or the beam shape whatever it is, ok. So, this is a typical or a simple example of rapid prototyping technique. So, whatever the part has come out here it is only a show and tell part or a concept part which is used to give a customer a feel that this is how it looks like or they can check the proportionality or they can check the form and the fit.

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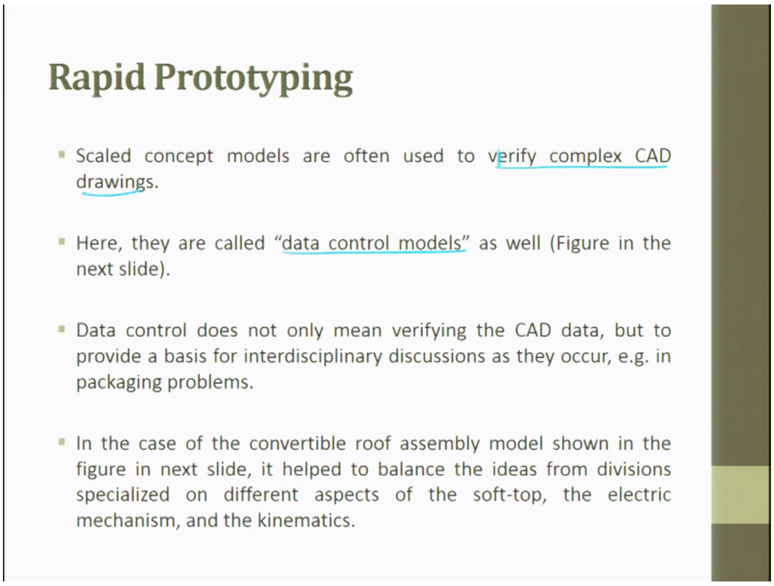

So, the scaled concept model are often used to verify complex CAD drawings. Here, they are called as data control models as well we will see it in the next figure, data control models. Data control does not only mean verifying the CAD data, but to provide a basis for interdisciplinary discussions as they occur; example, in packaging problems.

In the case of convertible roof assembly model shown in the figure in the next slide, it helps to balance the idea from divisions specialized on different aspects of the soft-top, and the electric mechanism, and the kinematics.

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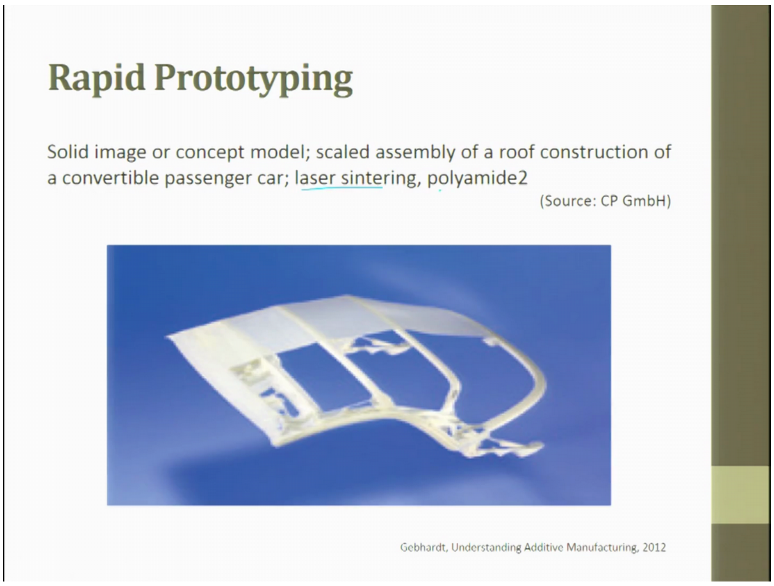

So, this is the concept model; scaled assembly of a roof construction of a convertible passenger car, ok. So, it is done by laser sintering and polyamide 2 is used as the material.

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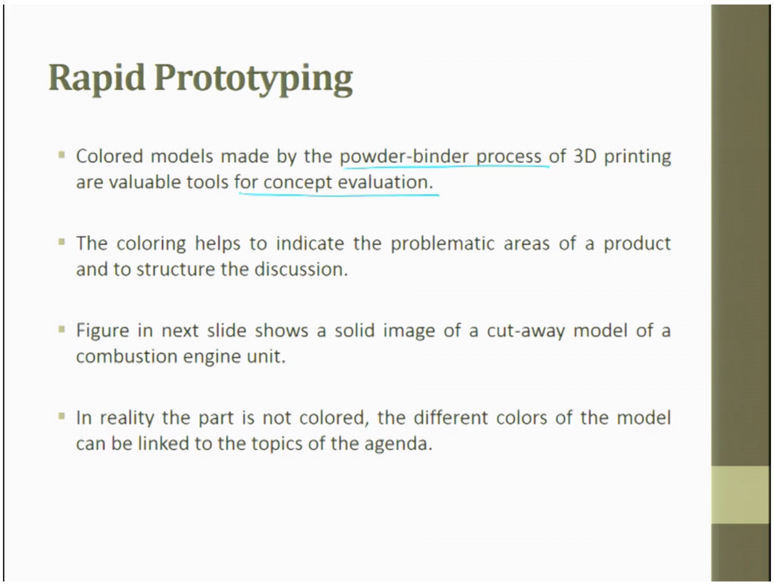

The coloured models by powder-bind process of 3D printing are valuable tools for concept evaluation. For example, if you are trying to give a topological information about a space so, you would like to show the mountain as brown in colour water blue in colour and the green pasture as green and constructed buildings of some colour.

So, here in rapid prototyping you have this advantage you can also blend colours, add while developing the a printing or while developing the part the colouring helps to indicate the problematic area of the product and to structure the discussion. Figure in the next slide shows a solid image of a cut away model of a combustion engine unit. In reality the parts are not coloured the different colour of the model can be linked to the topics of the agenda.

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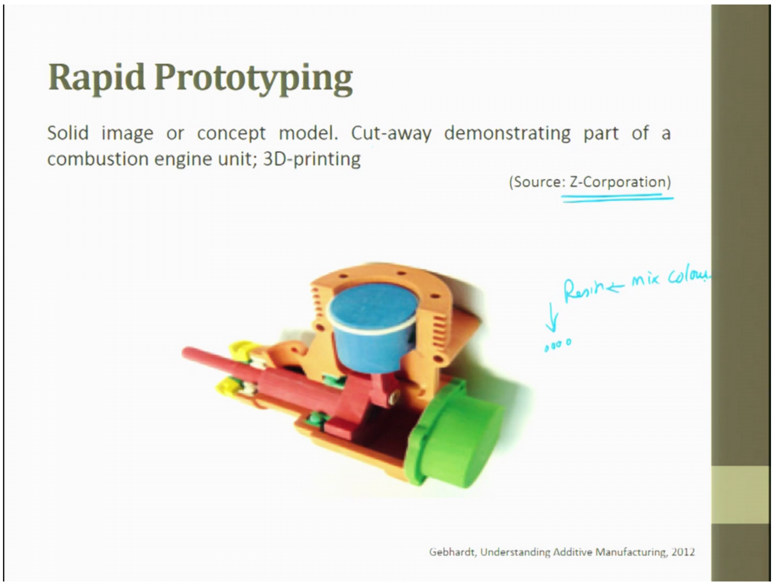

So, you look at here we have made parts of different colours. So, that it is very visible and you can also try to see where the problem lies. The example what I gave for topological information so, that is also possible. So, people try to get draw terrains, and then they use to get. So, we also try to add colours while printing.

So, cut away demonstrating parts of the combustion engine unit which is 3D printed is shown here. This machine which was developed was Z-corporation. So, here what they do is they try to use powder and they try to use resin, in that resin they try to mix colour. So, that is how you get the colour.

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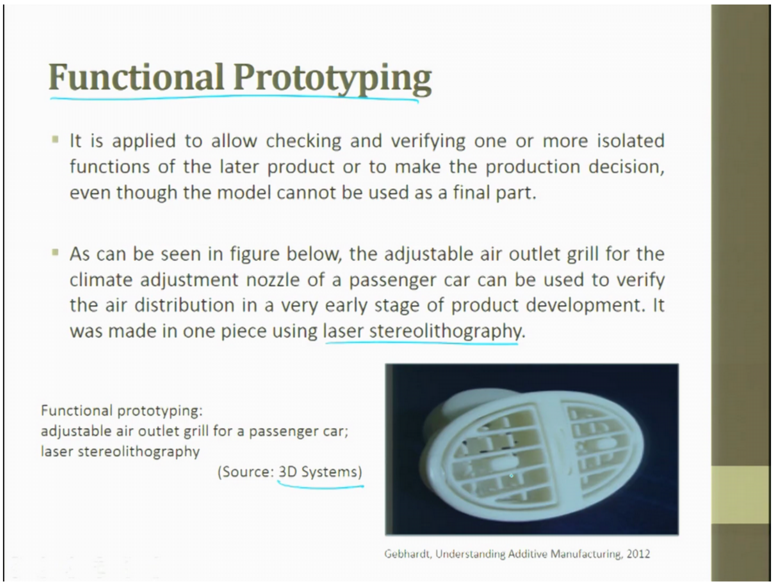

So, what is functional prototyping? It is applied to allow checking and verifying one or more isolated functions of the later product or to make the production decision, even though the model cannot be used as a final part. So, here what we do is we try to look at only functional aspects. Earlier we were trying to look at form fit and other things here we would also try to look at slightly more than that. Actually, when we talk about fits functional prototype is also used for looking at fits.

As can be seen in the figure below, the adjustable air outlet grill for the climate adjustment nozzle of a passenger car can be used to verify the air distribution in a very early stage of the product development. It was made in one piece using laser stereolithography. So, laser stereolithography was the process which we discussed till now and 3D systems is a company which develops this. So, this is the filter, this is an adjustable nozzle a head and then this can sweep and try to mix the air inside a car.

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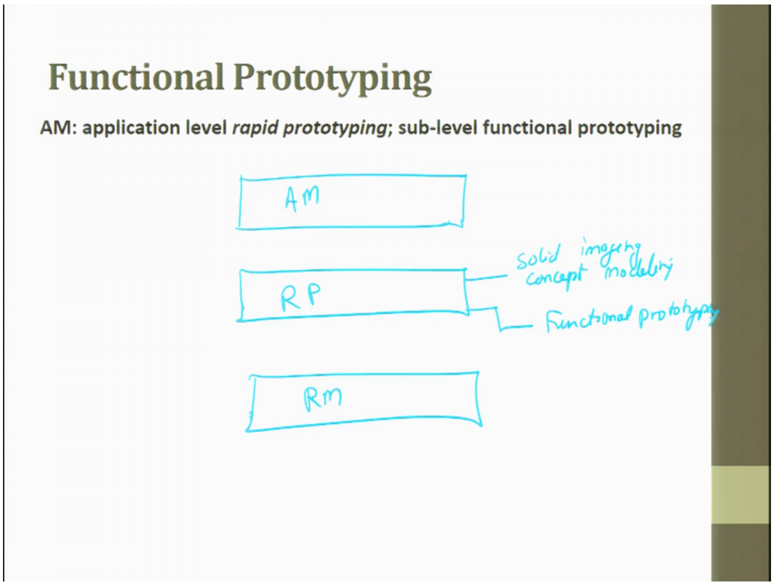

So, when we talk about function prototyping going back to the same figure this is additive manufacturing which is rapid prototyping, rapid manufacturing. We saw here earlier it was solid imaging and concept modelling. We have a next thing which is more towards functional prototyping.

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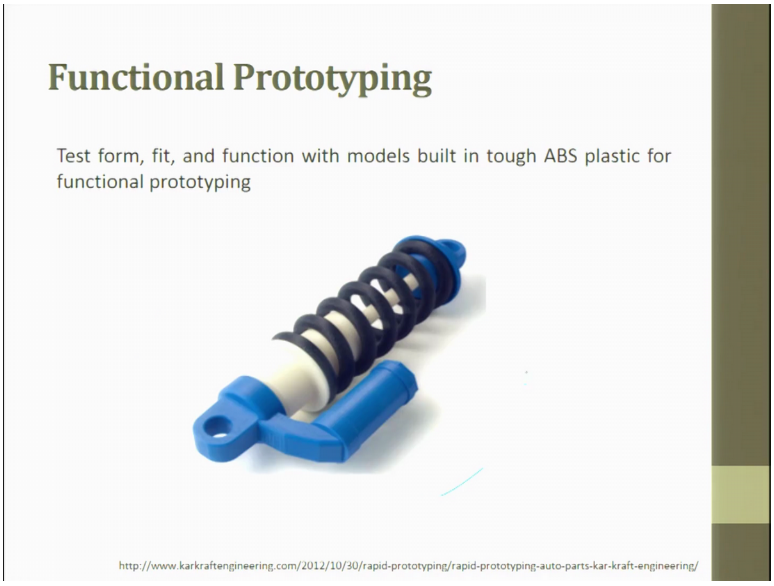

So, test form, fit, function with models built in tough ABS plastics for functional prototype is shown here. This is a shock absorber which is used for automobile application.

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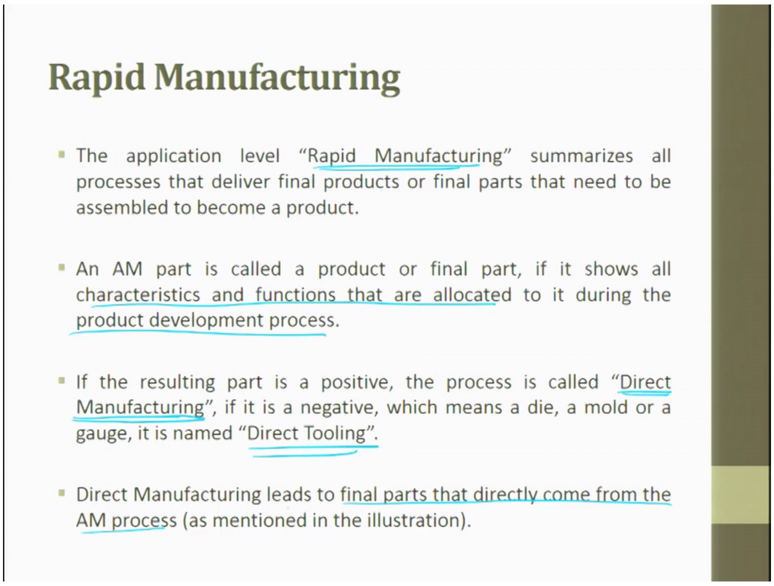

So, now let us move to the next part which is on rapid manufacturing. The application level rapid manufacturing summarizes all processes that deliver final products or final parts that need to be assembled to become a product. An AM part is called a product or a final part, if it shows all characteristics and functions that are allocated to it during the product development process, ok. So, during the product development process if you can add characteristics and the function that are allocated to it during the product development process, it can be done.

If the resulting part is positive, the process is called as direct manufacturing, if it is negative which means a die, a mold or a gauge, it is called as direct tooling. Please understand the difference between these two. The negative of direct manufacturing becomes tooling and the positive becomes rapid manufacturing. Direct manufacturing leads to final parts that directly come out of AM process. Today, we are looking at rapid prototyping getting converted into rapid manufacturing and producing the parts in the mass customized way what we want.

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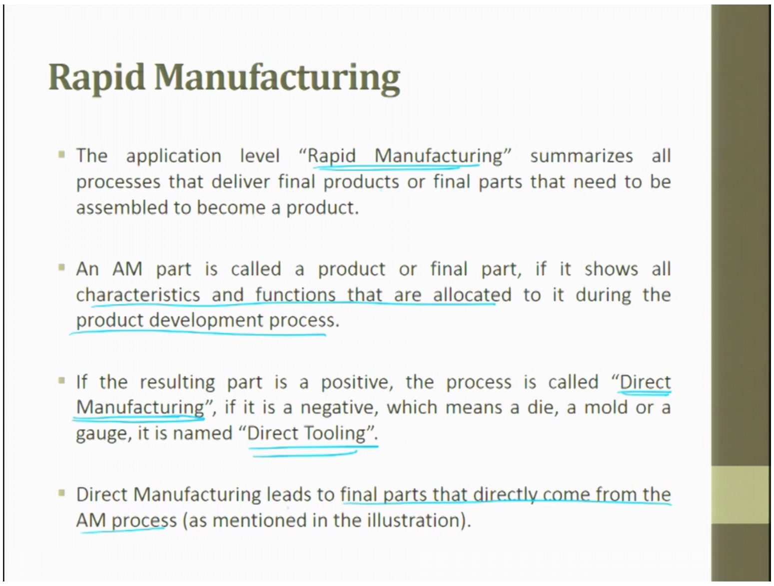

So, rapid manufacturing today a broad variety of materials from all material class – plastic, metal, ceramic are available to produce the to be processed directly using AM process. Here it is not important that the available material show exactly the same physical properties as the materials used within traditional fabrication process. However, it must be assured that the properties on which the engineering design was based can be realized with the chosen AM process and material. The figure shows here cobalt chromium alloys have been used for selective laser melting.

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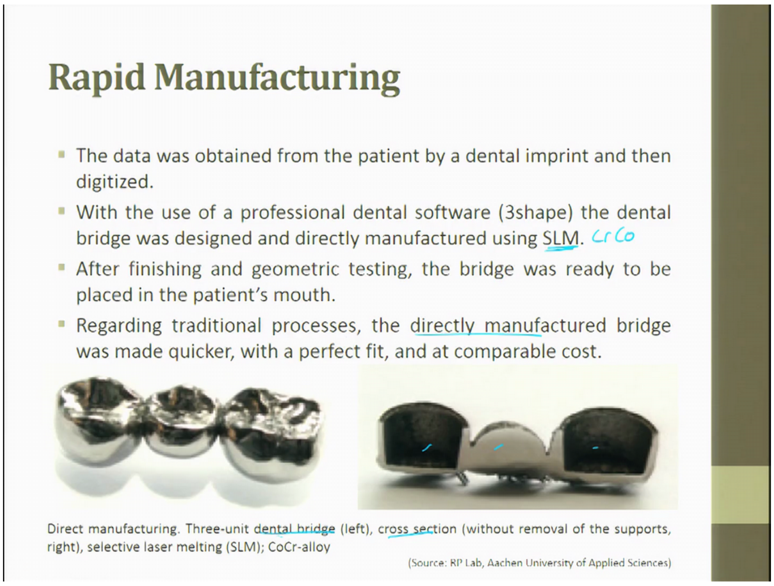

So, in rapid manufacturing, the data was obtained from the patient by a dental imprint and then digitized. With the use of the professional dental software 3 shape the dental bridge was designed and directly manufactured using SLM process – Selective Laser Melting process of chromium cobalt alloys. After finishing and geometric testing, the bridge was ready to be placed in the patients mouth. So, this is direct manufacturing three unit dental bridge which is there and when we try to take the cross section without removal of the supports the selective laser melting we see this one, we see this one is the cross section, and here what we see is the dental bridge.

So, what we do is we try to go to a patient and then patient we try to scan his teeth profile and then from the teeth profile the scanned data is converted into a CAD model, from the CAD model it is directly given to 3D printing or it is given to additive manufacturing through a process called as SLM we try to get the output. So, regarding traditional process, the directly manufacture bridge was made quicker, with a perfect fit and a comparable cost. So, this direct manufacturing now has become a it does come into regular use where dentists use it exhaustively for making teeth dental bridges.

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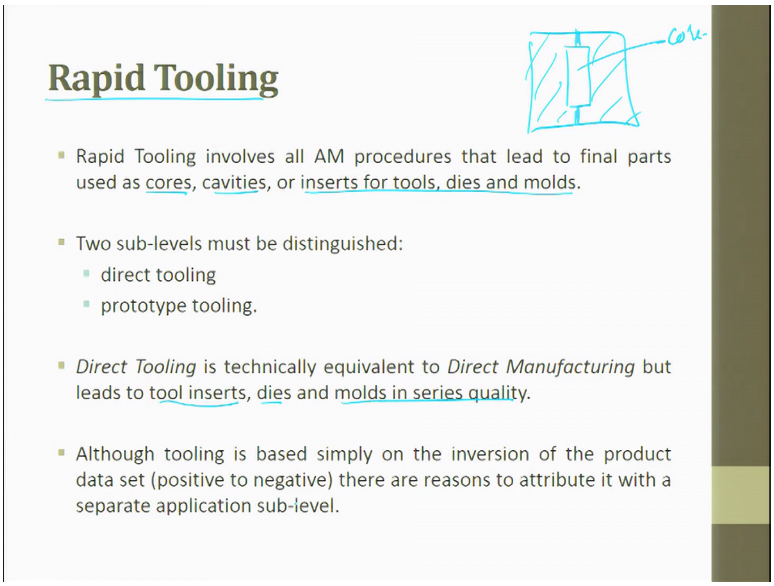

Rapid tooling which I told you is the direct tooling which is a negative of rapid manufacturing. Rapid tooling, involves all AM procedures that lead to a final product used as core, cavity or insert for tools, dies and molds. So, cavity core is in a whole or in a free space or inside a closed confined space you put a core, so that you try to make. So, you have a closed cavity and then here you do not want material so, this you put it as a core. This core cannot stand freely in here. So, you put supporting elements to make the core and now this portion will be made of the material, ok. So, you get this can be used for casting or molding.

Two sub level must be distinguished, direct tooling and prototype tooling. Direct tooling is a technical equivalent to direct manufacturing, but leads to tool inserts, die, mold in series quality. Although tooling is based simply on the inversion of the product data set there are reasons to attribute it with a separate application sub-level, ok.

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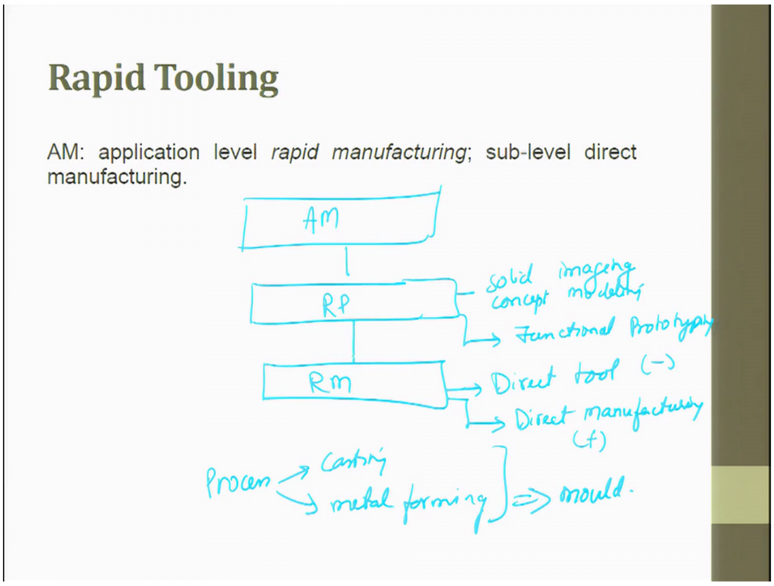

So, we are talking about rapid tooling and now the same diagram we will start using. So, additive manufacturing this is rapid prototyping and this is rapid manufacturing. So, here we had solid image imaging and then we have concept modelling, the next one we had is functional prototyping and RM is direct tooling and direct manufacturing.

So, now, you must be able to understand the difference between direct tooling and direct manufacturing positive, negative. So, this can be used. What are the processes which can use; generally we use to go for casting, and metal forming operations where we try to make a mold. The example what I gave in the first lecture was about making a ear replica of the ear. So, if you want to do we try to make a mold through rapid prototyping and then we try to pore a silicon in it to get the final product.

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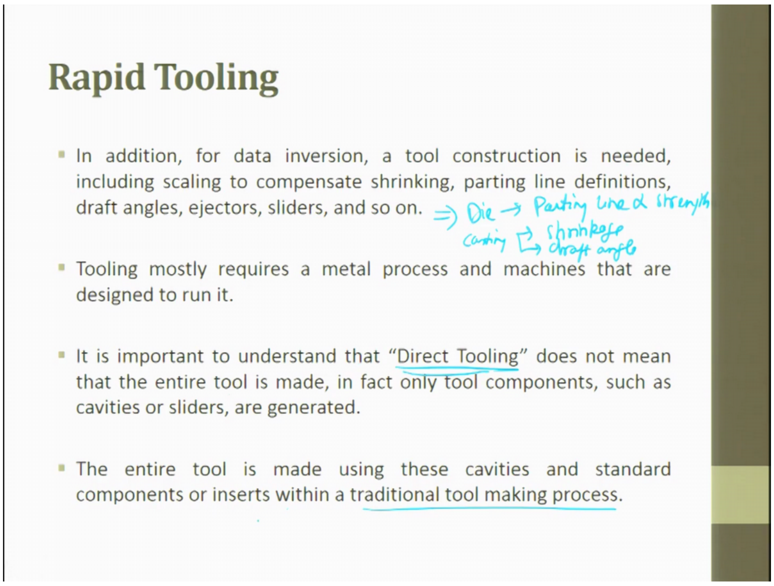

In addition to, for data inversion a tool construction is needed, including scaling to compensate shrinkage, part line definitions, draft angle, ejectors, sliders and so on. In a mold or in a die these are very important; die parting line is important because part parting line is directly proportion to the strength of the part. So, that is very important. Next is when you talk about casting the important thing which comes out is shrinkage and draft angle, so that the part can be removed very easily and when we talk about ejecting pins and sliders in metal forming these are very very important.

Tooling mostly requires a metal process and machines that are designed to run. It is important to understand that direct tooling does not mean that the entire tool is made. In fact, only tool components such as cavities, sliders are generated. Tooling means it is not the complete tool, it is only a part or a cavity or an insert is made. The entire tool is made using these cavities and standard components or inserts within a traditional tool making process, ok. So, you should understand the difference the entire tool is made using these cavities. The cavities are made from here and standard components or inserts with the traditional tool making process.

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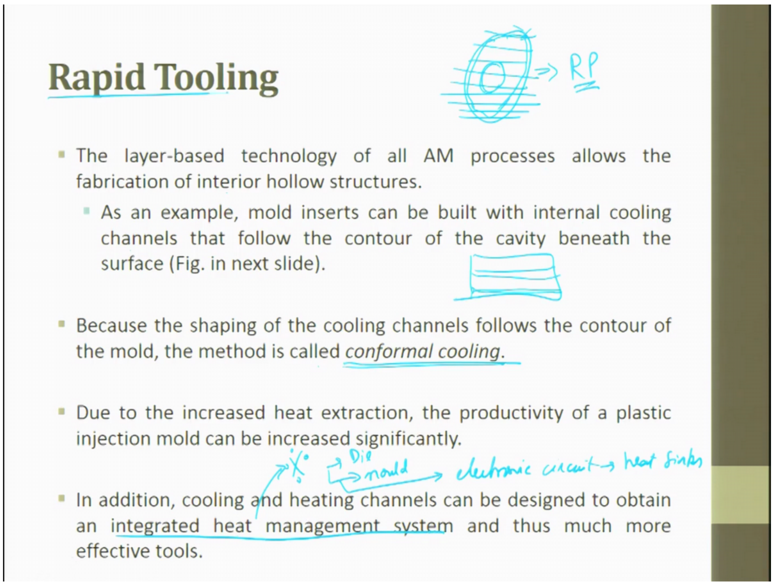

The layer-based technology of all AM processes allows the fabrication of interior hollow structure. For example, if I want to make an egg, want to make an egg; assume this is a shell of an egg and if I want to make a hollow structure inside it is possible and interestingly if you want to make a egg with a yolk inside, right without partitioning or breaking open the shell you want to construct this product rapid prototyping is the only technique which you can make.

If you want to do it by any other conventional techniques it is not possible without break opening the shell, only in rapid prototyping we do this layer by layer by layer by layer and make this part and once all the layers are made the interior material whatever is there can be removed, right, either by making a small hole here or something it can be removed or we can do something else so that this can be completely removed. If you want to remove it completely by just pushing into a liquid and then, just washing it that is also possible.

So, layer-based technology of all additive manufacturing process allows the fabrication of interior hollow structures. As an example mold inserts can be built with internal cooling channels that follow the contour of a cavity beneath the surface. For example, you have a die and through the die, you want to make a channel and this channel can be made while the part is manufactured rather than doing at the last because the shaping of cooling channels follows the contour of the mold, the method is also called as conformal cooling. The cooling channels follow the contour side is called as conformal cooling.

Due to the increase in heat extraction, the productivity of a plastic injection mold can be increased significantly. When you start making this the channels in the mold so, then the efficiency of the process goes high in addition cooling and heating channels can be designed to obtain an integrated heat management system. So, this is very important which people are talking out today because lot of dies, mold and in fact, electronic circuits, electronic circuits they have a sink heat sink the heat sinks are today manufactured by using rapid prototyping techniques or rapid manufacturing techniques. Wherein which the heat management can be done in a very very efficient way. For this rapid prototyping rapid tooling is also used.

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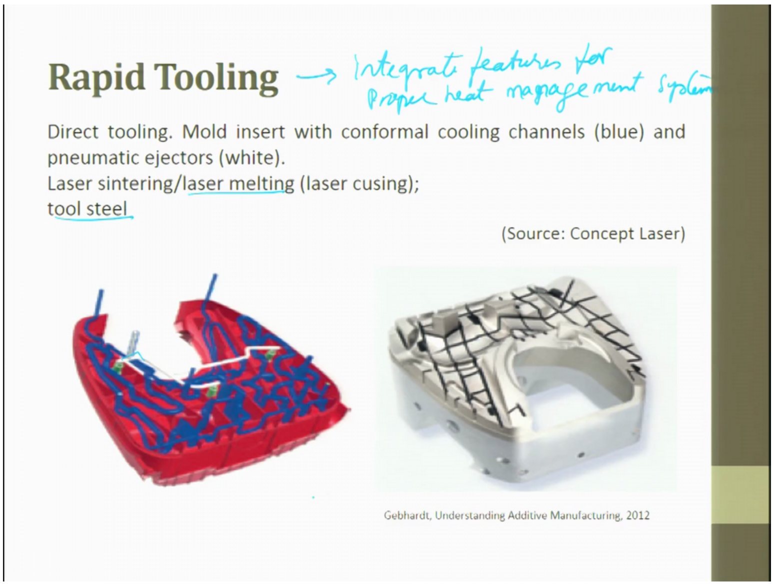

So, direct tooling is the mold insert with conformal cooling these are conformal cooling blue and pneumatic ejectors are white, these are white pneumatic ejectors. This is made by a process called as laser sintering or laser selective laser melting or using tools steel as a material we are able to integrate features for proper heat management systems. So, this can be made into action only because of rapid prototyping and rapid tooling, right.

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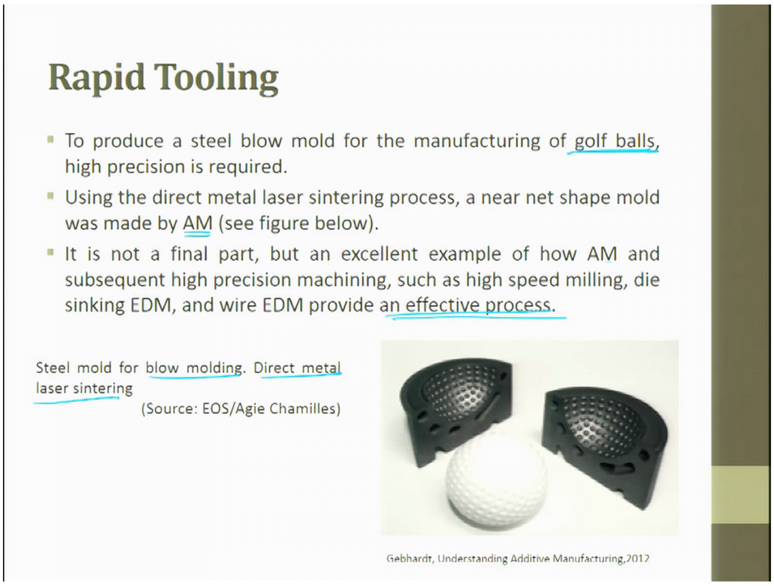

To see a steel blow mold for the manufacturing of golf balls, which needs very high precision we can also do it by rapid tooling. Using of direct metal laser sintering process, a near net shape mold was manufactured using additive manufacturing. It is not a final part, but an excellent example of how AM and subsequent high precision machining, such as high speed milling, die sinking EDM and wire EDM produces an effective process.

So, here these are molds for blow molding and where this mold is made by direct metal laser sintering.

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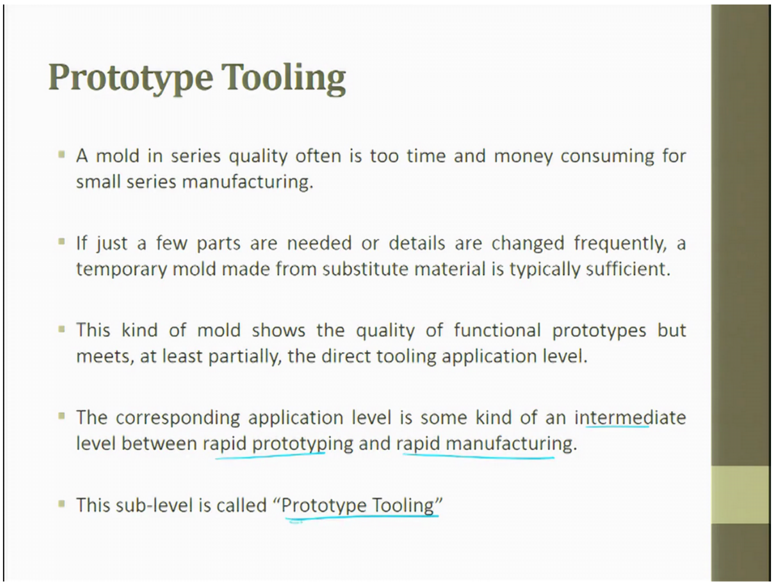

A mold is a series quality often is too time and money consuming for small series manufacturing. If just a few parts are needed or details are changed frequently a temporary mold made from substitute material is typically sufficient. This kind of mold shows, the quality of the functional prototypes, but meets, at least partially, the direct tooling application level. The corresponding application level is some kind of an intermediate level between rapid prototyping and rapid manufacturing this sub-level is called as prototype tooling.

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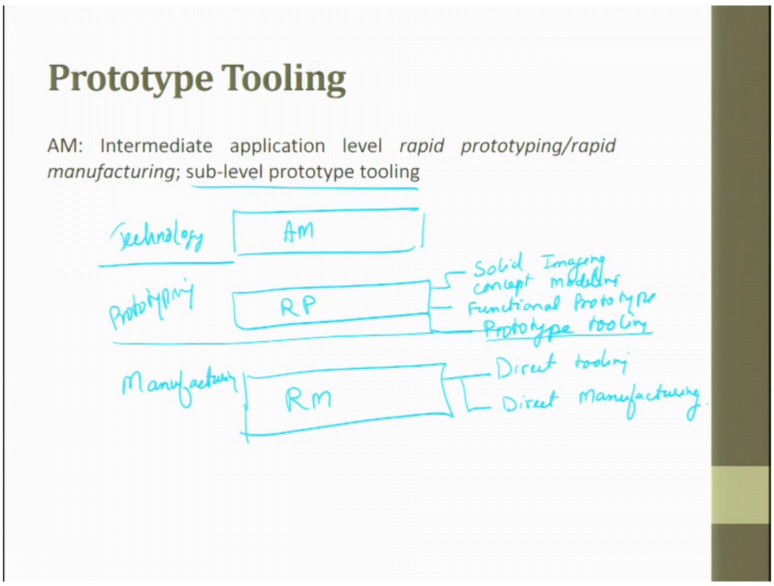

So, where does this sub-level come? This sub-level comes here you have additive manufacturing, you have rapid prototyping, you have rapid manufacturing. So, here you have direct tooling, you have direct manufacturing, ok, you have solid image solid imaging concept modelling, you have functional prototyping we discussed all those things, prototyping and then we have one more category is nothing, but prototype tooling, ok. Prototype tooling – this falls exactly at the bridge of prototyping and manufacturing. This is a technology we have right this is a technology we have.

So, what are we trying to say is I am trying to impress you saying that all this additive manufacturing, rapid prototyping, rapid manufacturing, what are all parts of it, at each level what comes, this is what we are trying to see in this lecture. So, prototype tooling is a sub-level which comes in additive in rapid prototyping.

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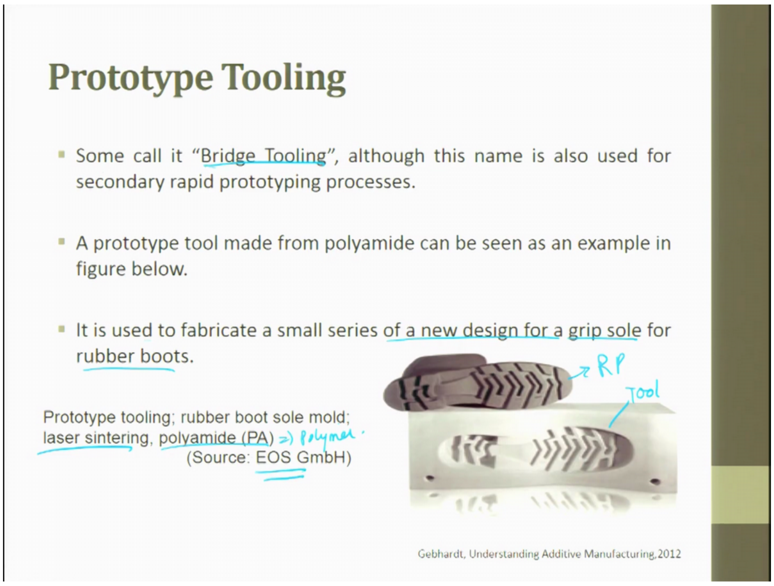

So, prototyping tools so called as bridge tooling, although this name is also used for secondary rapid prototyping process. A prototype tool made from polyamide can be seen as an example in the figure below, ok. This is used to fabricate a small series of new design for a grip sole that for rubber boots. For example, this is: what is the boot which they have made through rapid prototyping and the rubber was heated and then you got the product out; so, for this is the tool which is used. So, in order to make this tool and try to do some functional test to see how good is the gripping.

So, the prototype tooling is rubber boot sole mold is been made by using laser sintering and polyamide is the material; polyamide is a polymer material, ok. This is done by EOS machine. So, bridge tool is otherwise called as prototyping tool is also part of this rapid manufacturing.

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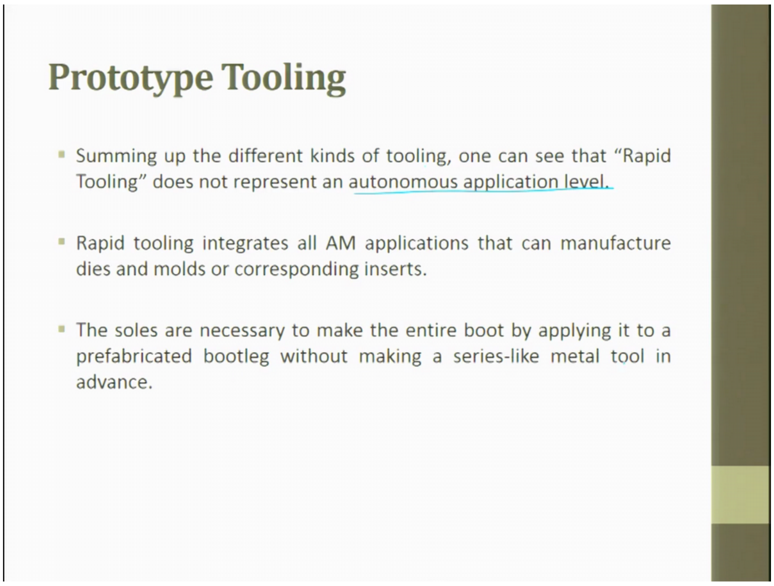

So, prototyping tooling, summing up the different kinds of tooling, one can see that rapid tooling does not represent an autonomous application level. The rapid tooling integrates all rapid manufacturing applications that can manufacture dies and molds or the corresponding inserts. The soles are necessary to make the entire boot by applying it to a prefabricated bootleg without making a series-like metal tools in advance.

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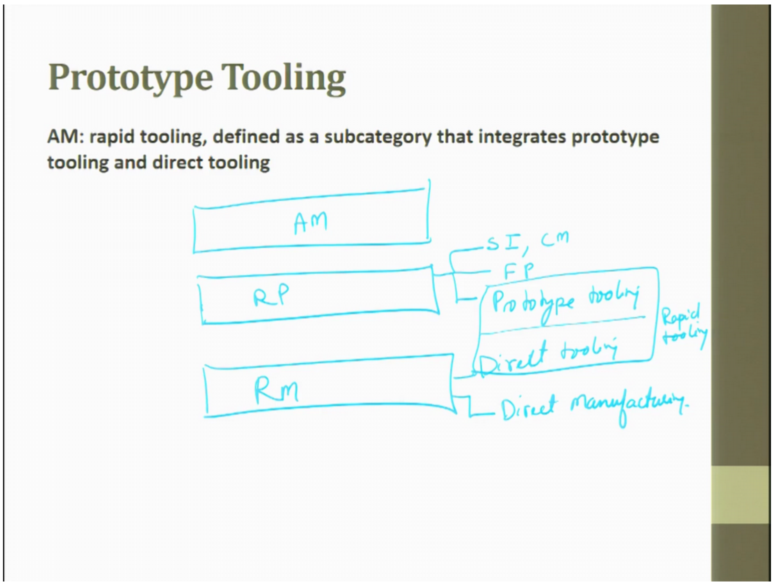

So, now let us see where does this rapid tooling falls by. This is additive manufacturing, this is rapid prototyping and this is rapid manufacturing and here you have this solid imaging and solid imaging concept molding, then you have functional prototyping then you had prototype tooling, and then here we had direct tooling and then we had direct manufacturing, correct.

Now, a combination of these two leads to a level called as rapid tooling, ok. So, this two encapsules and forms a terminology called as rapid tooling. So, prototype tooling, for making prototype you make a tool for directly getting the output you make the tool. So, finally, when you try to blend these two we have rapid tooling as defined as a sub category that integrates prototype tooling and direct tooling.

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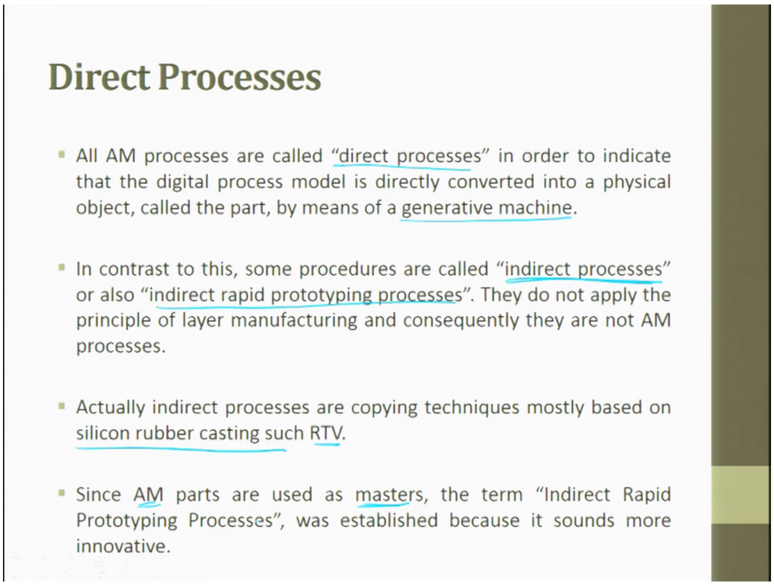

So, direct processes all AM processes are called as direct processes. In order to indicate that the digital process model is directly converted into a physical object called the part by means of generative machine. In contrast to this, some procedures are called as indirect process or indirect rapid prototyping process. They do not apply the principle of layered manufacturing and consequently they are not additive manufacturing process.

Actually indirect processing are copying techniques mostly based on silicon rubber casting such as RTV. So, they are called as indirect processing. Since AM parts are used as masters, the term indirect rapid prototyping process was established because it sounds more innovative. So, AM is used for making a master and from the master you are making prototypes. So, the term indirect rapid prototyping process was established because it sounds more innovative.

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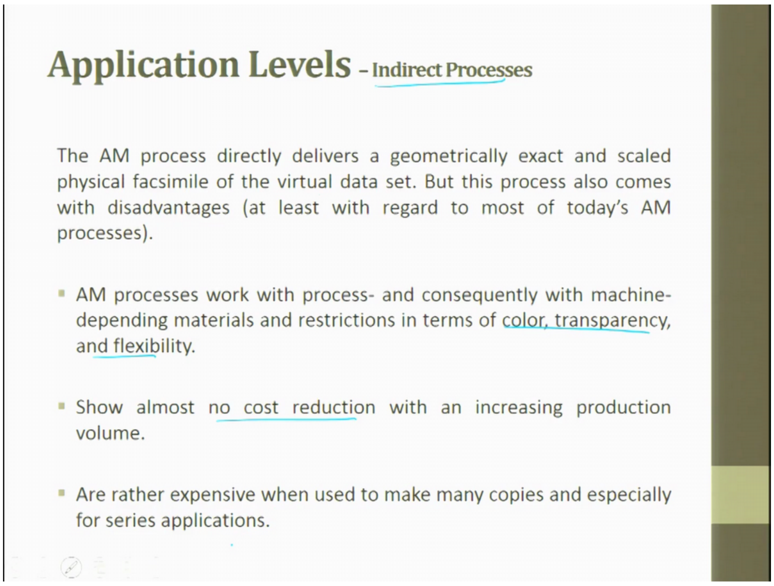

So, indirect process; an AM process directly delivers a geometrical extract and scaled physical facsimile of the virtual data set. But, this process also called comes with the disadvantage at least with regards to most of today's AM processes. AM processes work with process and consequently with machine-depending material and restriction in terms of colour, transparency, and flexibility. Shows almost no cost reduction with an increasing production volume; are rather expensive when used for making many copies and especially for series application. So, these are some of the disadvantages when we start talking about AM process today.

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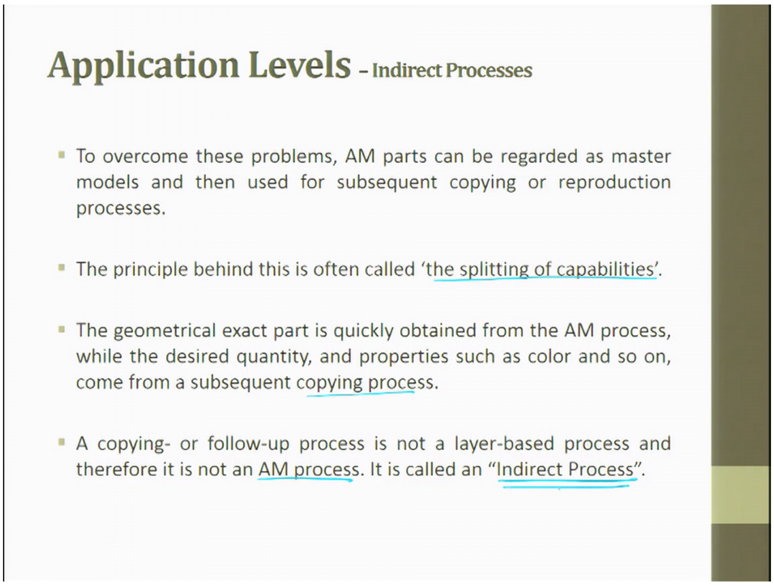

To overcome these problems AM parts can be regarded as master mold and then used for subsequent copying or reproduction process. The principle behind this is of10 called the splitting of capability. The geometrical exact part is quickly obtained from AM process, while the desired quantity, and property such as colour and so on, comes from the subsequent copying processes. A copying or a follow-up process is not a layered based process and therefore, it is not AM process. It is called as indirect process. Please understand the difference between direct process and indirect process, very important.

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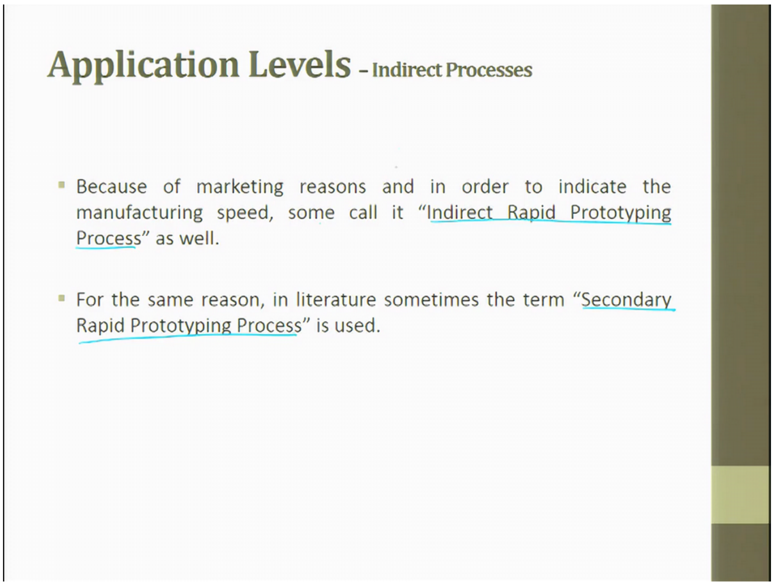

Because of the marketing reasons and in order to indicate the manufacturing speed, some call it indirect rapid prototyping process as well. For the same reason in literature sometimes the term secondary rapid prototyping process is also used. They are all part of indirect processes.

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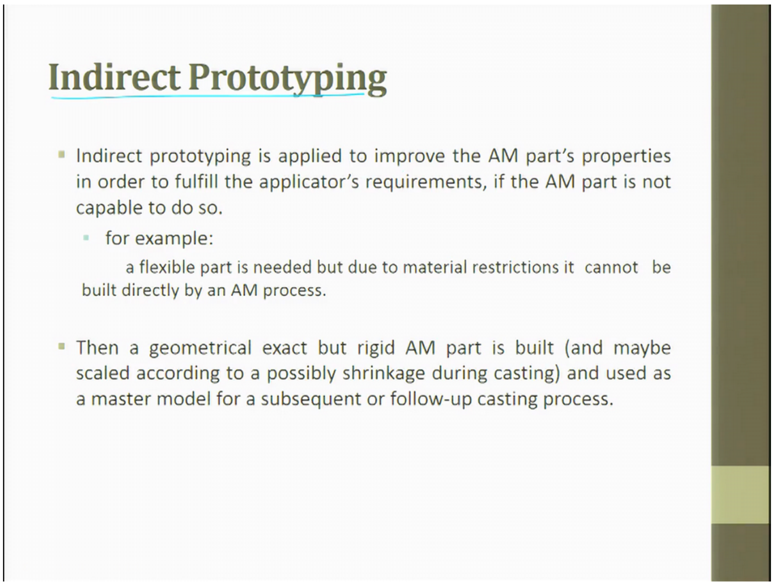

Indirect prototyping is applicable to improve the AM parts property in order to fulfil the applicators requirement, if the AM part is not capable to do so, for example; a flexible part is needed, but due to material restriction it cannot be built directly by an AM process. Then a geometrical extract, but rigid AM part is built and used as a master mold for a subsequent or follow-up casting process is indirect prototyping. I was giving you about the example of a ear that is indirect prototyping.

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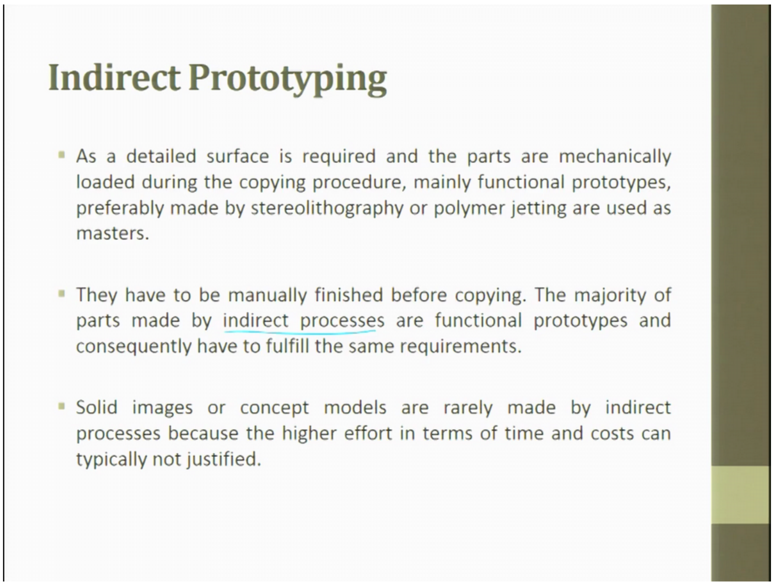

As the detailed surface is required and the parts are mechanically loaded during the copying procedure, mainly functional prototypes, preferably made by stereolithography or polymer jet are used as masters. They can be manually finished by copy before copying. The majority of the part made by indirect processes are functional prototype and consequently have to fulfil the same requirement. The solid images or concept model are rarely made by indirect processes because the higher efforts in terms of time and cost can be can typically be not justified.

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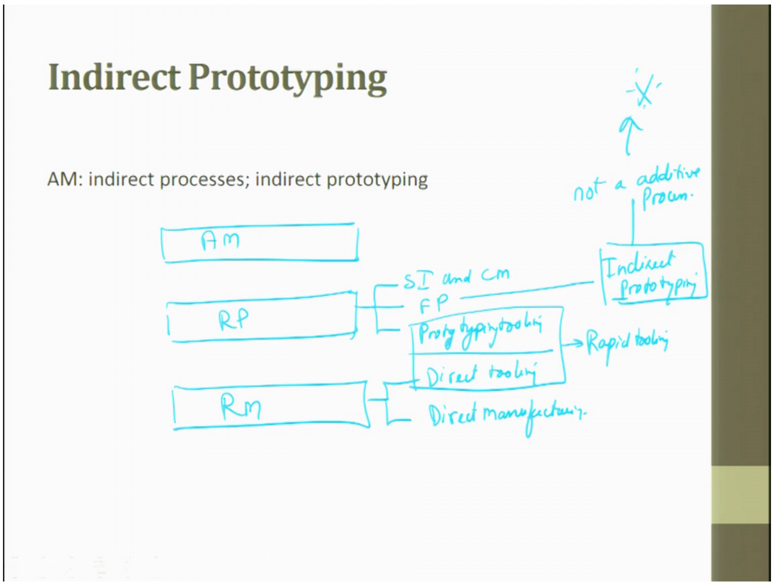

So, now when we talk about indirect; so, indirect processing as I told you if you go back this is additive manufacturing, rapid prototyping rapid prototyping and we have rapid manufacturing. So, here we have solid imaging and concept modelling, we have functional prototype, we have prototype prototyping tooling, we have direct tooling and we have direct manufacturing and these two put together they form rapid tooling. Now, from here functional prototype what we do is we try to make indirect prototyping which is not a additive process. This is very very important. Please, keep this in mind.

Thank you very much.