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

Welcome to the next lecture series in this course on product development processes.

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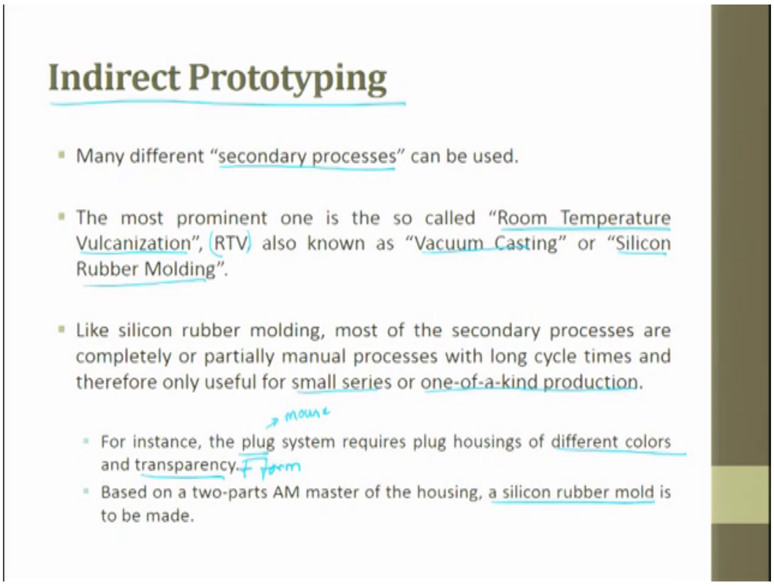

So, indirect prototyping many different secondary processes can be used for indirect prototyping. The most prominent one is also called as Room Temperature Vulcanization or it is otherwise called as RTV in short. It is also called as vacuum casting or it is called as silicon rubber mold. In the introductory lecture I was talking to you about the ear, which we made for the left side ear we made.

So, what we did was we did the right side scanning of the ear and then we did some tweaking with the help of the doctors and then what we did was, we tried to make it the by a mold by rapid prototyping. And then what we did was, we used this technique called as vacuum casting or silicon rubber molding to get the output what we want. So, that is nothing, but indirect type prototyping in fact, it is nothing but indirect type manufacturing itself we did. Like silicon rubber molding most of the secondary processes are completely or partially manual processes; with long cycle time and therefore, only used for small series or one of a kind production.

See this can be either when you talk about prototyping, it can be used for one at a time. If you want to even in prototyping today if you want to get a multiple customer feedback we always look for a small series a small batch size. So, this indirect prototyping technique can be used. For instance a plug system requires plug housing of different colours and transparency. So, there what we do was or instead of plug you can also take a mouse system, a mouse which is attached to a computer

So, if you want to make multiple mousses of a new design which is more economic and user friendly. So, we try to use we make this prototyping through this techniques, where in which we try to show the colour and the transparency as well as the form. Form to a customer get his feedback and find to in it. In fact, today now what researchers have found out is, every individual has his own ergonomic factors when from the wrist to the finger tip.

So now, they are talking about why do not we start customizing mousses for individual requirements and then start delivering it to their to them for their use. So, in that way indirect prototyping is the technique which is used. Based on two part additive manufacturing master of a housing, a silicon rubber mold is to be made to meet out the requirements.

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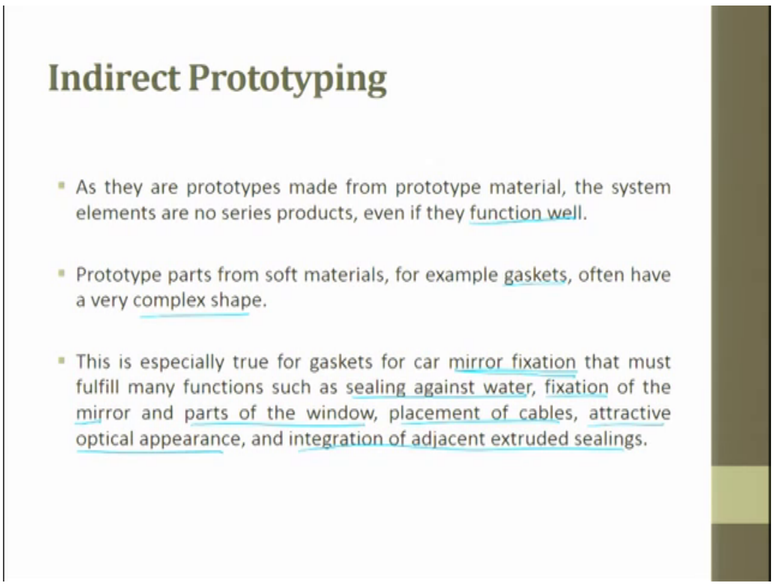

As they are prototypes made from prototyping materials, the system elements are no series products. Even if they are they function very well for example, the ear whatever we did we if we would said that that is a prototype. So, it is still find because if there is no dynamic load for it, it functionally serves a purpose it that the person has a left ear ok. Prototype parts from soft materials for example, gaskets that is rubber often have a very complex shapes.

So, we try to make it seal it and then see whether it is working, when we try to have metal to metal contact. This is essentially true for gaskets for car mirror or fixation that must fulfil many functions such as sealing against water, fixation of the mirror and parts of the window, replacement of placement of cables, attractive optical appearance and integration of adjacent extruded sealings

So, what we are trying to say is, when we try to make a mirror fixation it is not just to fix the mirror in a car. So, today it is all powered control mirror. So, you will have cables running by. You will have a small motor which tries to give you a x y plane rotation, then today in a high end cars you also have in the y is a direction also you can have a movement of the mirror. Then this mirror has to be sealed from water, then the mirror should also the fixation should be such a way such that the mirror is withstood even on major impact. For example, when it goes at 60 70 80 kilometre speed and hits or runs against potholes.

So, it should not fall down. So, that is next and it also are made to withstand higher impact when it touches the other car ok. So, all these things mirror fixing is an example, which the gasket which is made for this mirror fixing is an exact true example for indirect type prototyping.

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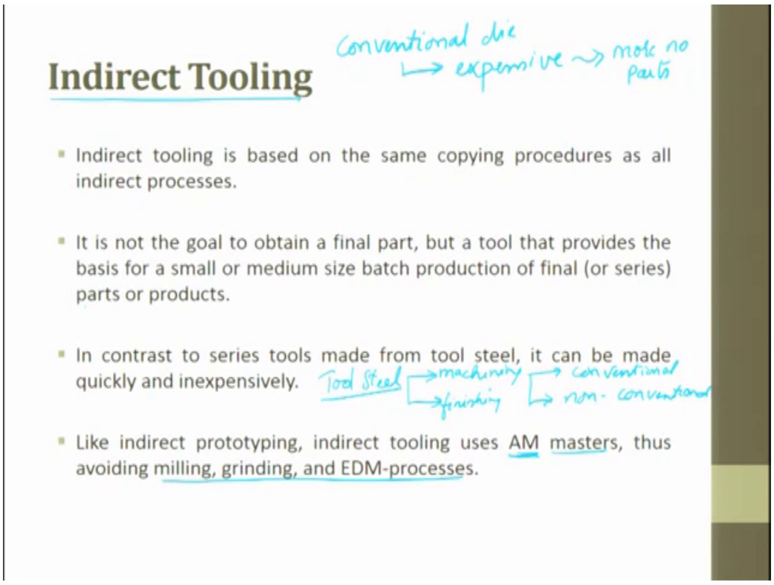

So, the next topic is indirect tooling. Indirect tooling is based on the same copying procedure as indirect processes. It is not that goal to obtain a final part, but a tool that provides the basis for a small or medium size batch production of final parts or products is nothing, but what we do is indirect tooling. In contrast to series tools made from the tool steel it can be made quickly and inexpensively as compared to that of die industry.

So, die industry many a times they use tool steel; this tool steel may many of the times it is made by machining operation machining can be conventional and it can be non-conventional. Non-conventional though you get the required output, but it has to it is it is a energy inefficient process. So, it takes a lot of time to make it then on top of it you will also have finishing processes which is coming by. So, that you finish the component and that is a huge challenge. Machining it is by non-conventional machining process you get the output, then after that we try to do finishing process. Finishing of a complex tool die takes a lot of time. So, today they are trying to innovate lot of processes in automating it.

So, if you look into the cycle of tool steel because you chose tool steel, you have to undergo all these processes to get the output. But if you can make the entire part without undergoing this non conventional or conventional and avoiding finishing you directly get a die whatever you want is the process which is called as indirect tooling ok. So, when you compare this indirect tooling, this processes are very fast that is why today we talk about metal based prototyping techniques, there are several techniques which has come.

So in fact, people have started using metal filament wire for making parts people have started making aluminium alloy powder, titanium alloy powder, aluminium alloy powders where in which directly they make a die and in fact, the finishing off late has also been improved.

The biggest challenge even in rapid manufacturing or in rapid prototyping what we talk about is this finishing is a challenge. So, people are trying to get out of this problem, but compared to tool steel going through the conventional root, if we get it done by additive manufacturing root then it is made very quickly and it is inexpensive. Like indirect prototyping, indirect tooling uses additive manufactured masters thus avoiding milling grinding and other EDM processes

So, what is happening, making of tool and these tools are what? One it is also expensive by the way. So, when we try to make a conventional die, it is expensive so, expensive. So, the justification comes by only making more number of parts. If you do not have to make more number of parts for example, you are looking for a small batch size of 10 parts then die is not the alternative. So, because this die finally, then again it needs a process from the meal forming or casting which again needs a raw materials stock to minimum quantity. So, this gets into a different completely different root. So, that is why people try to avoid this tool steel root of making die. They use this AM techniques to make indirect tools for meeting out to customer requirements and many a times the die first die whatever you make.

The die designing time itself takes almost close to 45 days. If it is a complex die it takes two months and then it is not the shape alone, you have to do shape and size it is also the simulation you have to do and find out how is the material getting distributed what is the load which comes at different points, how many injection points you should have all these things are too complex to do. So, if you decide to make a die metal die. So, the root itself takes six months and it is not necessary that after 6 months whatever you make gets accepted by the customer. Though we call modular designs can be followed, but finally, the shape and size and insert whatever you make has to be properly planned which takes a long time.

But if you follow this additive manufacturing root, that can be achieved very fast and we look for outputs.

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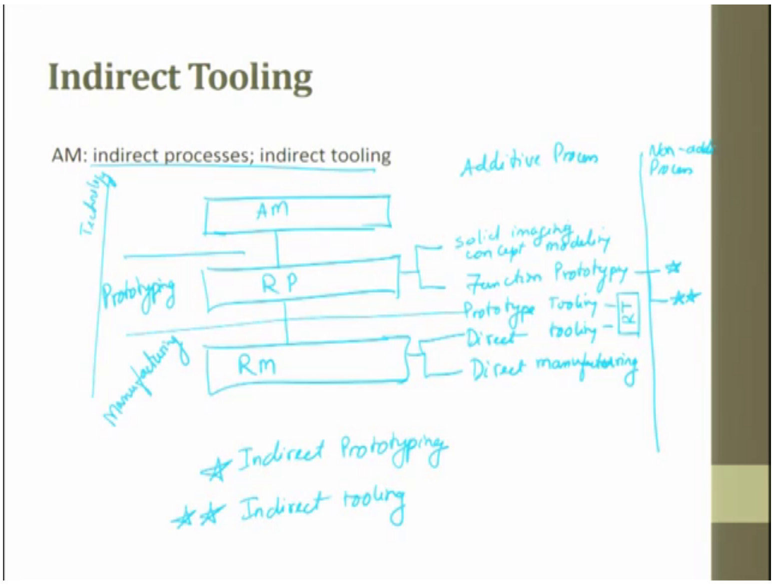

So, going back to our old diagram which we have been walking through in this first series of lectures, is the same diagram which I have been using. So, you will now appreciate where does this indirect tooling comes additive manufacturing then comes rapid prototyping RP, then comes RM rapid manufacturing ok. So, here we had solid image imaging, then we have concept modelling. This figure is very important if you remember this figure then it is very easy for you to understand the entire lecture of the first series whatever we talk about. Functional prototyping and then we had we had prototype tooling, then we had direct tooling, then we had direct manufacturing. So, these two comes from here ok.

When we bundle these two it is nothing, but which leads to rapid tooling ok. So, from here let me put a star here and this star represents indirect prototyping. And the other one and off shoot of this we will have we will have indirect tooling. So, now, you can understand where, does this indirect tooling come from rapid prototyping. So, this is a line which we draw, which is for prototyping and this is a place where we try to write manufacturing and this is what is technology this is technology ok.

And if I draw a diagram, till here it is called as additive processes and here it is non additive processes. So, you are trying to make a product which is not directly added, but you make a tool and from that tool you try to make a product. So, this diagram is very very important. If you look at it functional prototyping lead to indirect prototyping and then if you are looking forward from this and off shoot what you can do is you can try to take it for indirect tooling.

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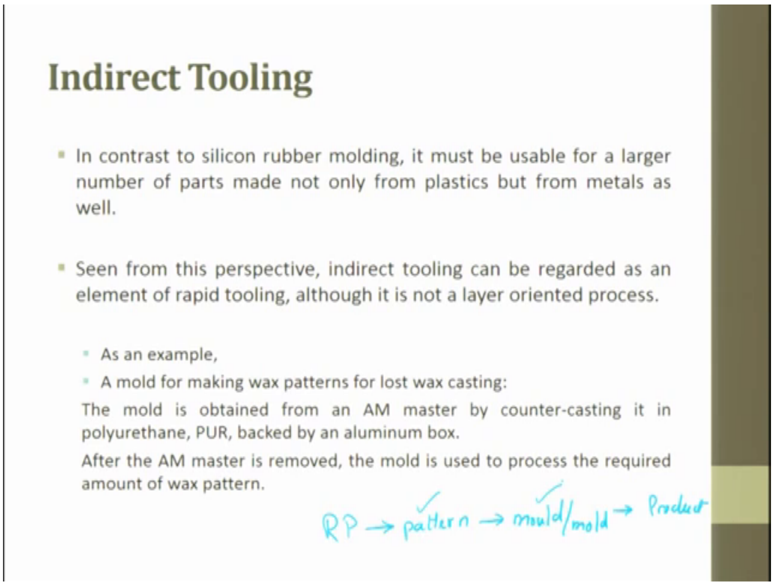

In contrast to silicon rubber mold, it may be use usable for a large number of parts made not only from plastic, but from metals as well this is what we discussed. Seen from this perspective indirect tooling can be regarded as an element of rapid tooling although it is not a layer oriented process because tool is made and then you pour it. As an example a mold for making wax patterns of lost wax casting is done through this. So, lost wax casting is you make a pattern and then from that you try to make a molds.

The mold is obtained from a additive manufacturing master by counter casting it in a polyurethane PUR and then you backed by an aluminium box back by an aluminium box after the AM part is removed, the mold is used to process the required amount of wax patterns. So, so what we are trying to do is, rapid prototyping leads to leads to pattern making. This pattern making leads to mold making this mold mold can be spelled in two ways mold and from here you go for the product. So, now, what we are trying to say is, we are trying to say this pattern can be made out of RP and from this pattern we try to make mold also and then we try to make a product.

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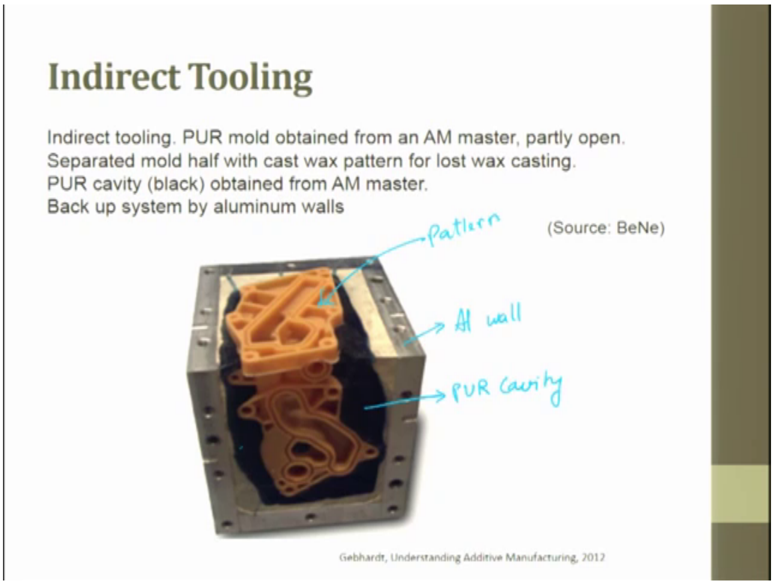

So, this is an example of indirect tooling. Indirect tooling PUR mold obtained from an additive manufactured master partly open. Separated mold half with cast wax pattern of lost wax casting technique is here. So, the cavities which are black obtained from AM master backed up system with an aluminium wall. So, this is aluminium wall or this is the this is the frame whatever it is and this are cavities PUR cavities through which you can start filling up material to get the output and this becomes your pattern this becomes your.

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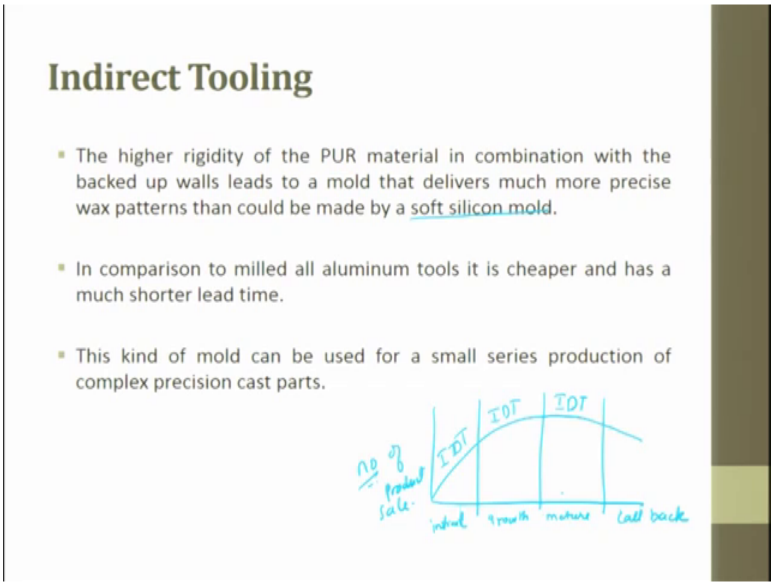

So, the higher rigidity of the PUR mold is combined with the backing up walls lead to a mold that delivers much more precise wax patterns, that could be made by soft silicon molds. So, soft silicon molds always have this problem. So, we always counter do it by reinforcing with a harder one. In comparison to milled all aluminium tool it is cheaper and has a much shorter lead time.

So, when we try to look at product life cycle ok. So, we can divide it into four phases. So, one is initial phase, next is growth, next is mature and the last one is failed or call back or whatever it is, this is with respect to number of parts number of product sale or whatever it is sale ok. So, now, what is happening? When we keep doing at the initial phase also we try to use this IIT indirect tooling or I can put it as IDT indirect tooling, and during growth also we try to use this IDT, mature stage also we try to do this IDT because we now we do not want to go back for this call back. So, at every phase we try to use these IDT techniques and start shifting this from the growth back to initial such that they have one more growth.

So, that is what company is do is they release new products, they release new machines or they release new versions such that they shifted back and come back to the initial stage of the business ok. So, for doing this we need to keep on using this indirect tooling in comparison to milling of aluminium tools. So, if you want to do by aluminium tools as I told earlier it is going to take lot of lead time. So, that has been shrunk very very shortly by using these techniques. This kind of mold can be used for a small series production and for complex parts also.

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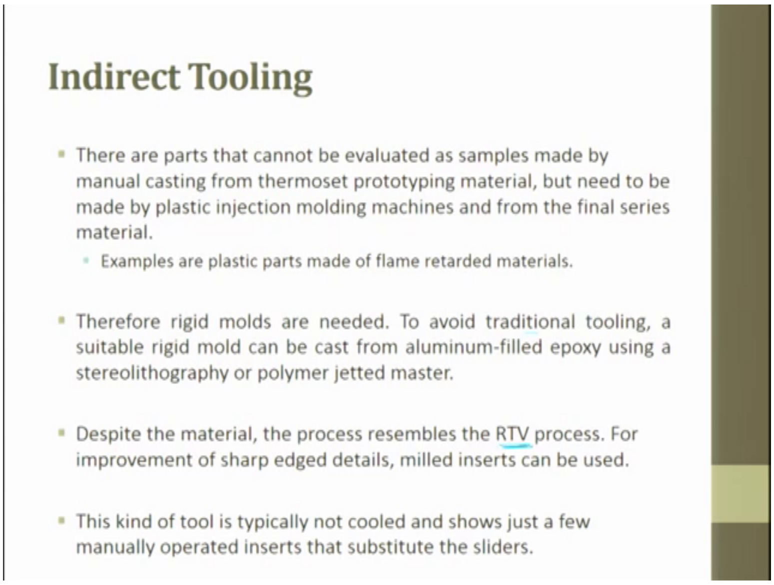

There are parts that cannot be evaluated as samples made by the manual casting from thermoset prototyping material. But need to be made by plastic injection molding machine and from the final series material for which we try to use this indirect tooling. So, that is what I said we can use rapid prototyping metal based rapid prototyping in making the die. Therefore, rigid molds are needed to avoid traditional tooling suitable rigid molds can be cast from aluminium filled epoxy using a stereolithography or a polymer jet master we can get that. And despite the material the process resembles the RTV process we can try to get for smaller production.

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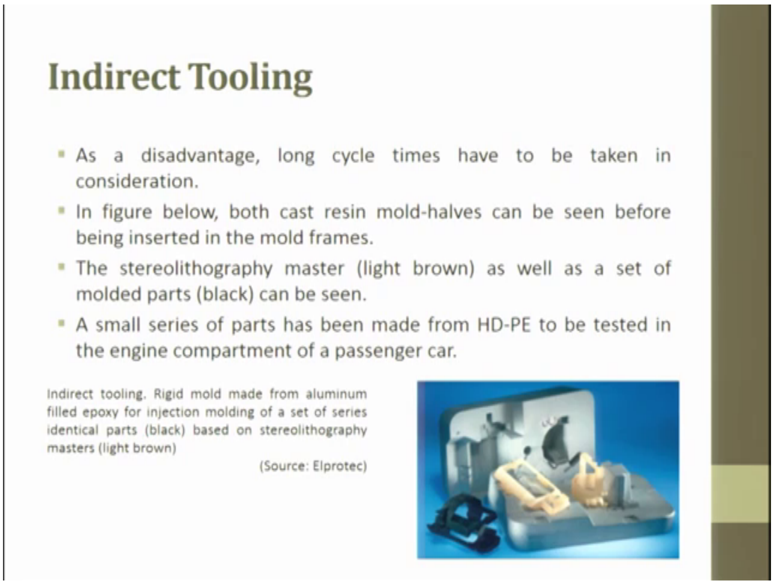

So, in the conventional one the disadvantage is long cycle time has to be taken into consideration. The figure below which is given as an example here is through indirect tooling. So, both cast resin mold halves these are two halves can be seen before being inserted in the mold frame ok. The stereolithography master lights brown as well as the set of mold parts black can be seen before getting inserted.

So, a small series of parts have been made from HD high density polyurethane to be tested in the engine compartment for a passenger car. So, they wanted to test it, they looked at the product they test it and then they have approved it. Indirect tooling rigid mold made from aluminium filled epoxy for injection molding of a set of series identical parts based on stereolithography master which is made.

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So, when we move towards indirect manufacturing; indirective manufacturing is based on additive manufacturing master as well. The goal is to obtain final part with properties equal to the traditional manufacturing products. Consequently indirect manufacturing belongs to the application level manufacturing which we will see in the next slide. As an example of indirect manufacturing figure below shows the six cylinder combustion engine housing completely made.

So, this is completely made through additive manufacturing master. So, indirect manufacturing combustion engine housing, additive manufacturing in the left side, and laser sinter polystyrene aluminium cast one of a kind part at the right side we try to get the output. Now this is placed on top of the cylinder and then they try to do testing of it.

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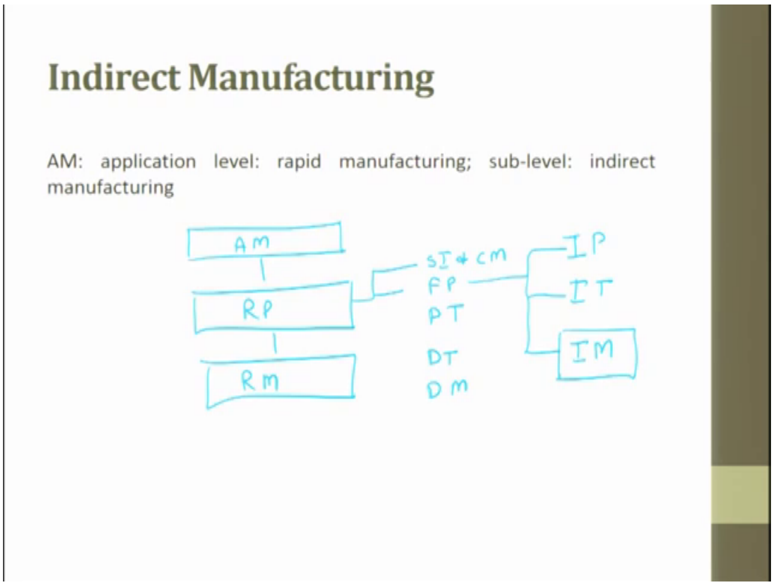

And this is grouted. So, these parts can be easily tested rather than a shaft which is to be made and where it undergoes a cyclic loading, the housing can be easily made through indirect manufacturing and we can do testing of it. So, now, let us go back to the base diagram which we keep talking where, does indirect manufacturing come.

So, additive manufacturing, rapid prototyping, rapid manufacturing and then we had our solid imaging and con concept modelling. Then we had our functional prototyping, then we had prototype tooling prototype tooling, then we have direct tooling, then we had direct manufacturing ok. And then from here I said last time here indirect prototyping, we had indirect tooling and now we have something called as indirect manufacturing ok. So, from here we took it went here and now we are what we are talking about is indirect manufacturing here. So, this is a base figure.

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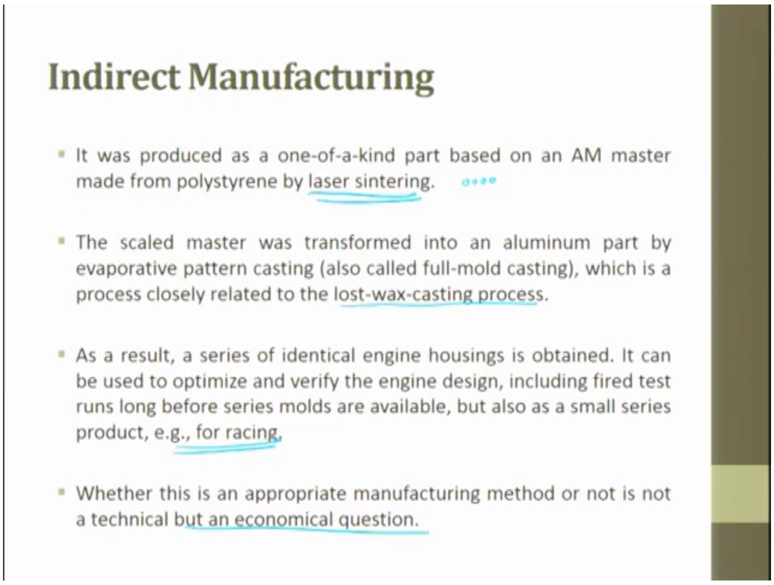

So, indirect manufacturing was produced as one of a kind part based on an AM master made from polystyrene by laser sintering. So, we will see later what is laser sintering process, but we just note down this word as laser sintering process. So, laser sintering is, you are using powder as the starting material and these powders are glued to each other by using heat source and this heat source is nothing, but laser ok. The scaled master was transformed into an aluminium part by evaporative pattern casting which is a process, closely related to lost wax casting process.

As a result a series of identical engine housing is obtained it can be used to optimize and verify the engine design, including fire fired testing run long before series molds are available but also as a small series product for racing it can be used. So, generally today when we talk about this racing cars, they are all one of its kind. So, here making a die and then producing multiple parts is of is of no use. So, what people do? They use this additive manufacturing techniques try to make here die and then from that die they try to cast and then get an output. And this tries to help them in they get the output they put it on the testing test bed see its performance.

And, if they have to change they go quickly back and work on the on the end product and then they go change the die if it is possible they put an insert there, if it is not possible they redo the die very fast. So, this is indirect manufacturing whether it is an appropriate manufacturing method or not is not a technical, but only economic place of major important thing.

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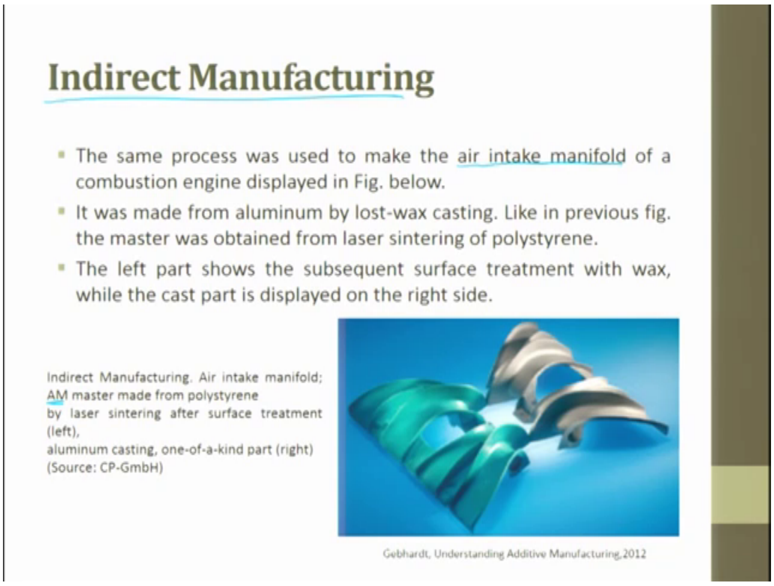

So, this is a part which is made out of indirect manufacturing. So, here air intake manifolds are made by additive manufacturing master, made from polystyrene by laser sintering after surface treatment of this is after surface treatment, aluminium casts one of a kind part is made using this indirect manufacturing. The same process can was used to make air intake manifolds of a combustion engine, displayed in the figure given below. It was made from aluminium by lost wax casting like in the previous slide whatever we have discussed the master was obtained by from laser sintering of polystyrene the left part we have already seen.

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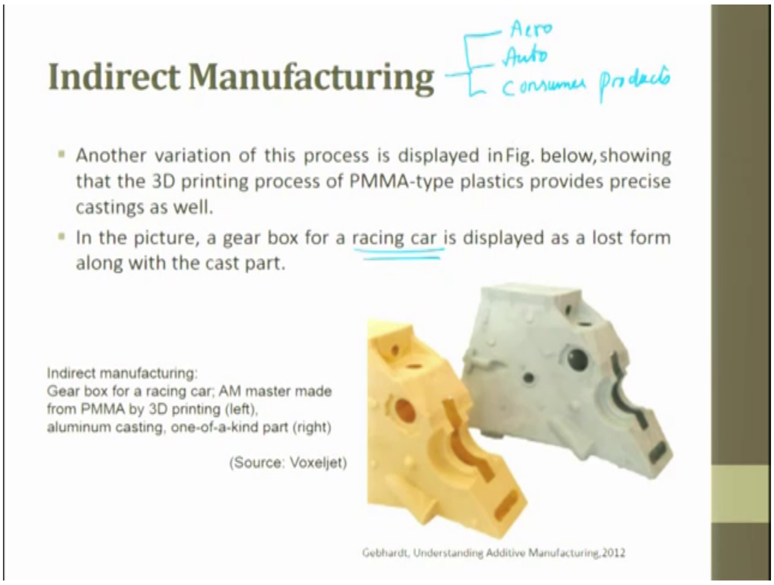

Another variation of this process is displayed in this figure showing that 3D printing process of PMMA type plastic, these are all plastic provided precise casting as well. In this picture a gear box for a racing car is made. So, indirect manufacturing is effectively used today to aero, in auto and in consumable products.

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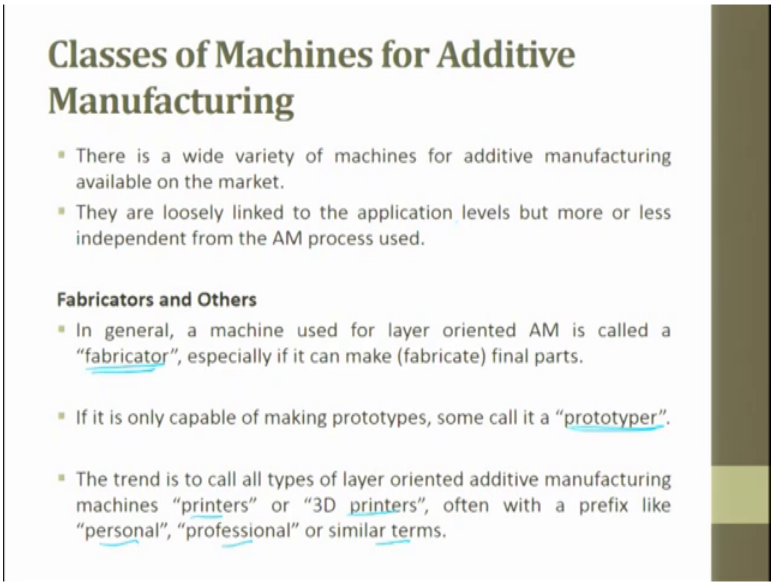

So, the classes of machine for additive manufacturing, there is a wide variety of machines for additive manufacturing available in the market. So, they are loosely linked to the application levels what we have been seen,, but more or less independent from the additive manufacturing process used. Fabricator and others in general a machine used for layer oriented additive manufacturing is called as fabricator especially, if it can make fabricate a final parts. So, it is called as fabricator if it is only capable of making prototypes then it is called as prototyper.

Please understand a machine used for layer oriented additive manufacturing is called a fabricator; if it is only for making prototypes it is called as prototype; the trend is to call all types of laser oriented additive manufacturing machines printer, 3D printer, often with a prefix like personal professional or similar terms are generally used in additive manufacturing.

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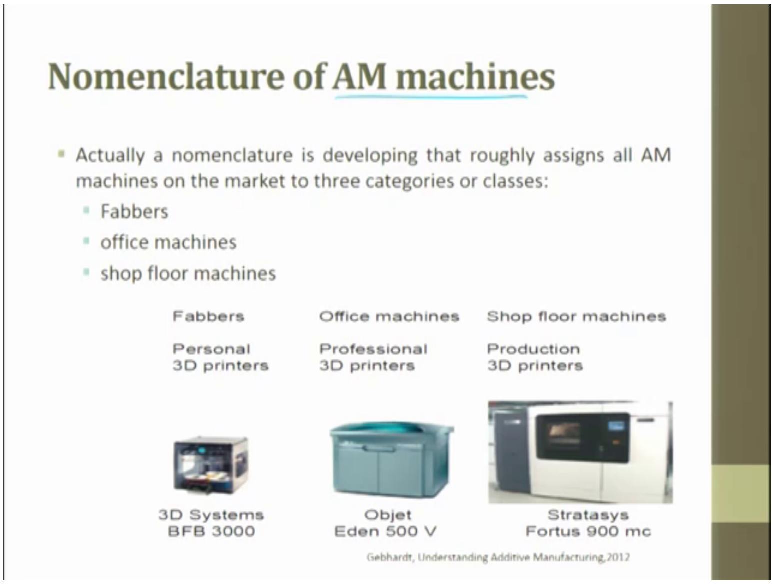

So, the nomenclature of additive manufacturing machines actually a nomenclature is developed that roughly assigned to all additive machines on a market to three categories; fabber office machines and shop floor machines. So, fabber is nothing, but personal 3D printing is machines like this fabbers then office machines are 3D printers which are slightly bigger, and shop floor machines are much more bigger for larger parts.

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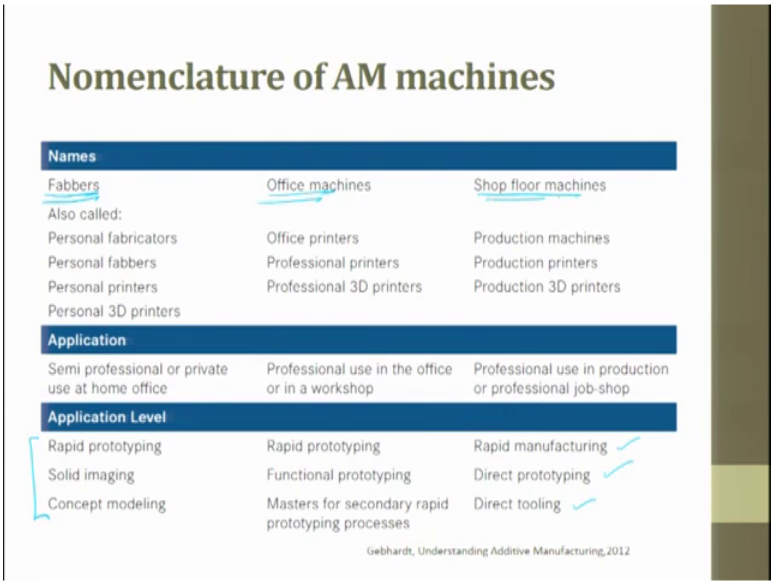

So, when we look at the nomenclature in more details names. So, these are also called as personal fabricator, personal fabber, personal printer, personal 3D printer. And application is semi professional or private use at home office the application level are rapid prototyping, solid imaging. And, concept modelling these are the application levels these fabbers would be used in general. Then office machines it can be called as office printers, professional printers, professional 3D printers.

Professional use in the office or in workshops, it is used for rapid prototyping, functional prototyping, master for secondary rapid prototyping process also can be made through this office machines. When we talk about shop floor machines, the production machines, production printer, the professional use in production or professional job shops these are the applications it can be used for rapid manufacturing, direct prototyping and direct tooling. So, these are the places where office shop floor machines can be used.

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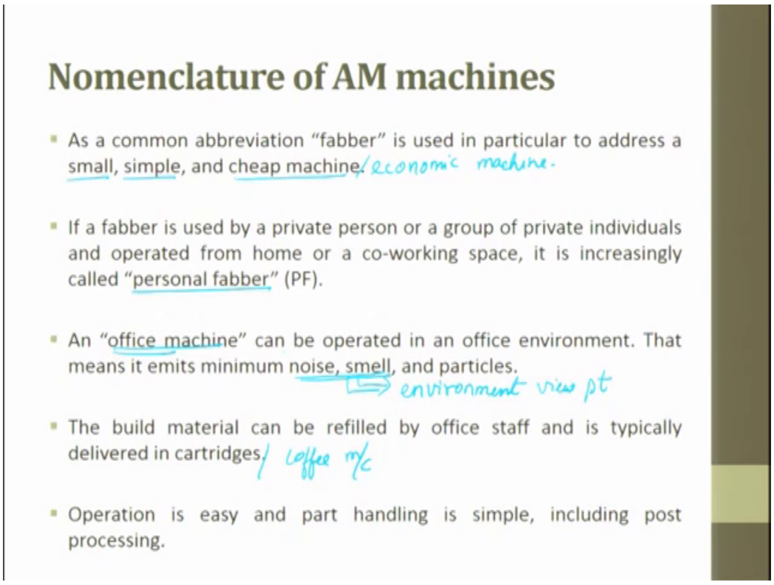

As the common abbreviation fabber is used in particular to address a small simple and a cheap machine you can say economic machine. If the fabber is used by a private person or a group of private individuals and operated, from home or a co-worker space it is increasingly called as personal fabber. Today like your two printing of papers, now 3D printers have also become a part of your domestic appliances. So, computer 2D printer, now 3D printer is also getting to the table top type.

An office machine can be operated in an office environment; that means, it emits minimum noise smell and particles. This is very very important noise and smell this is this is now talked about from the environment point of view very important. The build material can be refilled as it is typically delivered in cartridges just like your coffee machine. Coffee machines you get your coffee powder in packets, here you get it in cartridges you just replace the cartridge like your printer operation is easy and part handling is simple induced post processing.

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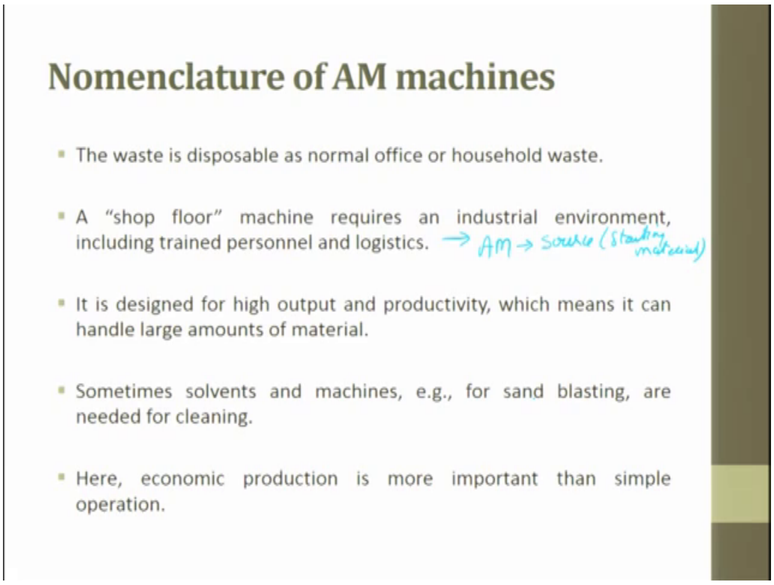

The waste is disposable as normal office or household waste it is important. The shop floor machines require an industrial environment including trained personnel and logistics. So, today what people are talking about is an additive manufacturing machine which can take several sources as the starting material, and use several different types of heat sources for joining this starting material to get the output it is designed for high output and productivity sometime solvent and machines are used. So, economic production is more important than simple operations.

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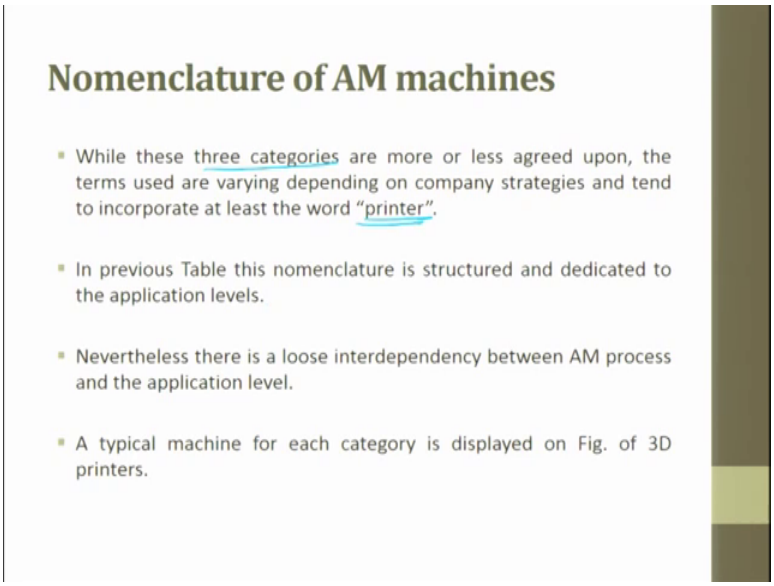

These 3 categories are more or less agreed upon the term which is used are varying depending on company strategy and trend of incorporating the at least the word printer. So, additive manufacturing means people have started using the word printer. So, in previous table this nomenclature is structured and dedicated to the application level, today it is again loosely used and people start a mixing up.

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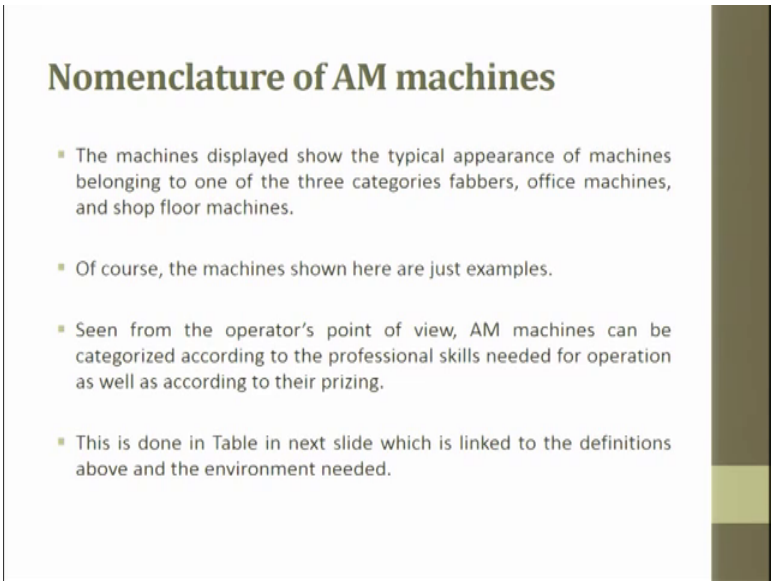

The machine displayed show the typical appearance of the machine belonging to one of the three categories fabber, office machine and shop floor. Of course, the machine show here are just examples. So, seen from the operators point of view, additive manufacturing machines can be categorized according to the professional skills, needed for operation as well as according to the prizing.

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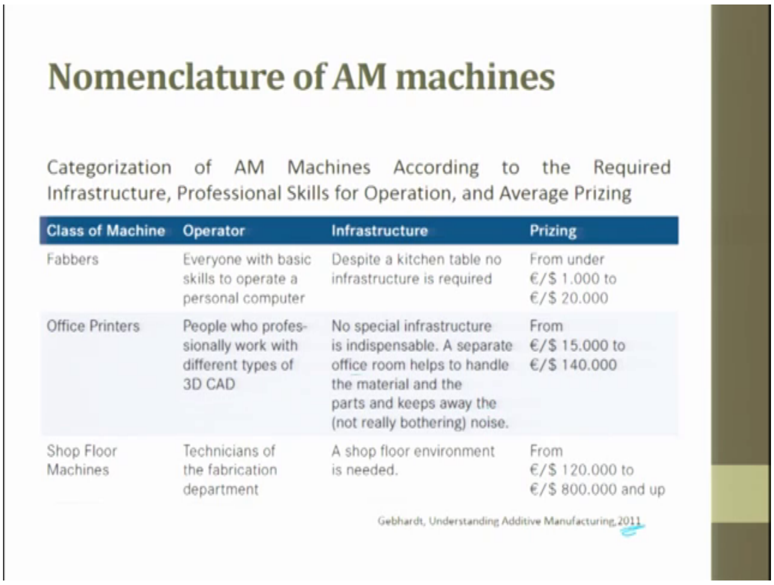

So, here is a table which further categorizes additive manufacturing machine, according to the required infrastructure, professional skill for operation and average prizing. So, these prizing are all tentative when this was done in 2011 this was done, today of course, there are new machines getting added. But, the class is almost the same and the operator skills are also getting shifted; that means, to say today the artificial intelligence have become more handy and it has been customized for applications.

So, the skilled of a labour is now tried to pushed towards the machine intelligence itself. So, class of machines are fabber, office, printer and shop floor machines. Everyone with basic skills to operate a computer can operate fabber machines, office printer a small amount of professional training is required. And, he has to know 3D CAD and the shop floor technical experts are required because placing the job after doing the job post processing all these things are required.

So, despite at kitchen table no infrastructure is required when you talk about fabber, it is just like your microwave oven it has come. No special infrastructure is indispensible, a separate office space helps to handle the material and the parts and keep away from the noise. So, it is used in shop floor these are the casting which is used.

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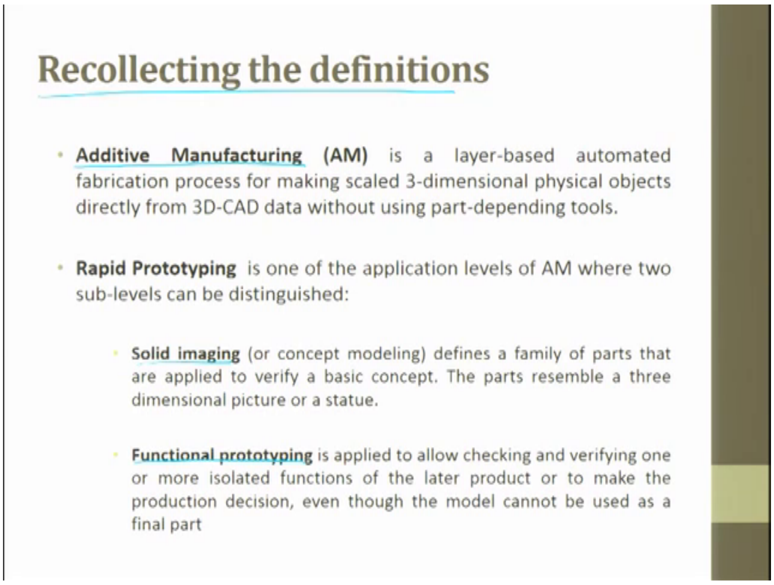

So, to recollect and recap whatever we have learnt till now, here are some of the definitions additive manufacturing is a layer based automated fabrication process for making scaled 3-dimensional physical objects directly from a 3D CAD data without using part depending tools is the definition for additive manufacturing. Prototyping is one of the application levels of additive manufacturing, where two sub levels can be distinguished.

One is solid imaging or concept modelling defines a family of parts that are applied to verify a basic concept, the part resembles a three dimensional picture or a statue. So, this is solid imaging. Functional prototype 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 those prototype are called as functional prototypes. So, these are under prototyping

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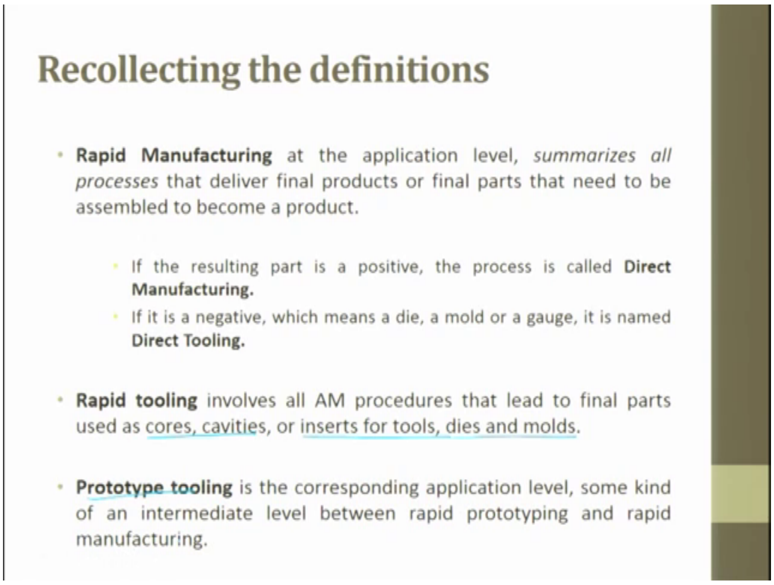

Techniques then when we talk about rapid manufacturing, at the application level summarizes all processes that deliver final products or final parts that needed to be assembled to become a product. So, that is nothing, but rapid manufacturing. In this we have two sub classifications which is direct manufacturing and direct tooling, if the resulting part is positive it is called as rapid manufacturing. If the resulting part if it is negative which means a die then it is called as direct tooling.

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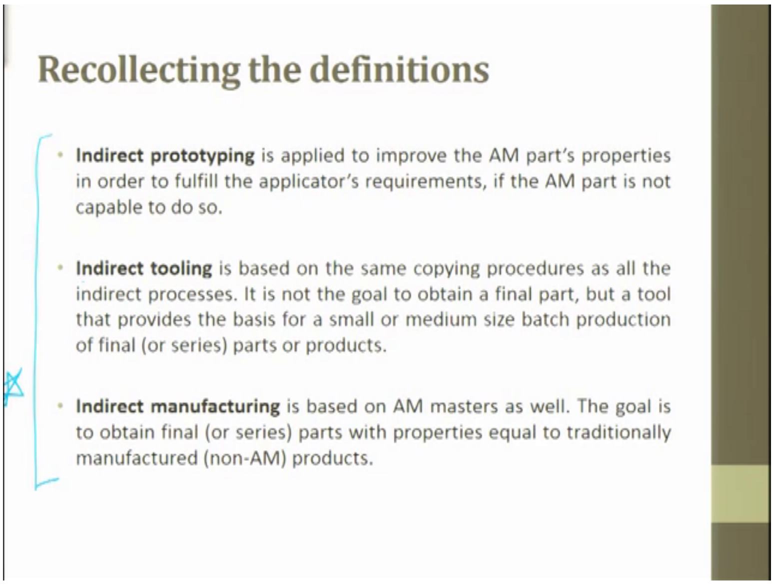

What is rapid tooling? Involves all AM processes that lead to a final part used as core, cavity or inserts for tool die and molds. Prototyping tool is the corresponding application level, some kind of an intermediate level between rapid prototyping and rapid manufacturing is prototype tooling. Then indirect prototyping, indirect tooling and indirect manufacturing was the last phase we saw. Indirect prototyping is applied to improve the additive manufactured parts property in order to fulfil the applicators requirement. If the additive manufacturing part is not capable to do so, we use indirect prototyping.

Then indirect tooling is based on the same copying procedure as all the indirect processes do. It is not the goal to obtain a final part, but a tool that provides the basis for a small or medium size batch production of final parts is indirect tooling. What is indirect manufacturing, is based on additive manufactured masters as well. The goal is to obtain final part with properties equal to traditional manufacturing products is called as indirect manufacturing. Please try to remember these definitions, which are the explanations which is going to help you to understand this course completely.

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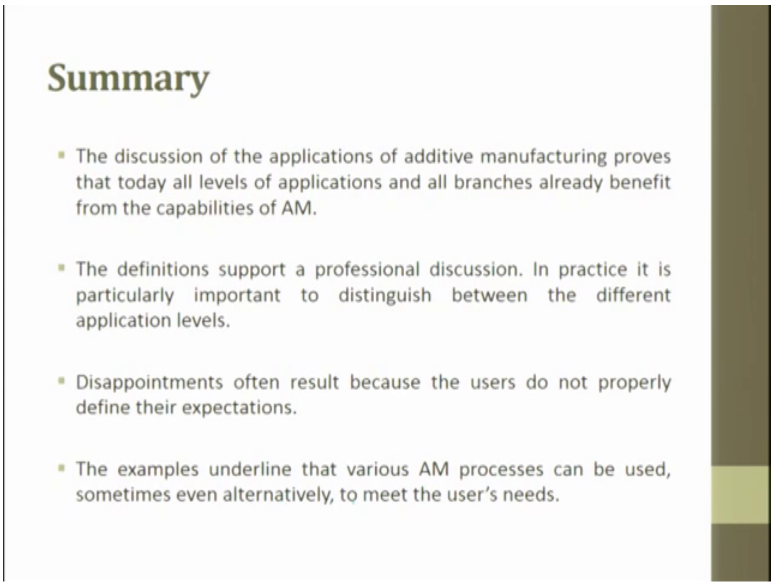

To summarise the discussion of the up application of additive manufacturing proves that today, all levels of application and all branches already benefit from the capability of additive manufacturing

The definition supports a professional discussion in practice, it is particularly important to distinguish between the different application levels. Disappointments often result because the user do not properly define their expectations. The examples underlying that various additive manufacturing process can be used sometime even alternatively to meet the user needs.

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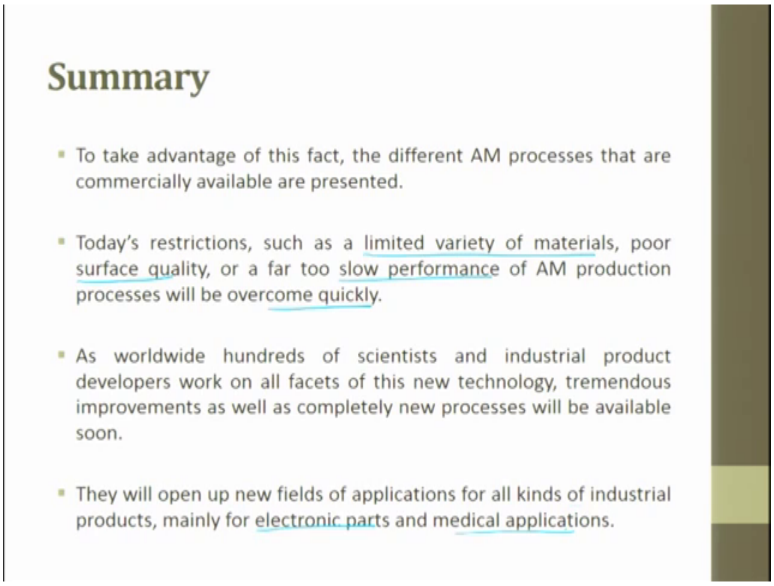

To take the advantage of this fact, different additive manufacturing processes that are commercially available are presented. Today restriction such as limited variety of starting material poor surface quality and far too small performance of additive manufacturing process will be overcome quickly, which are now the limitation people are getting out of it as worldwide hundreds of scientist and industrial product developers work on all facets of this new technology, tremendous improvement as well as complete new processes will be available soon.

They will open up new field of application for all kinds of industrial products namely for electronic parts and medical applications which is very much talked about today.

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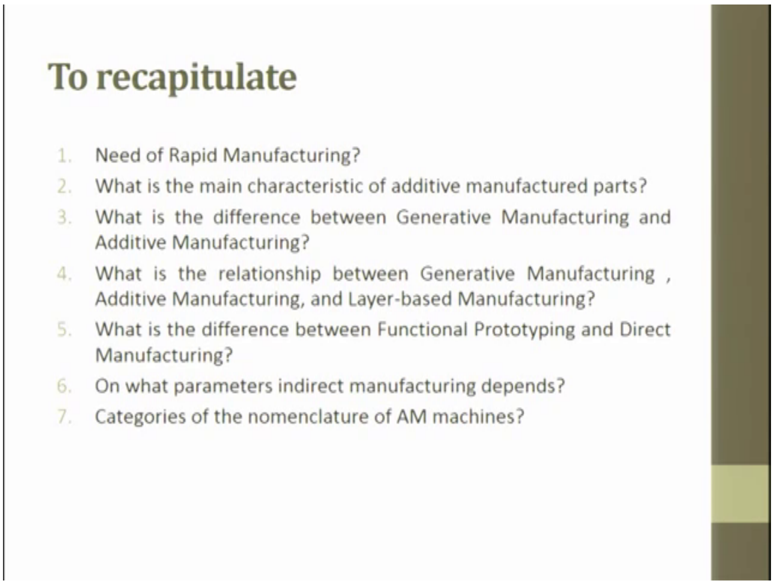

To recap what we saw need for rapid manufacturing, what is the main characteristic of additive manufacturing part, what is the difference between generative manufacturing and additive manufacturing, what is the relationship between generative manufacturing additive manufacturing and layer based manufacturing. What is the difference between functional prototyping and direct manufacturing; on what parameters indirect manufacturing depends and categories and nomenclature of additive manufacturing where, some of the topics which were covered in this presentation.

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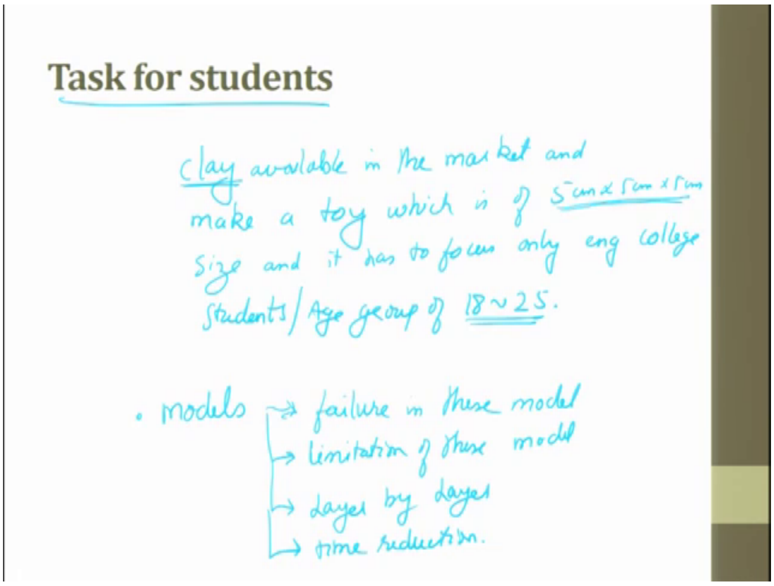

So, task for students, when you start executing this task it gives you a better understanding. So, the task is try to take clay, which is available in the market and make a toy which is of 5 centimetre cross 5 centimetre cross 5 centimetre size, and it has to focus only engineering college students or I will redefine it to the age group of 18 to 25.

So, you have to make it has to focus only engineering. So, this age group you have to keep in mind, you have to make a clay model which the dimension should not cross 5 centimetre cross 5 centimetre cross 5 centimetre. Please do this exercise and try to see how do we make models and then you will see what are the failures which can happen in these models. And, then you will also see limitations of these models. Of these models means I expect you to make more, but if you can make one it is also fine and then you should also see did you use layer by layering technique layer by layer technique.

If you used it, is there a time reduction for building of the same part. Please try to do; this will try to appreciate what we are studying in this course

Thank you very much.