Design Practice - 2
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Lecture - 35
LAB demonstration of Fused Deposition Modeling Techniques

hello and welcome to this design practice to module 35 just prior to this you have watched about two different modules which are corresponding to the FDM process that is a fusion deposition modeling process where you found out how you can actually take care of the zones which are the support and the zones which are the parent materials. Let us get into a slightly different you know gear today on rapid tooling I think I had just introduced this area in the last lecture.

But we will just elaborate on it a little more and try to finish up. So, rapid cooling broadly describes any mold making process that will create tools quickly and with minimum direct labor. So, basically when we are talking about let us say so when we are making a tool for example using injection molding for injection molding dyes for example or where there is a pressure dye casting and we need to make a dye. So, it basically gives a very quick way of arriving at the shape overall shape and size of an engineering component which would later on go into a product.

So, it is a very rapid manufacturing technique where you know it is merely that you fill something with the liquid which gets solidified and it makes the overall shape size etcetera. So, this is somehow classified as a rapid tooling and if I want to develop such a rapid tool there are many additive and subtractive manufacturing processes which need to apply and then also you know you have to integrate the data management process that comes out of let us say a CNC system or a computer system in a logical manner.

So, that a very complex profile topology etc can be created now this is like creating some kind of a dye or a mold and using it many times so that you can make many engineering components and extreme rapidity. So, it definitely uses rapid prototyping techniques can all be applied to a variety of applications from let us say injection molding casting even sheet metal stamping operations. Using a dye which has been manufactured falls under the category of rapid tooling the science of rapid tooling okay.

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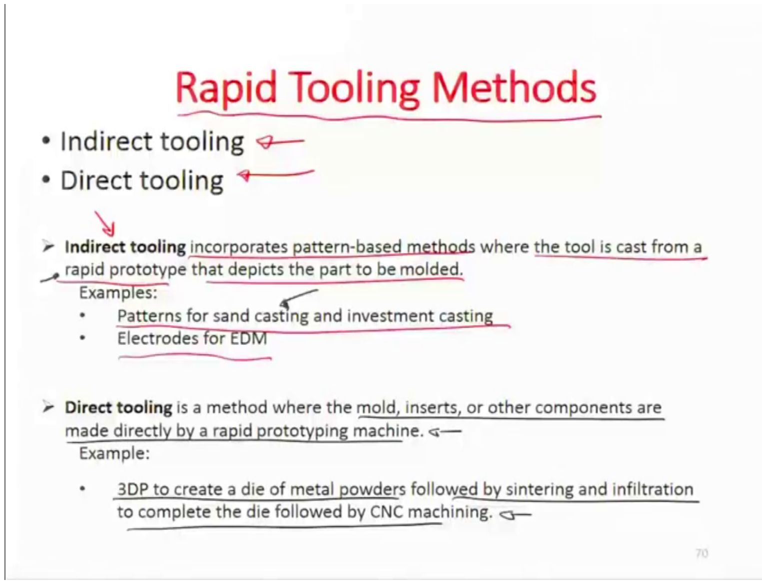

And so basically if I looked at what are the different kind of tools which are generated will have indirect tooling and direct tooling and I think we had just illustrated just begun to illustrate this area. So, indirect tooling is basically something which incorporates pattern based methods by casting a tool using rapid prototyping or other processes that depicts the part to be molded examples are for example sand casting and investment casting.

So, in sand casting what is going to happen is a wooden pattern okay and this pattern is used again and again for getting the sand into place inside a flask where this pattern can later be occupied by molten metal and a part comes out of it okay so this is actually an indirect tooling so although there exists a pattern but this pattern will not be used directly okay in place you know while you are actually injecting the material or making the material to go inside.

And therefore it is merely a shaping tool which is utilized before something is created which can be used for the tooling purpose of the overall shape of a cast that would come out okay so this is indirect tooling it is not directly participating. There is also a direct tooling it is probably a method where the mold inserts and other components are made directly by a rapid prototyping machine example let us say the 3d printing to create a dye of metal powders followed by sintering and infiltration to complete the dye following by a CNC machine is something that is a direct tooling that you are created creating which you which will participate okay.

In the process for example in pressure dye casting whatever is a mold is a direct tooling. So, now you have to create this tool so the tool is basically the one which occupies space and creates space for liquid metal to later on fill at a high pressure and generate an overall shape or size which is that of an engineering component. So, you are using directly the mold for doing this kind of a casting process.

Now when we look at for example the investment casting again there is a lost-wax method so you basically have a outer created by wax which would be later on filled and you know the acts will be disposed off. So, then again something which is used to pattern that wax around etcetera where the cavities could be created considered as an indirect tooling. So, there are these classifications of one which directly participates another which helps you know creating that cavity or that shape which would later be filled up by liquid okay in order to make the engineering part so, this is how the classification is.

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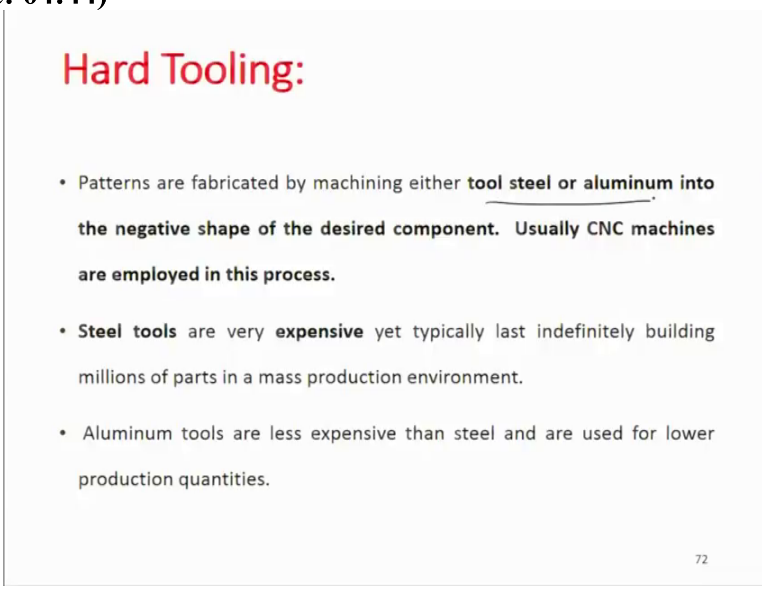

So, there can be soft and hard tooling as well so for example you know it can be used the soft tooling can be used to make multiple wax or plastic parts using conventional injection molding processes. It produces short term production patterns injected wax patterns can be used to produce castings okay. So, soft tools can usually be fabricated at the rate of ten times faster than a machine tool and they are usually polymeric in composition.

And basically made up of soft materials now when we look at the materials of tooling so it can be very many for example there can be wax patterns which are used to do indirect casting applications there can be also polymeric or plastic parts. So, these are all in the soft category of soft material similarly there can be hard material based for example steel or aluminum is shaped into a certain dye or a certain shape where you know the desired component is produced using essentially CNC machining or some other precision process.

And then this metal participates in for example pressure dye casting etcetera. So, there the boundaries are metals okay there the boundaries are hard components so therefore tooling can be either soft but made up of polymer wax and other alternate materials are hard based on the steel and aluminum and other different kind of metals.

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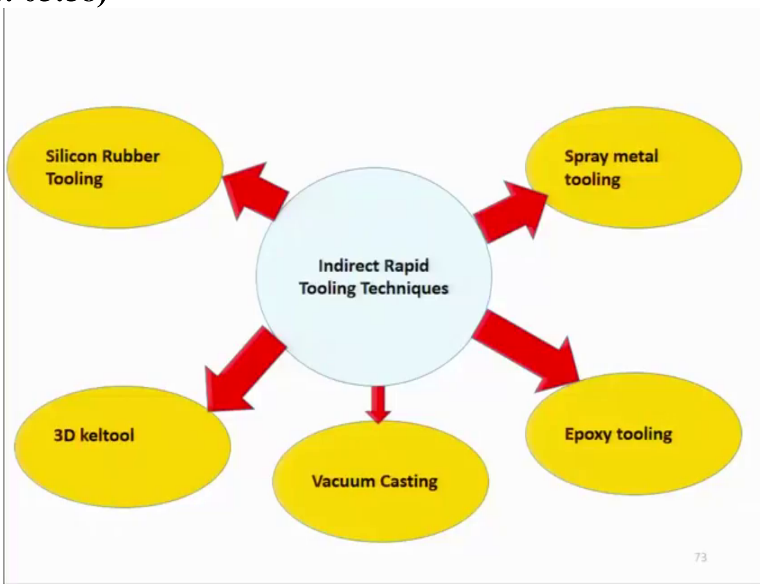

If I looked at the indirect rapid tooling techniques there are many folds for example you can have spray metal tooling you could have you know silicon rubber tooling you could have the 3d kal tool, the vacuum casting processes okay and then the epoxy tooling so these are some of the indirect rapid tooling techniques.

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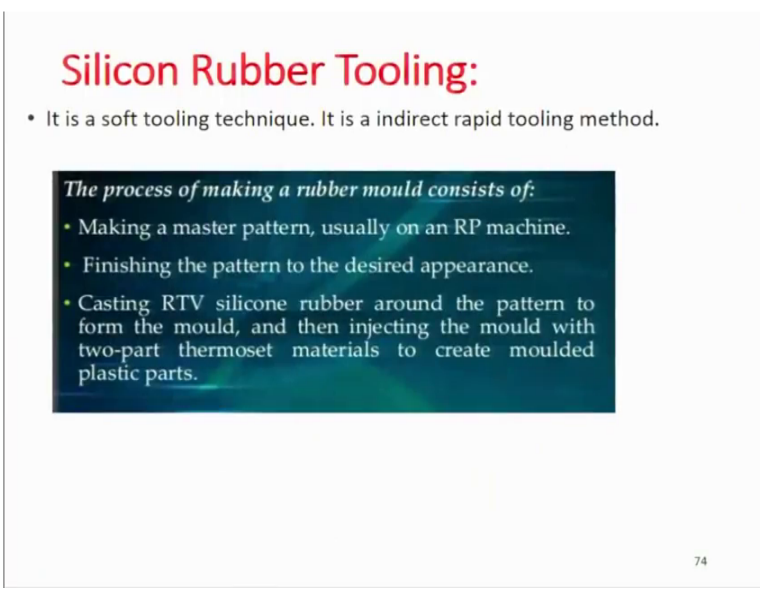

And when we look at silicon rubber tearing tooling for example it is a soft tooling technique it is an indirect rapid tooling method. So, the process would necessitate the making of a rubber mold with a master pattern of course which is usually made on a rapid prototyping machine and then we finish the pattern and the desired appearance is basically shaped up on the rubber pattern. And you can do different castings like for example the silicone rubber or RTV which we also known as which we also known as PDMS okay can be used or can be casted.

So, it is it is a soft tooling technique which is also you know indirect rapid tooling method. So, basically it comprises of the following steps. So, you basically make a master pattern usually on a rapid prototyping machine and finish the pattern to the desired appearance. And then casting of the silicone rubber or let us say what we better know as PDMS Poly Dimethyl Silicon Around the pattern to form the mold.

And then inject the mold with two-part thermostat material to create molded plastic part this is represented here.

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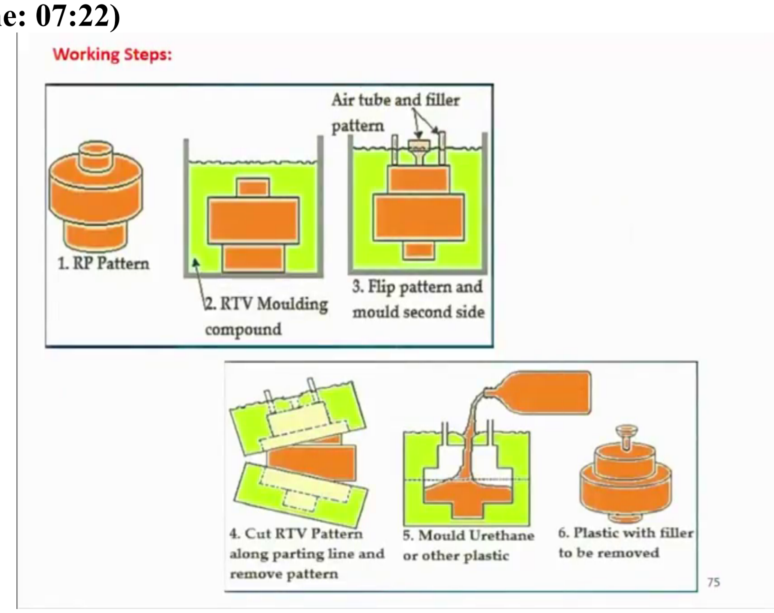

So, in the first instance the RP pattern is being made using some you know either FDM or other processes that I have explained in the last lecture. Then you basically cast around this, this material which is a silicone rubber it forms a very good matrix okay. In MEMS also we have seen this is all you know some kind of a very high aspect ratio application or micro casting material. Now once the negative of this pattern is created let us say you know you have a A tube and filter and all those things inserted.

So, that whatever goes in does not create any bubble or anything we must be able to open or cut this into half so that we can retrieve the pattern off. So, the pattern is retrieved here and this is now a mold cavity where there is again air vent and a pouring you know riser runner combination which is being shown here. So, once the material is poured and this material could be urethane or other plastic you know which can actually use this soft polymeric mold as a filler.

And so therefore this plastic can go inside and fill the space while all the air can get used out from the air vent that is creating this kind of a path. It can be solidified and this can be gotten rid of later and many you know cycles can be made through such soft molds or soft parts. So, this is what the silicone rubber tooling technique is like similarly.

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So, these are some of the illustrations of what can be done so with silicone rubber you can see this complex part being created through a plastic material where the plastic can be retrieved later and the mold can be used for the next run okay.

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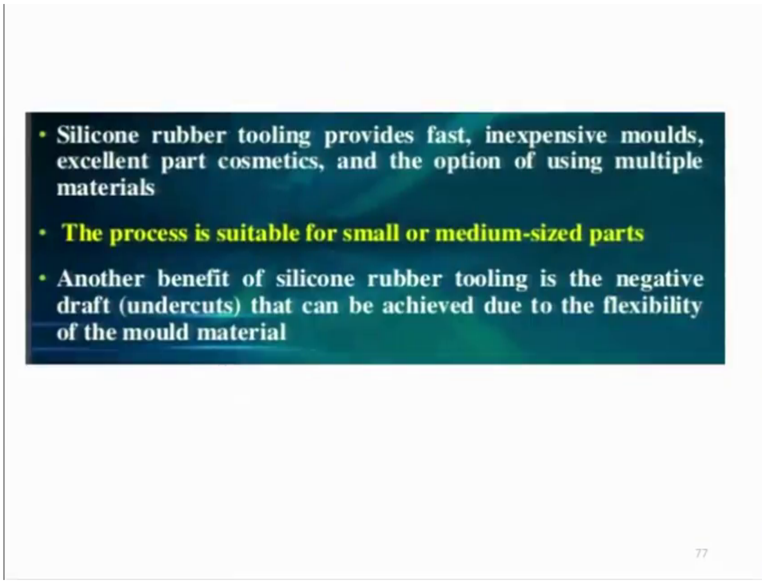

Then so obviously the silicone rubber tooling provides a fast and inexpensive process through a mold which can result in excellent part cosmetics you know options of using multiple materials etc and the same tooling is there and so it is a really a very flexible process of soft tooling. The process is also suitable for small and medium-sized plastic parts particularly which are abundantly utilized in many applications.

Another benefit of the silicone rubber tooling is the negative draft undercuts that can be achieved due to the flexibility of the mold materials. So, you do not really want to go much on the draft side actually make negative drafts happen. Because obviously the mold will expand a little bit because of its own soft nature and be able to accommodate the parts and we want to make sure the parts are as much aligned to the dimensions as possible okay.

So, this aspect has to be put in all the different you know tool making or indirect tooling making approaches for this rapid prototyping or this particular process this rapid tooling process.

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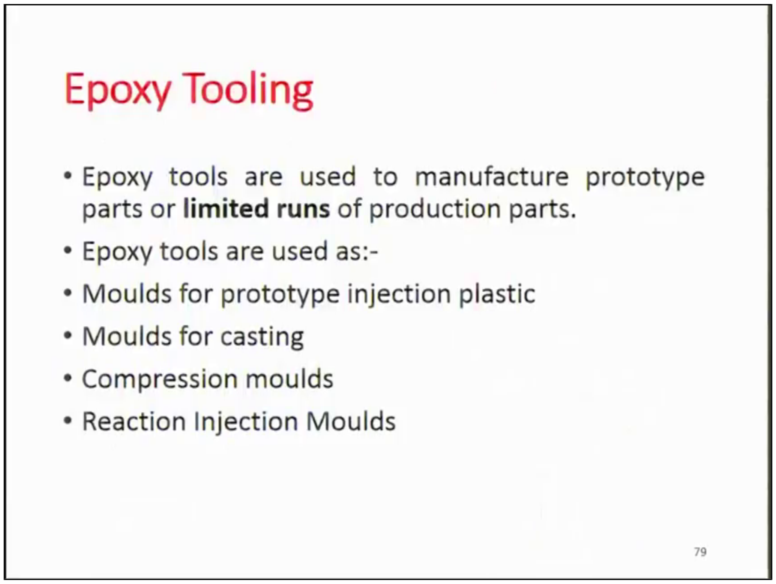

So, then there can be epoxy tooling so this is another way of just like we made a silicone rubber tool we can make a epoxy tool they used to manufacture prototype parts or limited runs of the production parts. So, here the epoxy tools are used as moles for prototyping of injection molded plastics it can be used as molds for casting it can be used as compression molds or you know reaction injection molds.

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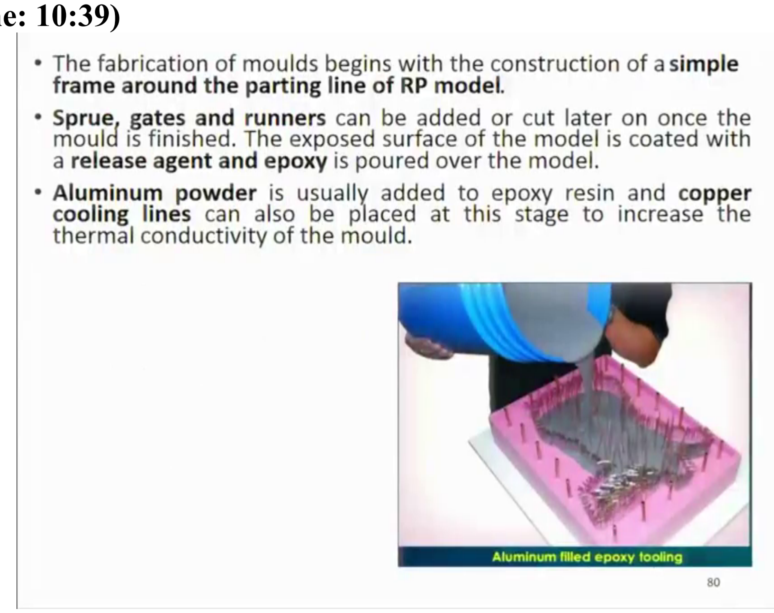

The basic processes are stated here so you have the fabrication of molds begin with the construction of a simple frame around the parting line of an RP model. So, there is a frame which has been made here you can see you know around the parting line and there are exactly two halves one is the upper half and the lower half which is about this parting line. And you have sprue, gates and runners which can be added or cut later once the mold is finished.

The exposed surface of the model is coated with a release agent and epoxy is poured over the particular model. This is the RP based mold which is used to carry the proxy, the proxy would go and fill the cavity okay. And generally aluminium powder is also sometimes added to the epoxy resin and copper cooling lines can also be placed at this stage to increase the thermal conductivity of the mold.

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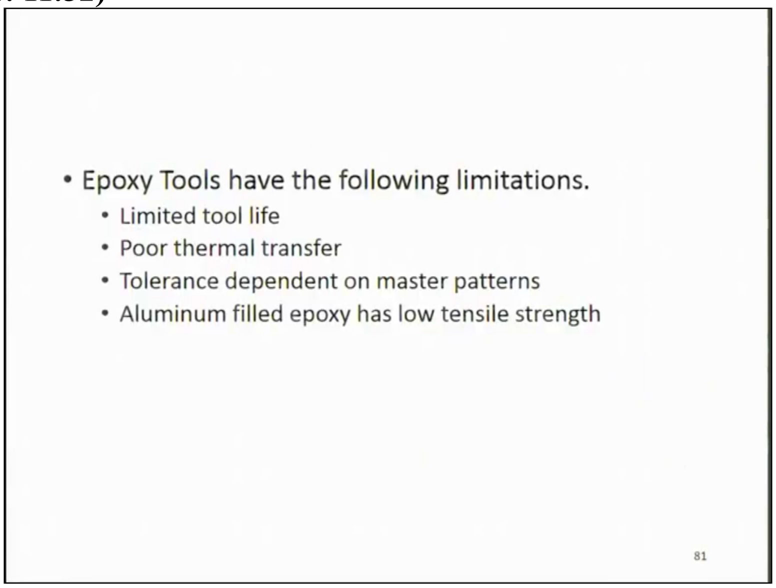

Once this pouring happens it dries up and creates again a aluminum filled epoxy so in a way the epoxy tooling method is used to make reinforcements okay which would be which would be getting rid of some of the problems associated with the silicone rubber mold which you saw in the earlier step. So, basically once the silicone rubber mold is made and the polyurethane part is made out of it that part can be again utilized in order to build a epoxy mold around it okay.

So, the epoxy and particularly the metal epoxy composite is able to ensure that you have a high-strength mold which last longer is able to be multiple used etc and so there whatever polyurethane part is coming out can be used as some kind of a core you know you a in order to basically make the mold completely in epoxy. This is showing that kind of run so with the certain core which is in place which you are not able to see in this figure.

And with a lot of these other you know copper lines etc which are for easy cooling the epoxy mold is being developed okay. So, this is developed along a party line meaning thereby that the patterns are spread patterns with one half being you know done through one half of the polyurethane part which comes out. So, basically the other half is also simultaneously processed and so therefore that is how a mold would realize.

The advantages that this epoxy tools would have are that number one that you know it is made of a slightly harder material so it lasts longer in comparison to what you saw in the silicone mold of the rubber mold. However they have limitations so you have limited to life again poor thermal transfer and sometimes you have to intentionally make cooling lines happen because the epoxy itself is a thermally insulating material.

You also have a tolerance dependency on the master pattern so basically the urethane pattern that you are formulating from the previous run has a certain surface issue or a surface tolerance issue it may need to be machined in order to serve as a core print for this or a core for this particular new epoxy pattern that you will be building. And obviously aluminum fill epoxy has low tensile strength so that way the overall mechanical properties of the mold is also severely compromised if we talk about epoxy tubes.

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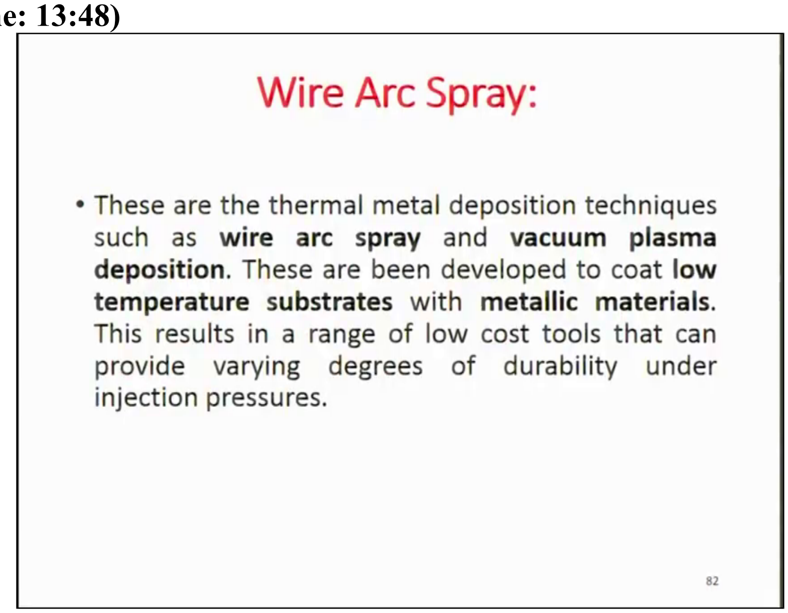

Now there are other techniques to make molds stronger you had already seen how the initial step silicon rubber tool was made one of them is thermal arc spray. So, basically here you can make a mold stronger by putting you know on the pattern a you know pattern can be made out of an RP model.

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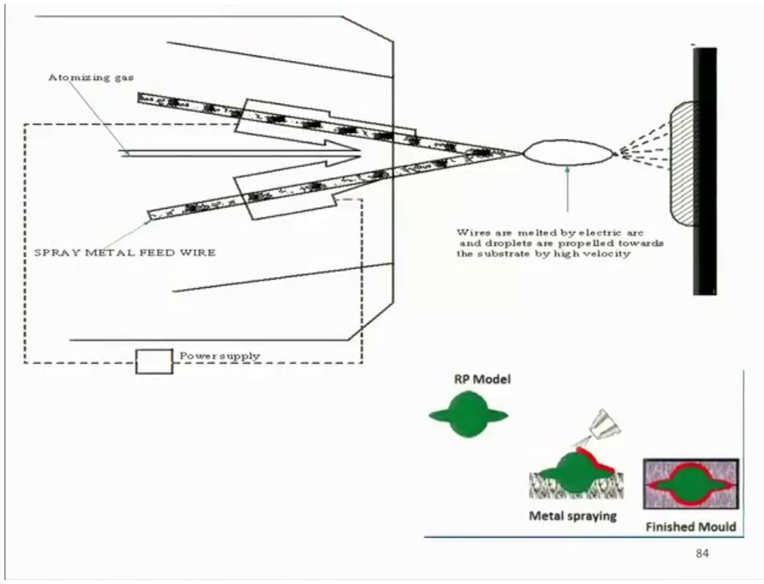

But you could essentially have metalized vapor being coated on the top of this pattern so typically these metalized vapors are coated by creating two metal electrodes and an arc and then blowing gas at a certain or inert gas at a certain velocity through it so that it can carry whatever you know the metal whatever metal droppings or whatever metal melt has been formulated in that arc region and can quickly atomized because of high velocity.

So, now the atomized form of that metal liquid metal which is being formulated and a small rate can be considered to be like a metal mist. And this mist is actually coated on the top of the pattern so that it can when the pattern is extracted it can comprise off metalize the surfaces of the mold which can later be thermally cured etcetera so that there is sintering between the material and then that can result in some longevity of the particular mold that is in question okay.

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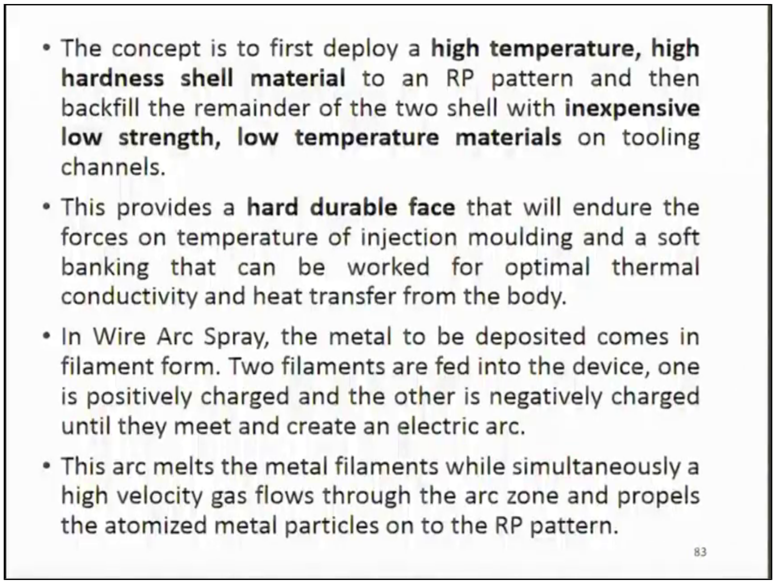

So, here the whole concept is about creating a high hardness shell material to an otherwise RP pattern and then backfill the remainder of the two shells inexpensive low strength low-temperature materials on tooling channels it can definitely provide a hard and durable face okay or the pattern using this wire ax process.

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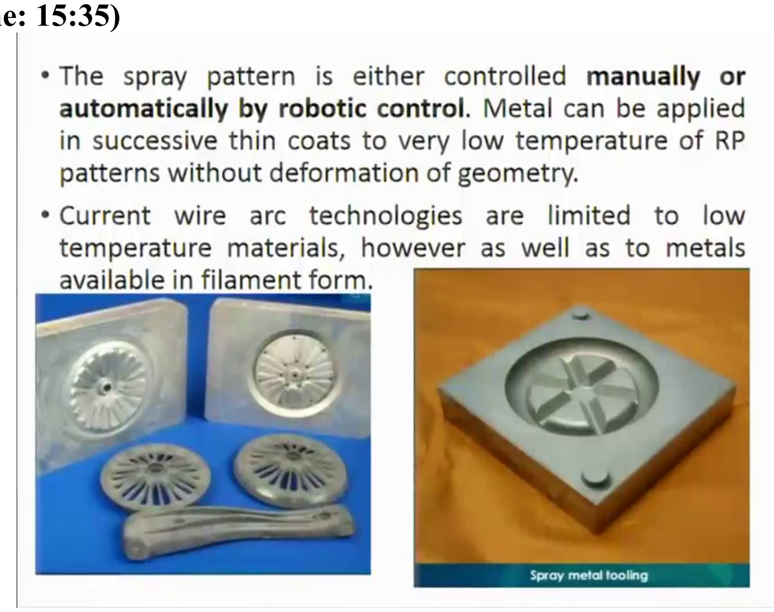

The spray pattern is either controlled manually or automatically by robot control these are some other parts which are being again sprayed through metal arc processes okay current wire rack technologies are limited to low temperature materials however as such materials are available in filament forms which makes the spray coating easier over patterns.

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Another soft tooling approach is the 3D Kaltool process which is based on a powder metal. It is used to make injection mold in certain other durable tooling from master patterns very similar to spray metal tooling. Only thing is in this case again you know the heat simpering approach is utilized to make the patterns harder. It was all generally developed in 1976 by 3M. It was sold and for the developed by the Keltool incorporated it was named has 3D Keltool later on.

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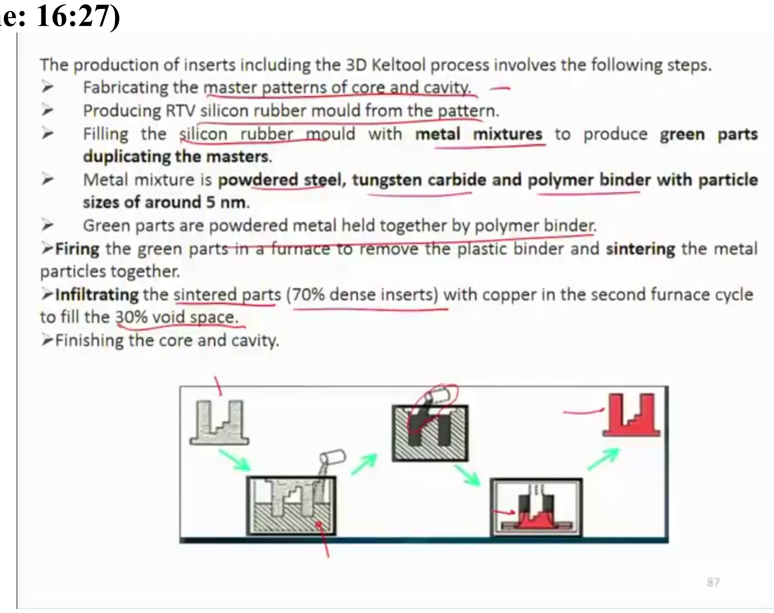

So, here what is happening is that you can see in the first step you are fabricating the master pattern through core and cavity and producing an RVT silicon rubber mold out of the pattern okay so this is the RTV silicon rubber mold. Filling the silicone mold with metal mixtures to produce green parts okay so green parts are powdered metals held together by polymer binders.

So, these are some metal polymer you know matrices just like you did epoxy aluminum matrix so that is a metal polymer matrix.

So, in similar manner there a variety of other metal mixtures which are there? So, you duplicate the silicon rubber mold with metal mixtures produce green parts and then the metal mixture is powdered with steel carbon tungsten, tungsten carbide and other hard materials even polymer binders with particles around the size of 5 nanometers. And then fire the green parts okay so you try to Center whatever is in the material together.

So, that there is some kind of a metal polymer matrix some of the polymer of course will be evaporated because of the high temperature. So, you have infiltrating of the sintered parts which are about 70% dense and you know and 30% wide space. So, this is like more like a hollow pattern kind of; there is more like a hollow material kind of a thing or where the polymer part of the polymer binder may be evaporated in some case just sintering together or putting in place together the metal powder which is around.

So, this is this acts like a pattern okay which can be an indirect tool which is utilized in many of these cavities. So, what we have learnt is that through various surface hardening techniques for example wire spring and sintering or even epoxy aluminum composites or even you know some kind of polymer hard materials like tungsten carbide composites etcetera firing them to a temperature where the polymer goes away and there is something local sintering between the metal etcetera.

The objective that we are developing here is to produce an indirect tool. Now this tool goes and makes a cavity through a material which would otherwise be used for injection molding or some other means without directly participating into the process. So, this is how the indirect metal indirect tooling business would be. There are many direct tooling techniques also for example this very famous direct access injection molding we also know it better as AIM okay.

A laminate tooling molds or pro metals or copper polymide molds let us look at some of these approaches particularly I would be more interested to describe this direct access injection mold.

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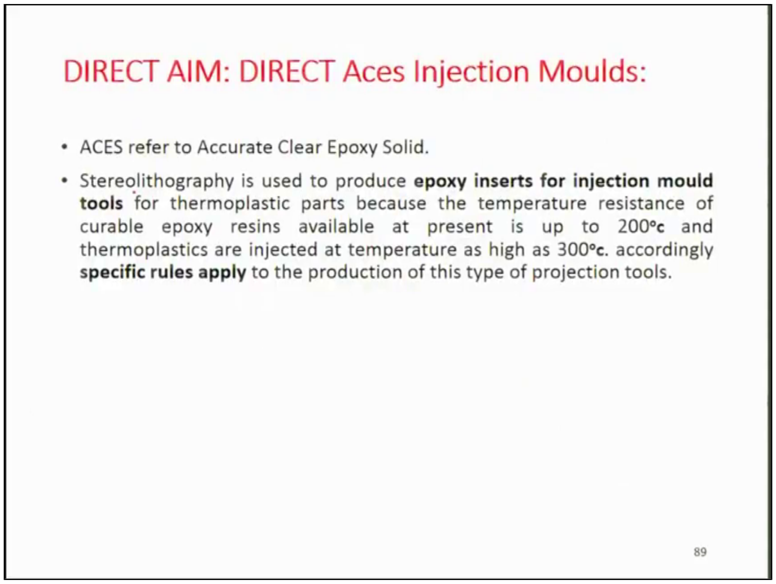

So, in this particular process called the direct in access injection mold and it refers to accurate clear epoxy solid this ACES term comes from you know solids made up of epoxy stereo lithography or Rossella processes are used to produce the epoxy inserts for injection molds for thermoplastic parts because the temperature resistance of the curable epoxy resins available at present is up to about 200 degree Celsius and thermoplastics are injected at temperatures as high as 300 degree Celsius.

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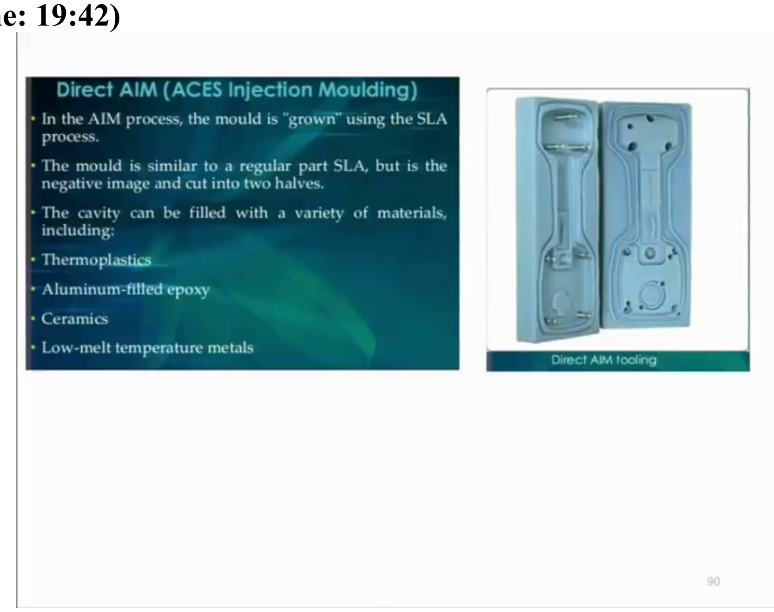

So, accordingly specific rules apply to the production of this type of projected tools so in the aim process the mold is typically this is a mold in the aim process okay it is grown using stereo lithography approach you know how stereo lithography works with a part by part building. I had explained this quite clearly when we talked about you know the rapid prototyping part. So, a mold is similar to a regular SLA part but is the negative image of the particular part to be built and is cut into two half.

So, you have spread pattern orientation okay as you can see in this particular case and there can be a lot of intricacies defined within the pattern the negative of the imprinting intricacies are defined within the pattern because of the high accuracy approach of the stereo lithography process itself okay. So, the cavity can be filled with a variety of materials of course so this is the direct tooling okay.

So, now you are building with the SLA a tool which can be infused with thermoplastics aluminium field epoxy ceramics low-temperature metal you know components all these things can be extracted directly from the mold. So, you have a direct cavity being made by a SLA technique. So, this is how some of the; you know direct tooling approaches could be done.

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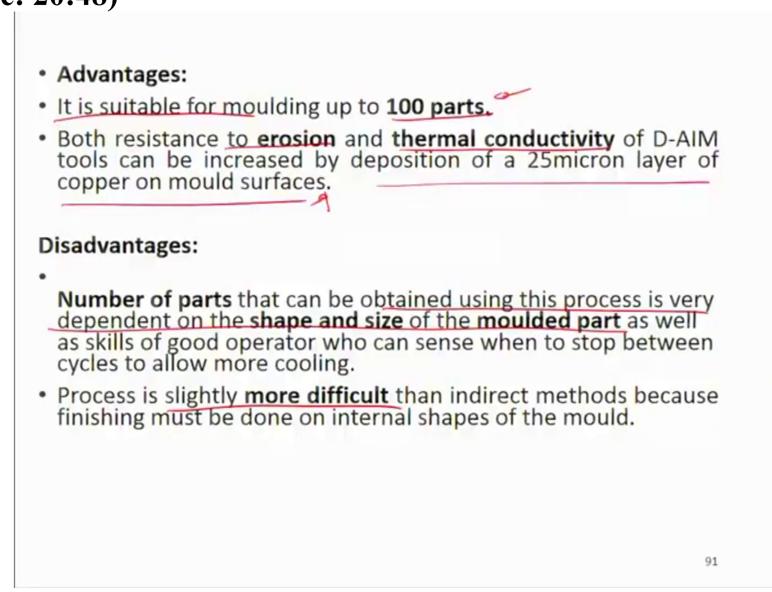

There are many advantages and disadvantages of this so advantages are that it is probably suitable for slightly longer about 100 parts you know both resistance to erosion and thermal conductivity are questionable in particularly the AIM process. But you can increase this by deposition of a 25 micron layer of copper on the mold surface and then sintering it just by using one of the techniques as you use in the indirect tooling case before. There are many disadvantages one of them is the number of parts that can be obtained using this process is very dependent on the shape and size of the molded parts.

If they are too intricate then this you know 100 part estimate may not really work out well it may break the mold just before that you know you can also have if you look at the operator concern of the skill level concerned or people this is a slightly more difficult process okay then indirect methods because you are making the tooling itself and therefore there may be an aspect of machining there may be an aspect of changing something on the overall dye cavity that is propping up through the SLA process.

And there is a very important role being played by skill of operators who are making such tools from manufacturers.

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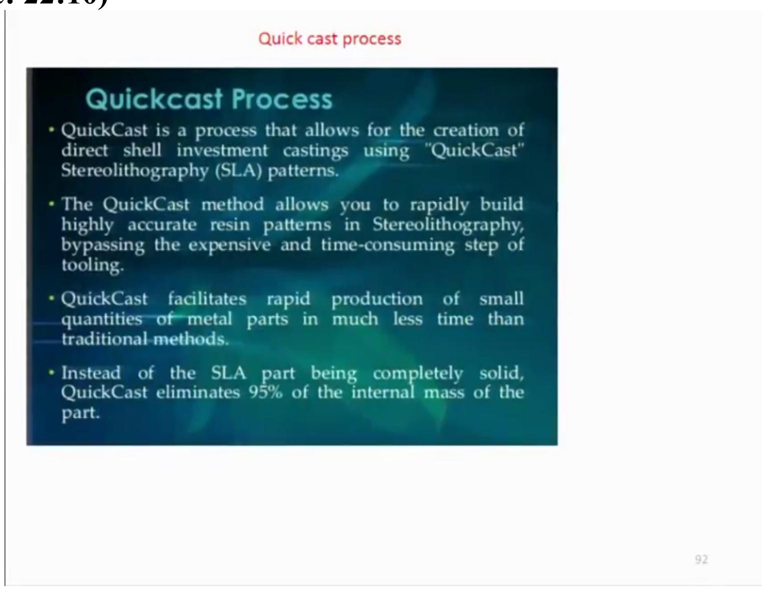

So, this is one of the direct tooling examples the other is quickcast process so you know one of the variants of this aim is or SLA based processes this quickcast process. So, it is a process that allows creation of direct shell investment casting using you know quickcast lithography patterns lithography patterns. So, here the idea is that the SLA part being completely solid you know with this quickcast approach you can eliminate 95% of the internal mass of the part.

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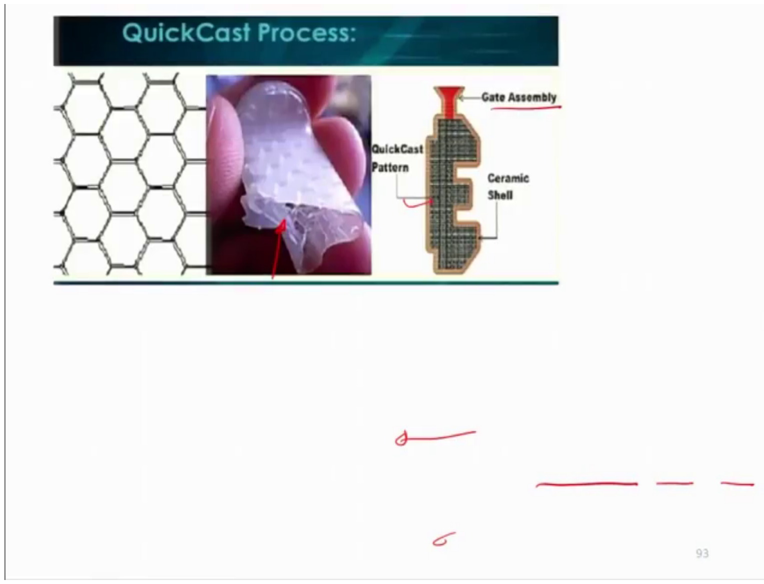

Something like this you know you can see all these different quickcast molds being manufactured ok by making some kind of a mesh pattern kind of a thing which is still able to be used as a insert for more making etcetera. So, with this I would like to complete this section on rapid tooling okay. So, in the next particular module we will start in next week another interesting area of mechatronics and intelligent products.

So, you know what I plan to do is probably to give you a introductory 25 minutes or 30 minutes lecture on that followed by some lab level demonstrations for about two hours when we can talk about things like data acquisition etcetera at the lab level so that you can understand more of applied mechatronics ok with some theoretical formulation in mind with that I would like to end this particular module, thank you very much.