Metal Casting
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Module - 05
Permanent Mould And Special Casting Processes.
Lecture - 04
Investment Casting Process-II

Welcome friends, in our previous lecture we have learnt about the history and developments of the investment casting process. Now, let us continue this topic in this lecture also. Before that let us review what we have learnt in our previous lecture.

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So, here these are the special features of investment casting process. What are these special features of investment casting process? It can produce very thin and most complex features, second feature is it offers excellent surface finish most of the times no machining is required or very negligible machining is required.

Next special feature, it offers excellent dimensional accuracy. Finally, it can be used to cast all metals and alloys.

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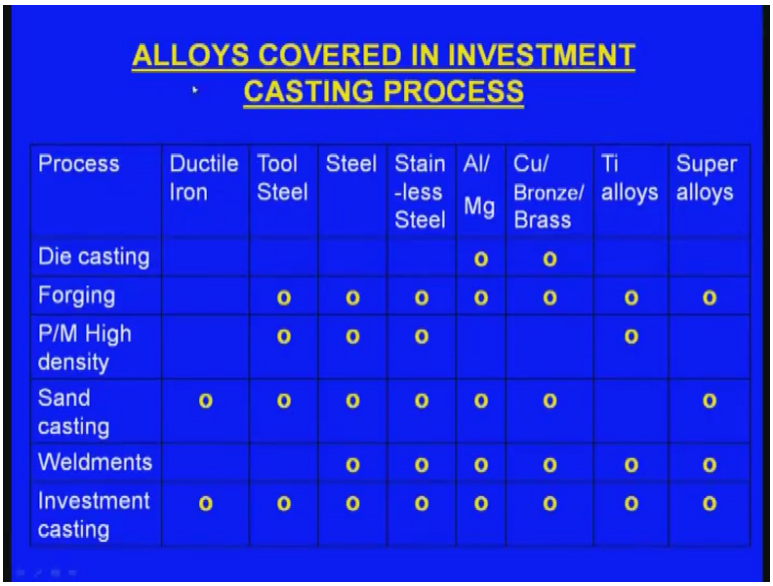

Process	Ductile Iron	Tool Steel	Steel	Stain -less Steel	Al/ Mg	Cu/ Bronze/ Brass	Ti alloys	Super alloys
Die casting					o	o		
Forging		o	o	o	o	o	o	o
P/M High density		o	o	o			o	
Sand casting	o	o	o	o	o	o		o
Weldments			o	o	o	o	o	o
Investment casting	o	o	o	o	o	o	o	o

Now, these are the alloys covered in investment casting process, but before that if we see different manufacturing process or the casting process. What are the alloys that can be covered in these manufacturing process or the casting process. If we see the, consider the die casting process aluminum-magnesium alloys can be cast using the die casting process or copper bronze brass can be cast using die casting process. What about the other alloys, ductile iron, tool steel, steel, titanium alloys, super alloys cannot be cast using die casting process.

Next one if we consider the forging, yes tool steels, steels, stainless steel, aluminum magnesium alloys, copper, bronze, brass, titanium alloys, super alloys can be used for the forging. But ductile iron cannot be used for forging. If we consider the powder metallurgy process- tool steels, steels, stainless steel and titanium alloys can be manufactured using powder metallurgy process. But ductile iron, copper, bronze, brass and the super alloys cannot be manufactured using powder metallurgy process. Similarly, if we consider the sand casting process ductile iron, tool steels, steels, stainless steel, aluminum, magnesium alloys, copper, bronze, brass and super alloys can be manufactured using sand casting process. But titanium alloys cannot be manufactured using sand casting process. And finally, if we consider the weldments, steels, stainless steel, aluminum, magnesium alloys, copper, bronze, brass, titanium alloys and super alloys can be welded. But ductile iron, tool steels cannot be welded.

Now, let us come to the investment casting process. Ductile iron can be manufactured using investment casting. Tool steels, steels, stainless steel, aluminum, magnesium alloys, copper, bronze, brass, titanium alloys and super alloys can be manufactured. If we see here all the alloys can be manufactured using investment casting process. Virtually, there is no alloy which cannot be manufactured using investment casting process. So, that is the unique and greatest feature of the investment casting process.

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Now, in the previous lecture we have seen the developments of the investment casting process during the twentieth century.

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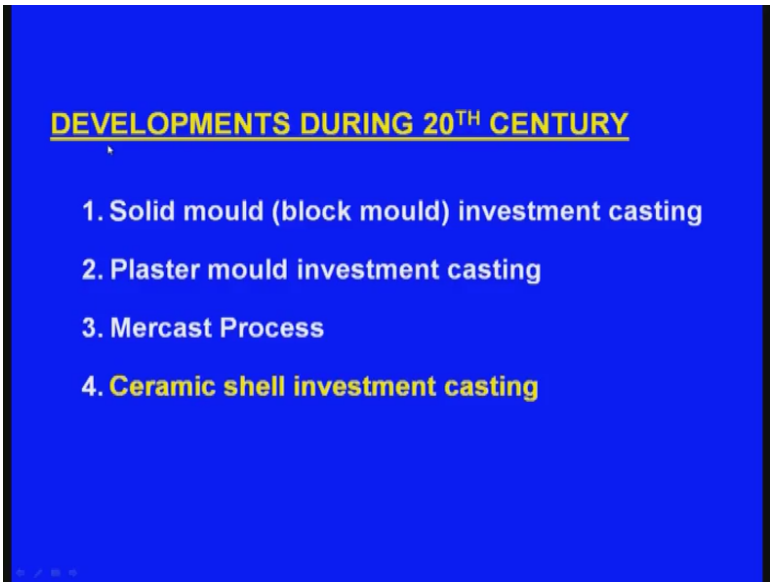

Now these are the developments. Initially the solid mould or the block mould investment casting was used, where the entire what say mould was filled with the ceramic material. Of course, wax was used as the pattern material and they used to pour the molten metal after draining of the wax.

Later the ceramic material was replaced by the plaster mould. So, this used to give the better surface finish in the investment casting process. Later, mercast process was developed, where mercury was used as the pattern material. But there are certain problems associated with this mercast process. So, this no more in use. Finally, ceramic shell investment casting was developed recently and this has gained what say importants all over the world. So, in the ceramic shell investment casting process we initially we make the pattern most of the times it is made up of wax.

Now, this wax pattern will be dipped in a ceramic slurry. A ceramic slurry will be prepared. Then after dipping this what say wax pattern inside the ceramic slurry, it will be taken out and a stucco coating will be given around the wax pattern. After this stucco coating is dried out, again it will be dipped inside the ceramic slurry. Likewise, this will be repeated this cycle will be repeated about say five to seven times. Finally, a shell is created around the wax pattern.

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Now, let us concentrate on this, Ceramic shell investment casting process. So, we are already learning this.

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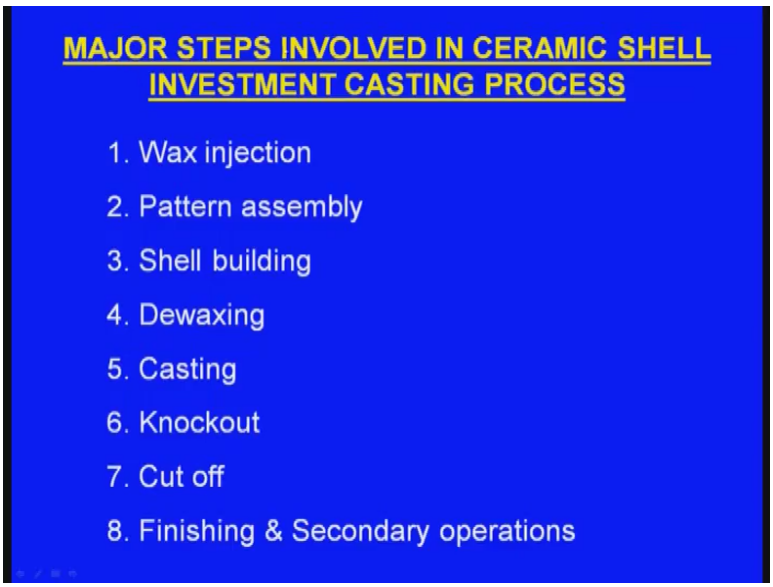

So, these are the major steps involved in the ceramic shell investment casting process. The first step is the wax injection- wax will be injected into the pattern dye and it will be removed. Next one several such patterns are assembled together here. So, that is the second step. Next one as I told before this wax assembly or the wax pattern will be dipped inside the ceramic slurry. It will be taken out, then stucco will be what say

sprinkled around the pattern. Then it will be dried out, again it will be dipped inside the ceramic slurry, again it will be taken out and stucco will be sprinkled around the pattern and it will be dried. So, this process this cycle is repeated five to seven times finally, a shell is created.

Next one after the shell is created it will be dried then dewaxing will be done. So, next one casting, next one knockout, next one cut off, next one finishing and secondary operations. So, in the previous lecture we have completed the wax injection. Now, let us see the pattern assembly.

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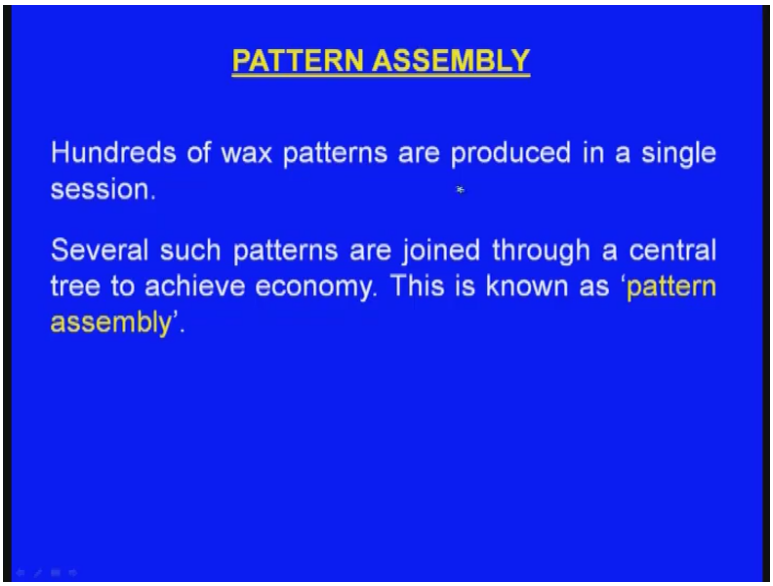

Hundreds of such patterns are produced in a single session and several such patterns are joined through a central tree to achieve economy. When we join several such patterns and make a single what say dipping. Then there will be economy, cost will be reduced. So, this is known as the pattern assembly.

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So, let us take an example case study pattern making for a golf head. So, this is the golf head looks like this. How it is manufactured? It is manufactured by investment casting process.

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Now, this is the typical wax injector now.

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Hundreds or thousands of wax patterns are produced in a single session. So, these are all the wax patterns for the golf head.

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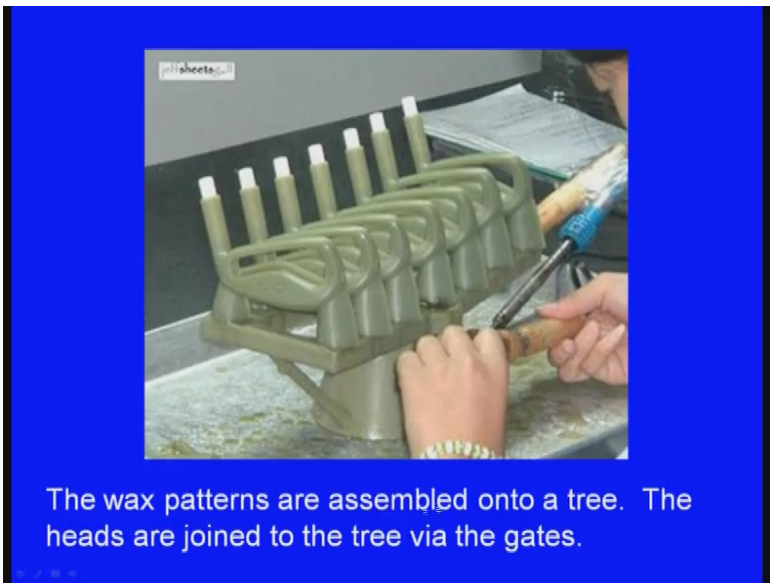

Now, the wax patterns are assembled onto a tree. So, this is the common tree and here we can see one, two, three, four, five, six, seven, seven patterns are assembled here with a single tree. The heads are joined to the tree via the gates. So, this is the assembled pattern.

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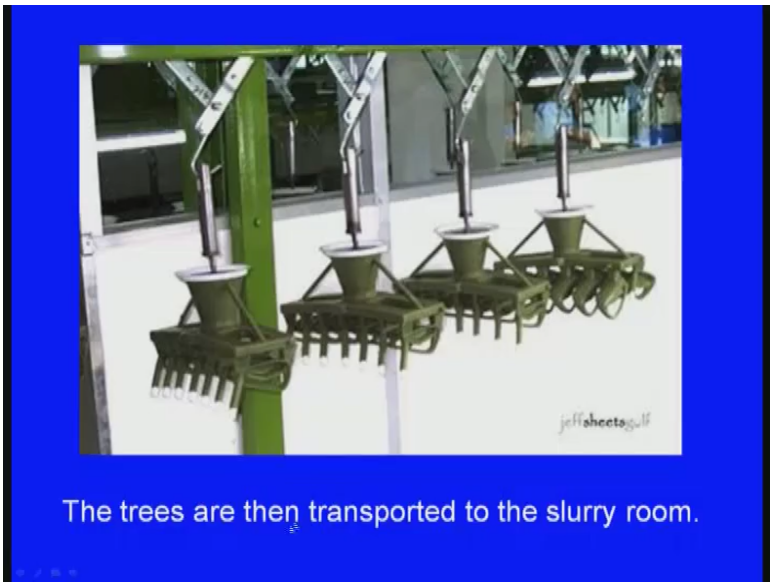

This trees are then transported to the slurry room. There the ceramic slurry will be there this pattern assembly will be dipped inside the ceramic slurry. Next one shell building- How to do the shell building? How to make the ceramic shell? Before that we need to learn the ingredients of the ceramic slurry. What is this ceramic slurry made up of?

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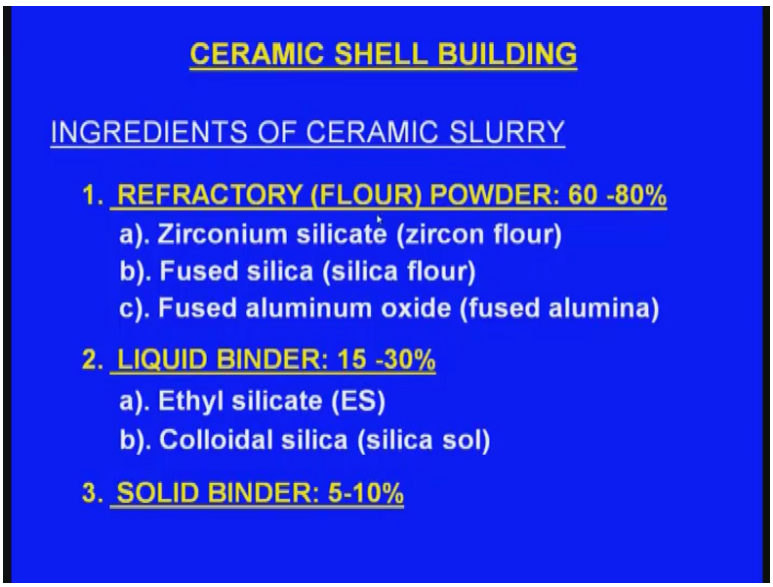

So, these are the three ingredients are there. One is the refractory powder or it is also known as the flour refractory flour. So, it comprises 60 to 80 percent. Next one second

ingredient is the liquid binder. So, it comprises 15 to 30 percent. Next one solid binder will be there it will be 5 to 10 percent.

Now, what are these refractory powders? The most commonly used refractory powders are first one is the zirconium silicate. It is also known as zircon flour, second flour is second refractory powder is fused silica. It is also known as silica flour, third one is the fused aluminum oxide. It is also known as fused alumina. So, these are the ingredients of the refractory powder. Second ingredient is the liquid binder, again there are broadly mainly there are two types- one is the ethyl silicate, second type is the colloidal silica. So, anyone can be chosen and finally, a solid binder also will be used. So, from 5 to 10 percent.

So, these are the ingredients of the ceramic slurry in the investment casting process.

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Now, these there are various stages of slurry. First dip slurry is a fine texture that can easily get down to the details of the grooves and engraving graphics. So, generally two three ceramic slurries will be used, not to a single ceramic slurry. The first ceramic slurry is a very fine one means the ingredients are very fine one. So, that when the pattern is dipped inside this fine ceramic slurry it will be occupying and it will be flowing all around the what say details of the pattern.

Next one there will be another ceramic slurry will be there. So, the ingredients of the second ceramic slurry will be coarser than the first one.

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Next slurry coating is coarser than the first dips as the right it builds a thick ceramic shell around the wax tree. So, this is the second what say ceramic slurry. After the what say pattern is dipped in the first ceramic slurry or the fine ceramic slurry now it is brought to the second one. So, this is coarser again it will be dipped and it will be taken out. Now a stucco will be sprinkled around the pattern. Then it will be dried out, after it is dried out, again it will be dipped inside the ceramic slurry.

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Now, the slurry has to dry between successive dippings that is very important. Temperature and humidity are carefully controlled. So, this is all about the shell building. Next one is the dewaxing, prior to the pouring of the molten metal into the ceramic shell. Wax inside the shell has to be drained out completely and this process is known as dewaxing. Generally, an autoclave is autoclave oven is used for the dewaxing process.

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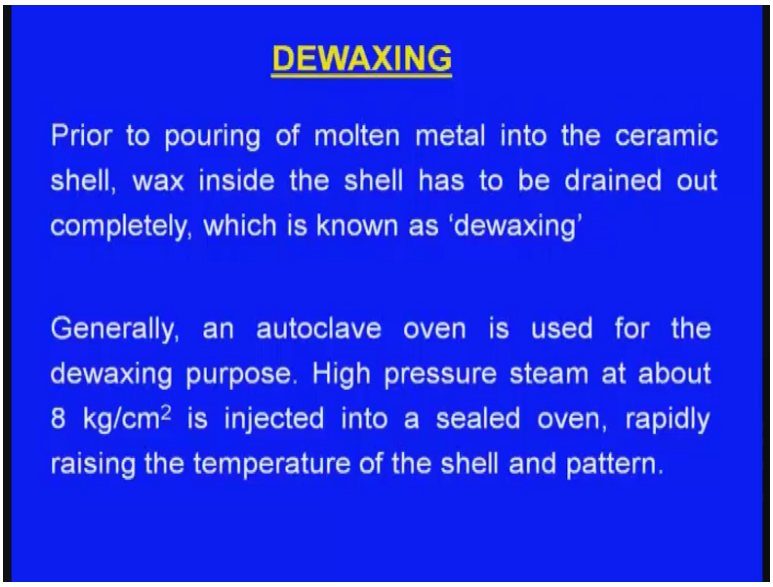

So, inside this automatic what say autoclave oven high steam pressure at about 8 kg per square centimeters is injected into the sealed oven. Then what will happen the wax

pattern will be melted, the wax will be melted and it will be removed from the ceramic shell.

Now, let us see the what say operation or the construction details of a auto autoclave oven.

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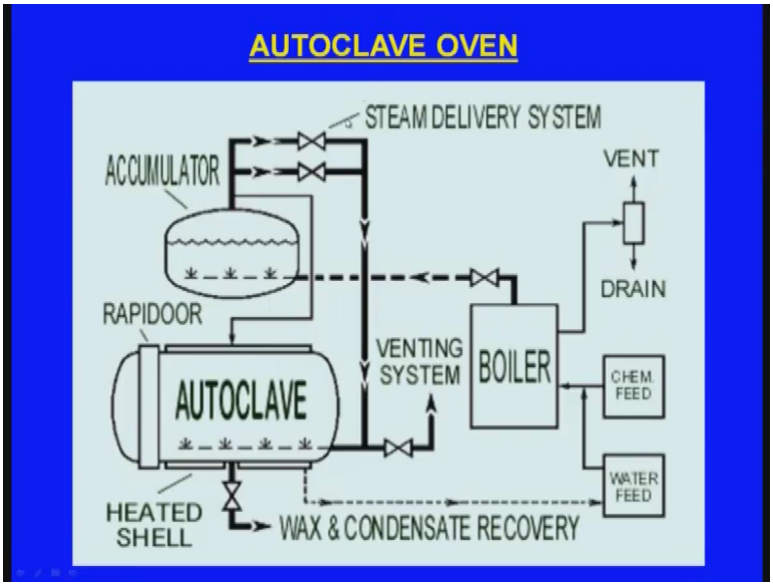

Now these, this is the schematic diagram of an autoclave oven. So, here we can see a steam is produced in the steam boiler. Now you see here there is a control, now it goes to the accumulator. Here it will be accumulated and here it comes out and here there are again controls. So, from the accumulator steam comes to the autoclave chamber. So, here there is a chamber and here we can place the patterns here like this. So, this what say steam at a very high pressure comes and what say it will be injected into the autoclave.

Now, because of this high temperature and because of the high pressure the wax pattern will be melting. The wax that is inside the ceramic shell will be melting and it will be removed. Now, here there is wax and condensate recovery. So, it comes out they again there is a control valve you see. When we open this control valve the water steam and the melted wax will be coming out. That wax again it will be what say refined, it will be purified and again it will be use for making the pattern. So, this is the what say working principle of the autoclave oven. Next one is the casting. Casting means pouring the molten metal into the ceramic shell.

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The ceramic moulds must be heated up before molten steel can be poured into them. So, before we pour the molten metal these shells must be heated.

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Steel is being poured from the crucible into the iron what say mould into the iron head mould you see here.

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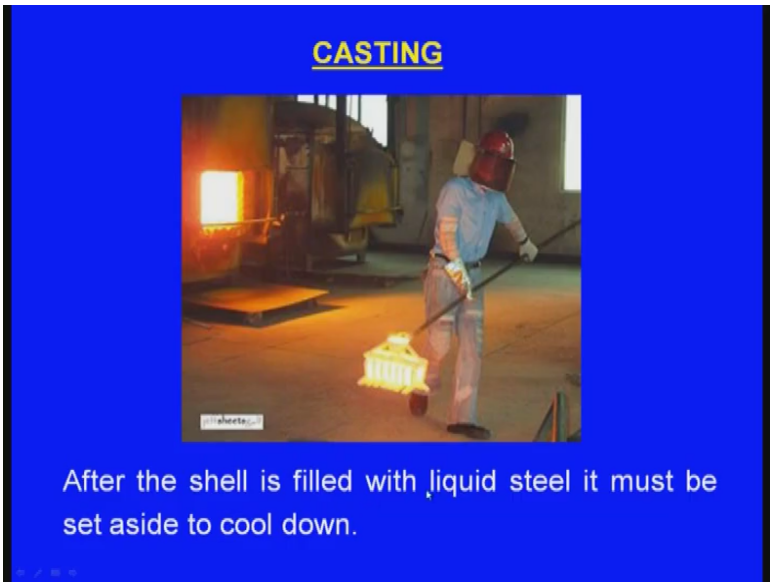

After the shell is filled with the liquid steel it must be set aside to cool down. So, it will be kept aside. So, it takes time for cooling.

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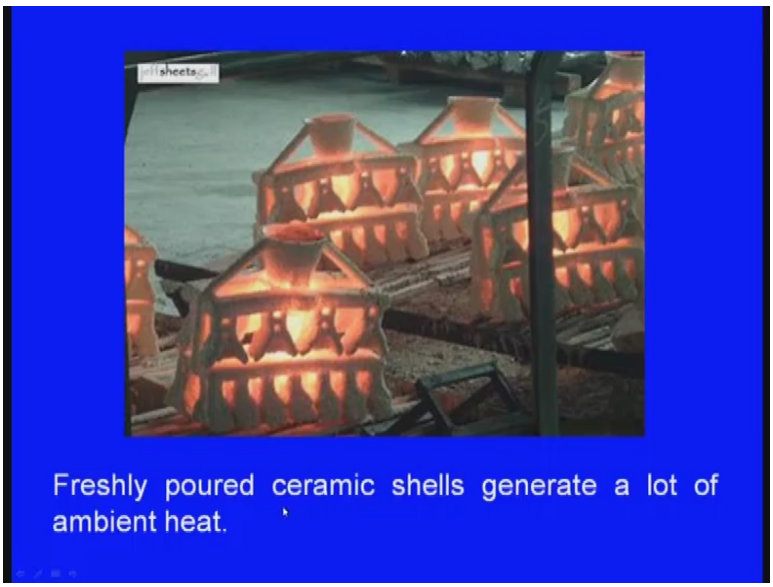

Freshly poured ceramic shells generate a lot of ambient heat. Now we have poured the molten metal into the ceramic shell. It after sometime the metal will be cool cooling and it will be solidifying. Now the next process is the knockout. Knockout means breaking that shell and removing the casting outside

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A motorized chisel is used to break the ceramic shell away from the cast part.

Sometimes it is broken manually, but most of the times a motorized chisel is used to break the ceramic shell to take the what say casting outside.

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Now, here we can see here the metal tree is sand blasted to remove any remaining ceramic shell. After we break the ceramic shell of course, we take the casting outside, but still small traces of ceramic shell will be adhering to the casting. So, these traces of ceramic shell are to be removed from the casting. That's why we are using a sand blasting system. So, here is you can say there is a sand blasting what say chamber is

there sand blasting chamber the castings will be kept inside, then sand will be blasted on the casting.

So, if there are any traces of the what say ceramic shell. They will be removed because of the sand blasting.

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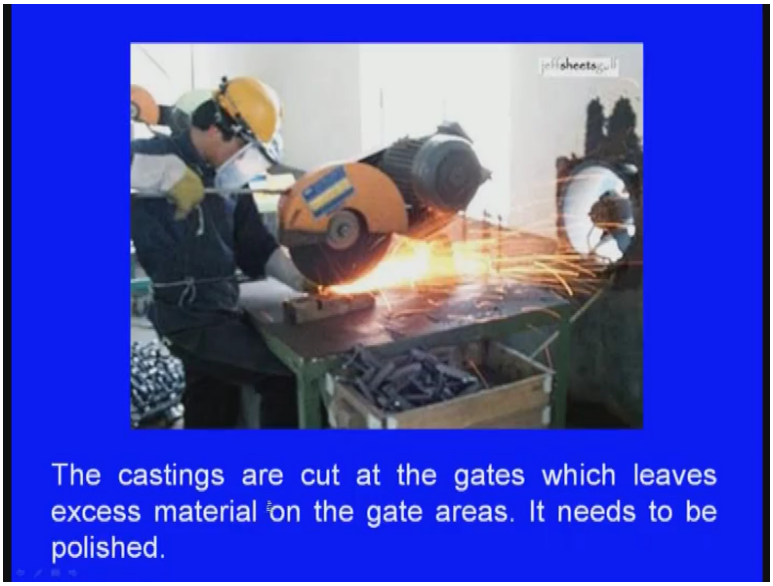

Next one is the cut off. What is this cut off? The castings are cut at the gates which leaves the excess material on the gate areas. It needs to be polished. Previously, you have seen that when we make the wax patterns several such wax patterns are assembled together, now after we get the casting we have to separate the individual castings. So, that is the cut off. So, for that most of the times a grinding wheel is used for separating the castings from the assembled tree.

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Next one is the finishing and secondary operations. The castings are heat treated to normalize the metal. So, that is one of the finishing operations.

Next one heat treatment ovens can vary in size.

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Appropriate surface finish is polished on the parts. Mirror and satin finishes are the most common these days. We have to obtain the appropriate surface finish on the castings. So, that also is a part of the secondary operations.

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Finishing and secondary operations you can see here again. Here the heads are cleaned for final cosmetic preparations, they are cleaned. So, that there will be a very good and pleasant appearance.

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The final production step involves adding cosmetic paint also. That also is a part of the secondary operations.

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Now, the final product will be free from flaws and visually appealing. So, this is the final part of the casting golf head.

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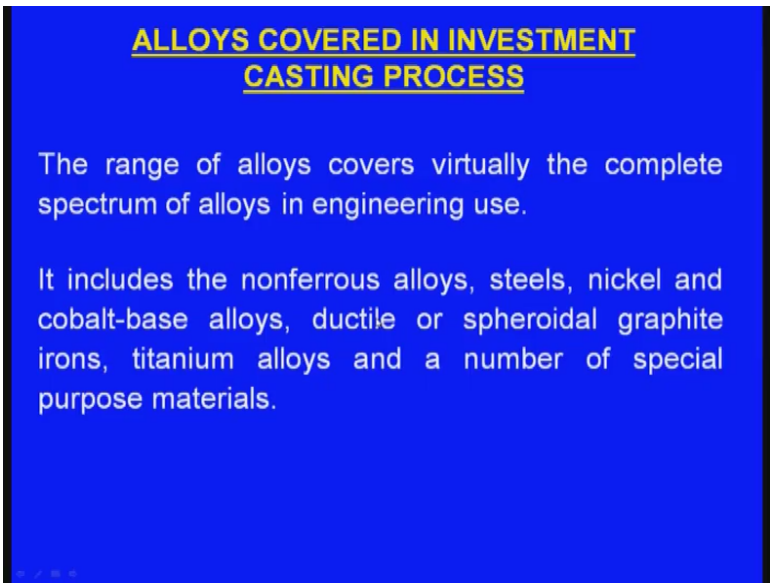

Now, let us see the alloys covered in the investment casting process. Now, in fact this is the special feature of the investment casting process. Most of the alloys can be cast, in fact virtually all the alloys can be cast using investment casting process. The range of alloys covers virtually the complete spectrum of alloys in engineering use. It includes the nonferrous alloys, steels, nickel and cobalt base alloys, ductile or spheroidal graphite

irons, titanium alloys and a number of special purpose materials. There is no material which cannot be cast using investment casting process.

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So, these are the common investment cast alloys. One is the ductile iron, carbon steels, tool steels, stainless steels, aluminum-magnesium alloys, copper, bronze and brasses, titanium alloys and super alloys. So, these are the common cast alloys. In fact, any alloy can be cast using investment casting process. Now let us see the common applications of these what say investment cast alloys. First we will see the investment casting of ductile iron.

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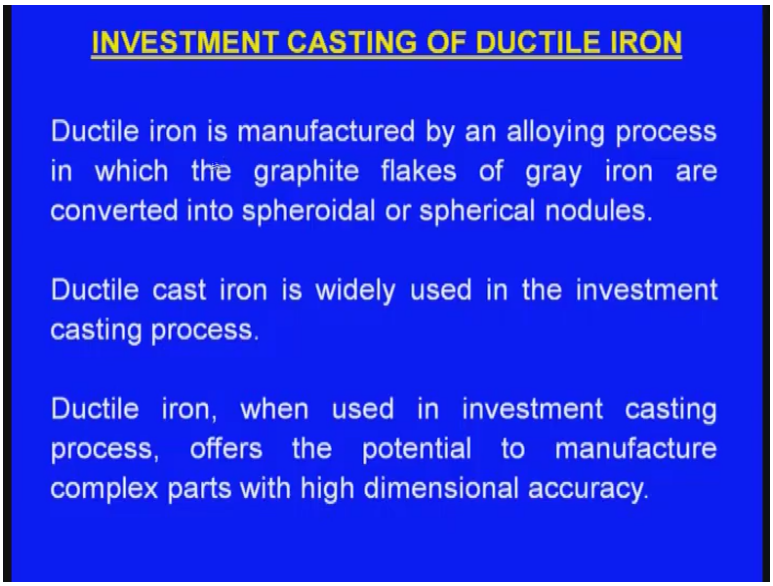

Ductile iron is manufactured by an alloying process in which the graphite flakes of gray iron are converted into spheroidal or spherical nodules.

Generally, what saying the cast iron the graphite is appearing in the form of the flakes. This is known as the gray cast iron, but this will be modified in the coming to the ductile iron. These graphite flakes are modified and a treatment is given such that these graphite flakes are converted into spheroidal or spheroidal nodules. That's why ductile iron is known as the spheroidal cast iron or it is also known as the nodular cast iron.

Now, ductile cast iron is widely used in the investment casting process. Ductile iron when used in investment cast casting process, offers the potential to manufacture complex parts with high dimensional accuracy.

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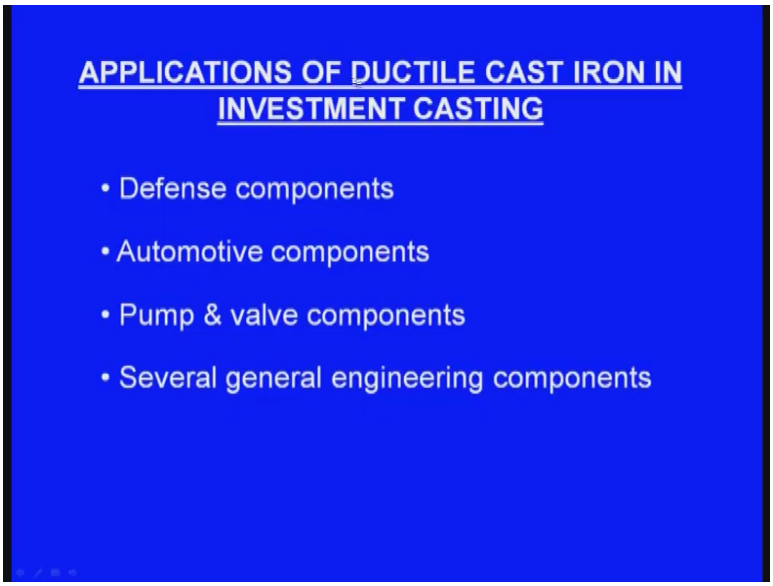

Applications of ductile cast iron in investment casting process. Defense components can be produced. Automotive components can be produced. Pump and valve components can be produce and several general engineering components can be produced using investment casting process.

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Now, let us see a an example. This is the inlet plate used in a gas compressor made up of ductile iron and it is made by investment casting process.

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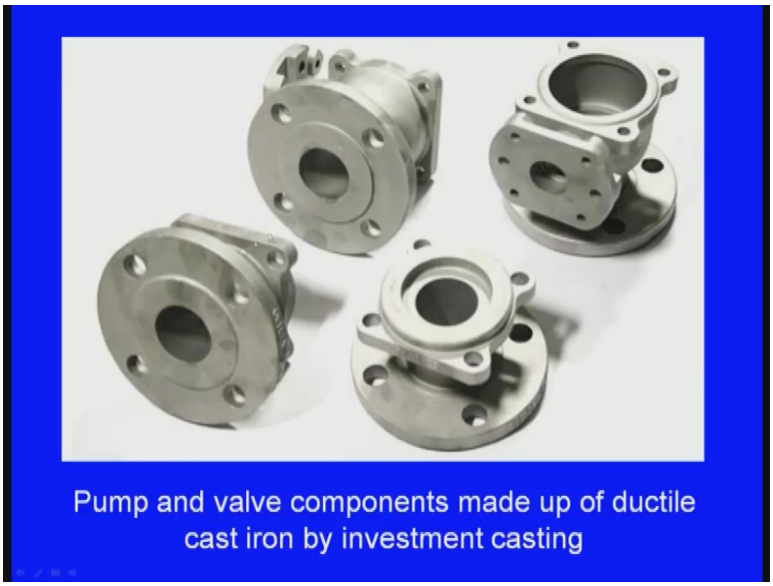

Now, now you can see here some more components. Pump and valve components made up of ductile cast iron and it is made these are made by the investment casting process.

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Wheel cassette part made up of austempered ductile iron by investment casting process. Next one let us see the investment casting of carbon steels.

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Carbon steel investment castings are commonly used in a broad spectrum of industries. Important applications- Locks and internal lock mechanisms, lock bodies and keys, door handles and door closer units, mining applications, military and firearms. And finally, transportation what say parts the all these are manufactured using investment casting process.

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Now here we can see these are the hard what say hardware and lock components made up of what say carbon steel and these are produced by investment casting process.

So, these components require very good surface finish and excellent dimensional accuracy and further this components posses what say complex features. So, these carbon steels and these carbon steel components are produced by the investment casting process.

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And he we can see here military and firearm castings these are made up of carbon steel and these are produced by investment casting process, very fine surface finish.

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Next one let us see the investment casting of tool steels. Tool steels refer to a variety of alloy steels that are particularly used for making different tools. We use the cutting tools, the lathe tool, the milling cutter, the planning cutter. All these tools are produced by the investment casting process and here for example, we can see tool steel parts produced by investment casting process. So, these are the what say tool steels produced by investment casting process.

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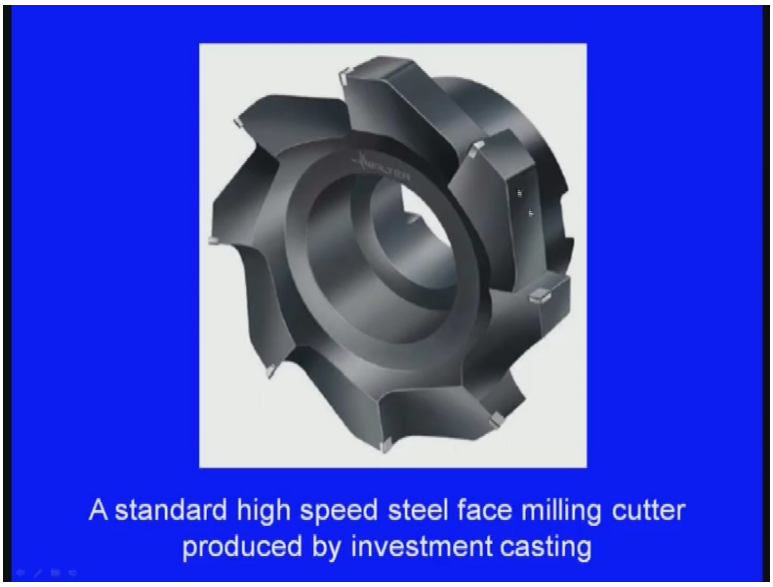

Next one this is a standard milling cutter produced by the investment casting process.

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Next one let us see the investment casting of stainless steels. Stainless steel investments castings can be produced to a mirror finish for the ultimate in a corrosion resistance, even in what say salty marine conditions. Among the stainless steels, austenitic grades are commonly in use for most of the investment casting applications.

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Here we can see this is the pelton wheel blades made up of austenite stainless steel and produced by investment casting process.

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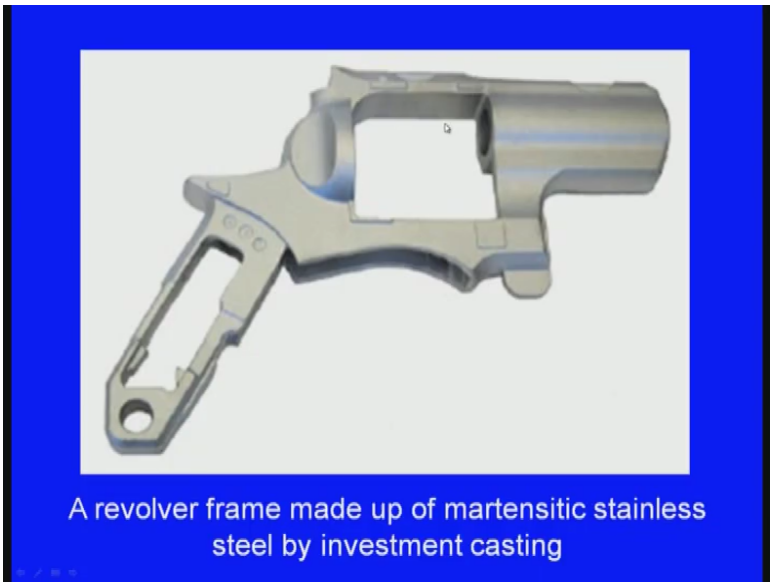

This is a revolver frame made up of martensitic stainless steel produced by investment casting process.

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Now, this is a duplex stainless steel corrosion resistant valve produced by investment casting process.

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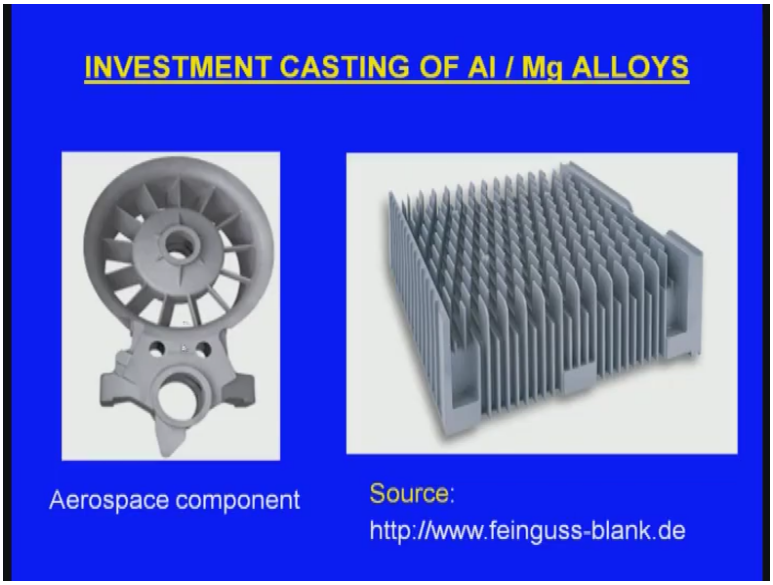

Now, let us see the investment casting of aluminum and magnesium alloys. Here we can see the an aerospace component. So, these are produced by the investment casting process and here we can see in this component there are several thin fins you can see.

Extremely what say very good surface finish is required and the fins are very what say thin and complex features are there and this what say parts are produced by the investment casting process.

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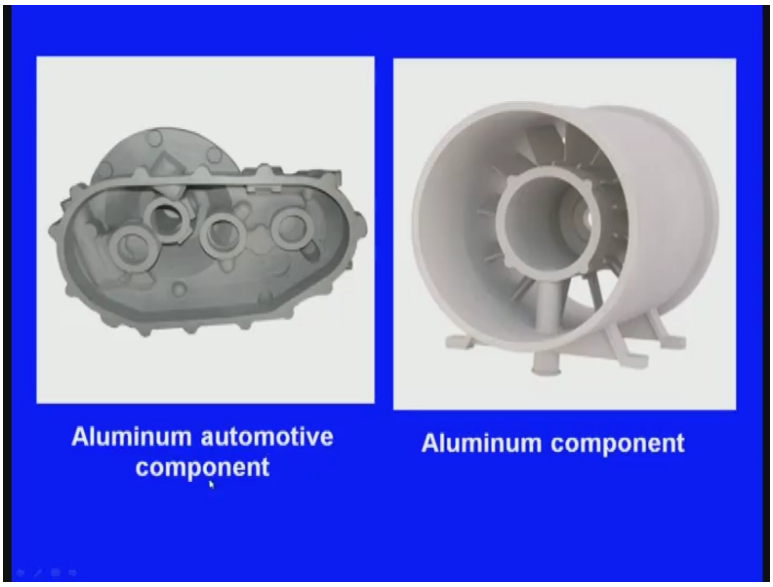

Next one aluminum automotive component. Here we can see again this is produced by the investment casting process. Again you can see here this is another component, again produced by the investment casting process.

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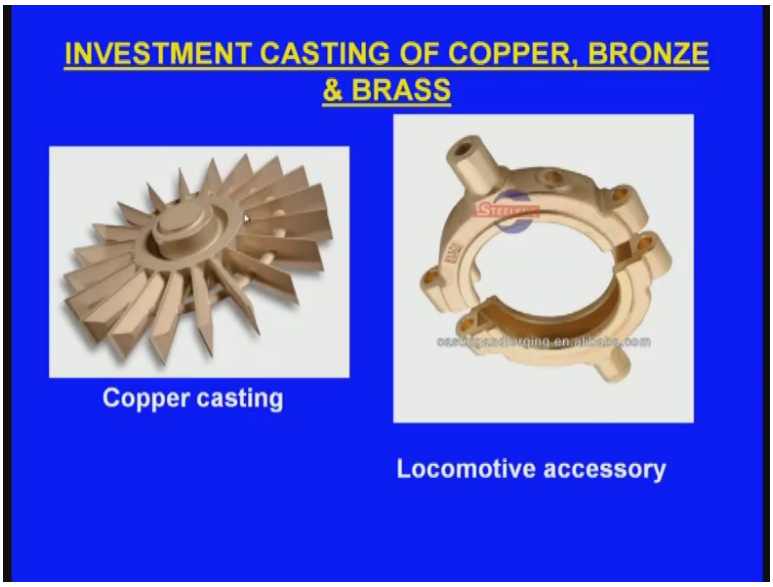

Investment casting of Copper bronze and brass and here we can see this is a copper casting thin blades are there. So, these are produced by the investment casting process. So, this is the locomotive accessory, again it is produced by the investment casting process.

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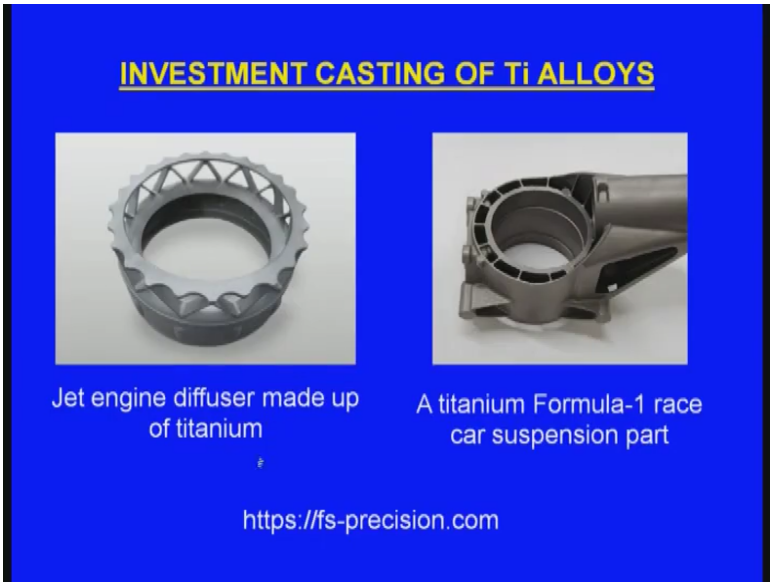

Now let us see the Investment casting of titanium alloys. Jet engine diffuser made up of titanium. Here you can see a component with what say complex features and thin sections and which requires very good surface finish and it is produced by, the this titanium alloy component is produced by the investment casting process. A titanium formula one race car suspension part. Again it has got thin sections and complex sections again it is produced by the investment casting process.

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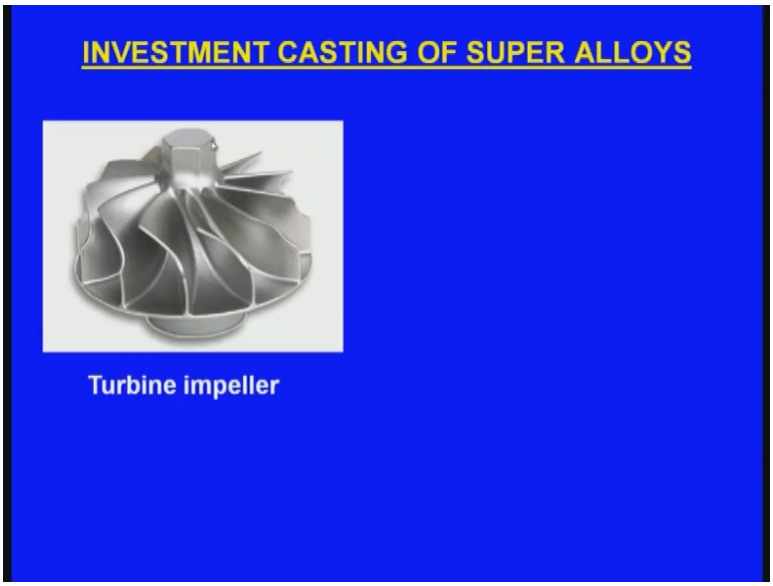

Next one finally, let us see the Investment casting of super alloys. This is the turbine impeller, you can see the what say a complexity of this blades. Very thin blades and they have got the complex what say features and this titanium impeller is manufactured by investment casting process.

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Now, let us see the rapid prototyping in investment casting process. Recently, this rapid prototyping has emerged as a what say means for producing the patterns. The most what say tough what say face of the investment casting is the producing the pattern. Once we

produce the pattern we can dip it inside the ceramic shell and we can build this what say ceramic shell and we can produce the casting. But producing the pattern is very difficult. So, that's why rapid prototyping has emerged to produce the patterns

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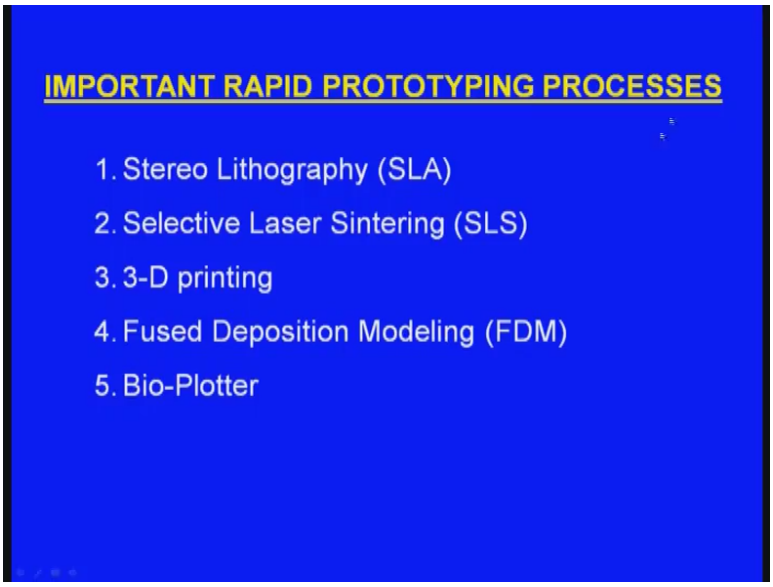

Now, let us see the important rapid prototyping process. One is the stereo lithography. It also known as SLA. Next one selective lasering, laser sintering SLS. Next one 3D printing. Next one fused deposition modeling FDM. Finally, bio plotter. So, these are only a few important rapid prototyping process. In fact, there are more process. Now let us see these what say process and their principles briefly.

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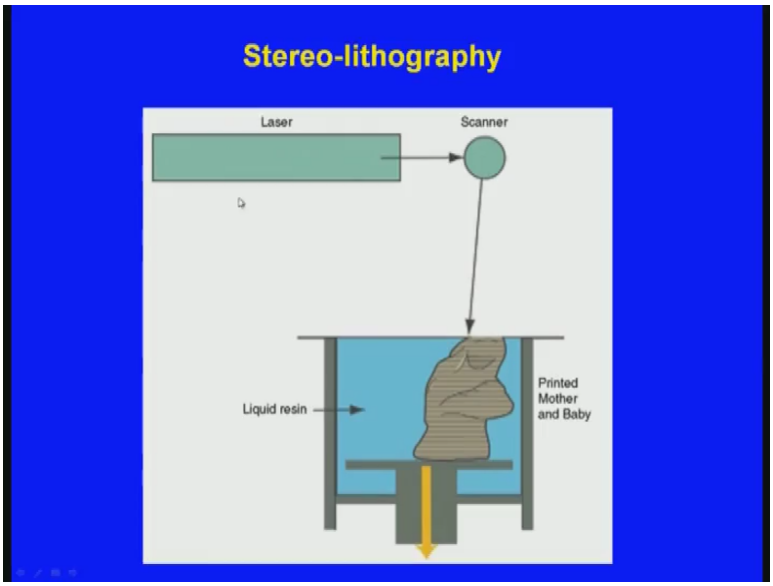

First one let us see the stereo lithography. Now, here there is a liquid resin and here is the laser system and yes here there is a scanner. This laser will be falling on the liquid resin. So, this is a photopolymer where ever this laser falls there it will be, the liquid resin will be cured and it becomes solid. Likewise, where ever we want to what say have a what say solid body. There the laser will be scanned. So, finally, we get the what say required component. So, this is the basic principle.

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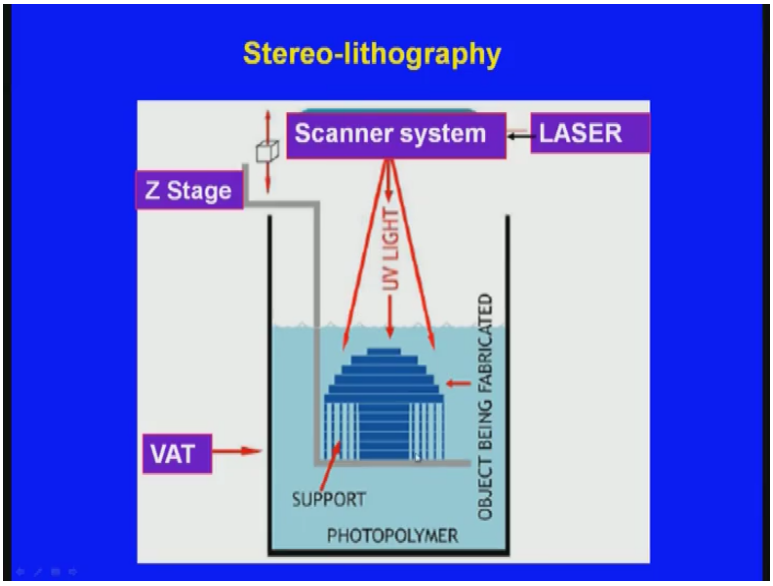

So, this is the what exactly happens. So, this is a VAT means like a tank and inside there is photopolymer will be there. So, what is the specialty of the photopolymer when what say light or the laser falls on this photopolymer, it will be cured. It will become a solid particle. Now here we can see, this is the support, this is this is the stand and here we can see laser. It is connected to the laser and laser beam will be falling here. Initially the first layer. It it is the what say z stage will be moved up.

Now, may this is the stand this is the stand stage. The stage will be at the top here somewhere here. Now, it will be what say cured layer by layer. The laser scanning system will be curing, the first layer. Then it comes down, means the solidified layer will be going inside the photopolymer. Now, again photopolymer will be covering the solidified layer. Again, the laser will be curing the second layer. Then it comes down. Again the polymer fills that what say cured layer. Again the laser will be curing the third one. So, gradually that what say stage will be coming down and the laser system will be curing one layer after another layer. Likewise, the entire solid is what say cured like this. Of course, these are the supports. So, this is the principle of the stereo lithography.

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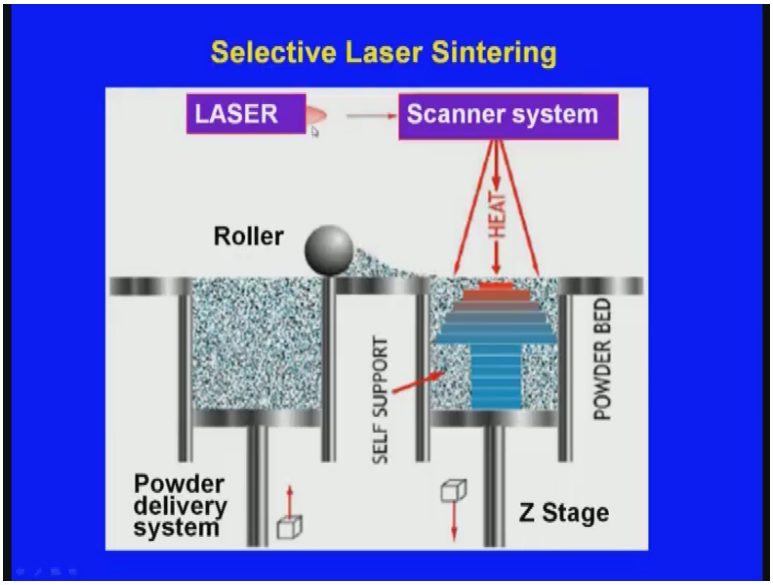

Next one is the selective lasering laser sintering. So, this is similar to the previous one stereo lithography, but here in the case of the selective lasering sintering. In the previous case the liquid what say a polymer is used and here powder is used. That is the primary difference and here also laser scanning system will be there. Now, what is the principle

here yes there are two stages here right. One stage for the powder and another stage for the pattern.

Now, initially yes the it moves little up the powder what stage and there will be a roller. This roller will be rolling and it is spreads this powder evenly in this what say stage. Now, the scanning system will come and it will be curing the first layer. Once it cures the first layer this Z stage will be coming down. One step it comes down. Again it most by this powder stage will be moving one step upwards. Again the roller will be moving and it moves the what say powder it distributes evenly here. Again the scanning system will come and it will be curing the second layer. Again then the this stage will come down that Z stage will come down one step. Again this goes up, again roller will go and it will distribute the powder evenly above this stage. Again the scanning system will cure the third layer. Likewise it is similar to the stereo lithography, but here it is the powder is used for making the pattern.

Finally the whole what say pattern is created like this. So, this is the required pattern.

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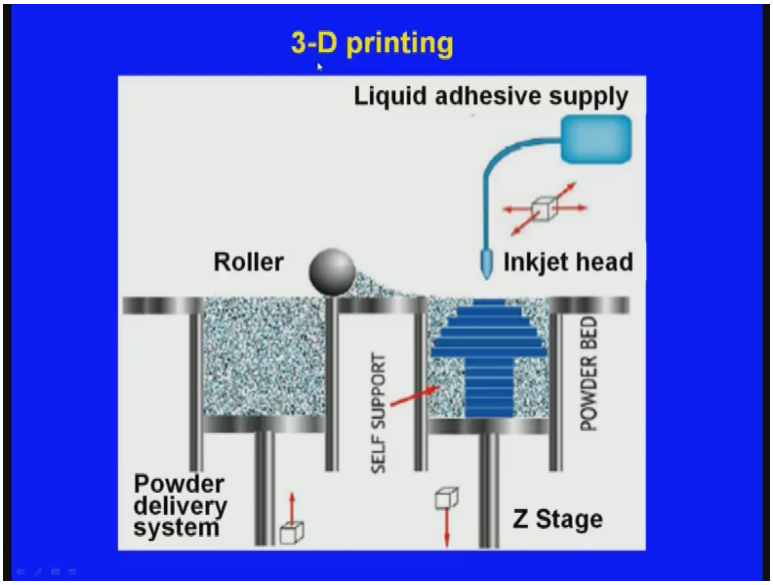

Next process is the 3D printing. This also similar to the the previous one. The selective laser is sintering, but in the in this case of the selective laser sintering for curing purpose we were using what say laser system, but here laser system is replaced by the liquid adhesive. Same principle yes there are two stages are there. This is the powder what say stage. So, every time this powder stage will be moving up one step upwards and here

there is a roller. This roller will be rolling and the powder will be distributed above this Z stage evenly.

Now, this liquid adhesive will be released and where ever again it is connected to the computer. In which there is a model is created. Now where ever we want to cure right here the liquid adhesive will be distributed. Now, it will be hardened, now it comes down by one step and the powder stage will be moving up by one step. Again the roller will be there, roller will be rolling and it takes the powder and it distributes the powder above the Z stage evenly. Again with the help of the what say scanning system. Thus liquid adhesive will be distributed over the second layer and it will be hardened. Again it comes down and the powder stage will be moving one step above. Likewise the principle is similar to the selective lasering system sintering.

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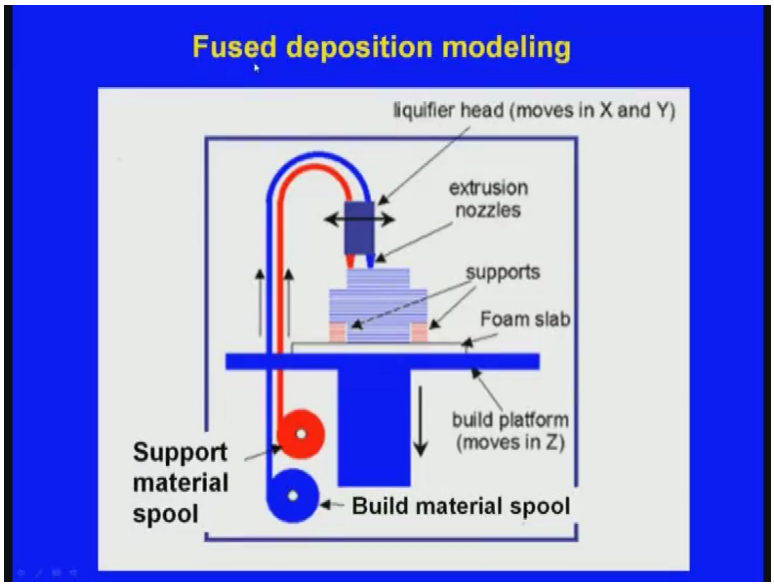

Next one is the fused deposition modeling and here we can see this is the support material spool and this is the build material spool. Two spools will be there. So, these will be moving like this and here we can see this is the extrusion nozzle will be there. Now, this building build material spool will be passing through the extrusion nozzle, yes then it will be spreading and here it will spread. So, again it will be connected to the computer.

Now, the liquifier head moves in X and Y direction, you see here. It will be moving in the X and Y direction means it will be making a thin sheet at a time. Then it will be

coming down, the stage will be coming down. Again it will be making a thin sheet because it is moving in the X Y direction. In the next stage it will be making making another sheet it will be curing another sheet likewise.

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Finally these are the ice patterns. Ice patterns are found to be what say very effective in the investment casting process.

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And here we can see these are all the ice patterns.

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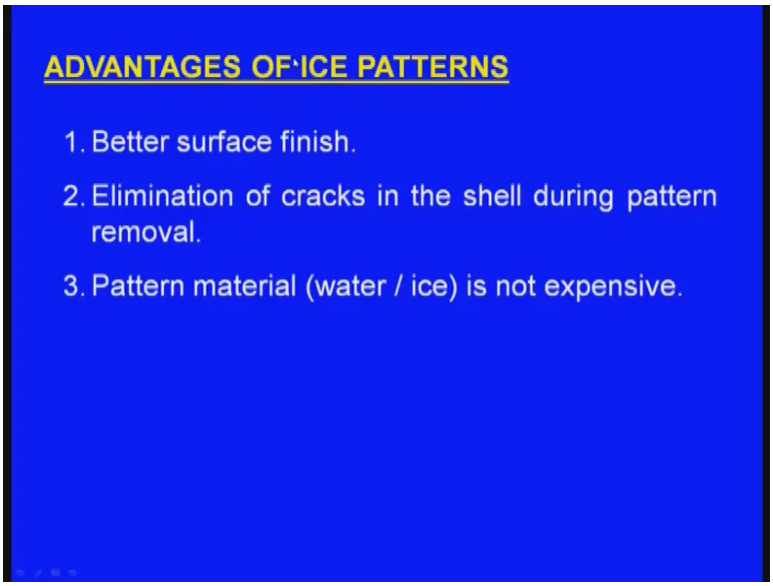

Now, what are the advantages of ice patterns. First advantage is the better surface finish. Very good surface finish is obtain using the ice patterns. Next one elimination of cracks in the shell during the pattern removal. Most of the times when we use the wax pattern yes what we do yes we put it inside the dewaxing chamber or the autoclave oven what will happen when we try to heat the what say ceramic shell in which there is wax. First wax will be expanding because of that the ceramic shell will be cracking. So, these are the drawbacks of using the wax as the pattern material. But here the cracking of the ceramic shell doesn't arise.

Why if we heat the ceramic shell inside the oven ice will be there. So, ice will be when we raise the what say temperature because of the abnormal expansion of the water what will happen, the volume will be coming down till what say four degree centigrade because the volume is coming down the shell won't be cracking. So, that is the greatest advantage of using the ice patterns.

Next one pattern material water or ice is not expensive. If it is the wax pattern means we need to purchase the wax not only wax. We need what say make a blend of the wax. So, these are expensive, but ice pattern what is the raw material, water it is not expensive. Again this is a what say good advantage of using ice patterns. Friends in this lecture, in this two lectures we have seen the developments of this process during the twentieth century and we have seen solid mould or the block mould investment casting process.

Next one we have learnt the plaster moulding investment casting process. Next we have seen the mercast process in which the pattern material is the mercury. Finally, the last one is the ceramic shell investment casting process.

So, these are the four developments of the investment casting process, we have studied and in the ceramic shell investment casting process. So, these are the different steps we have seen wax injection, pattern assembly, shell building, dewaxing, casting, knockout, cut off, finishing and secondary operations are the steps involved in the ceramic shell investment casting process and we have completed this.

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And we have seen that it can produce the very thin and most complex features and it offers the excellent surface finish. It offers the excellent dimensional accuracy and it can be used to cast all the metals and alloys and we have also seen that among several manufacturing and casting process investment casting has the unique what say speciality of covering all the alloys, virtually all the alloys. Most all the alloys can be cast using investment casting process. So, with this we are completing the investment casting process and in the next lecture we will learning about the continuous casting process. Until then good bye and.

Thank you.