Metal Casting
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Module - 05
Permanent Mould And Special Casting Processes
Lecture - 03
Investment Casting Process-I

Good morning friends, in today's lecture let us learn about investment casting process. Investment casting process was a very ancient process. Now, why should we learn it today or why investment casting process, the reasons are many, what are they?

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Investment casting can produce very thin and most complex features. If we want to produce very thin sections, say of the order say 0.75 mm are in the cases where extremely complex features have to be produced then, investment casting is the only solution.

Next reason, it offers excellent surface finish. Sand castings do not give us very good surface finish. We have to machine it to obtain a good surface finish whereas; investment casting offers us excellent surface finish. Most of the times no machining is required or minimum machining is required. Next reason it offers excellent dimensional accuracy. Means, the difference between the size of the pattern and their size of the casting is

almost 0. So, it offers the excellent dimensional accuracy. Next one it can be used to cast all the metals and alloys.

Now, let us see this, how it can be used to cast all the metals and alloys.

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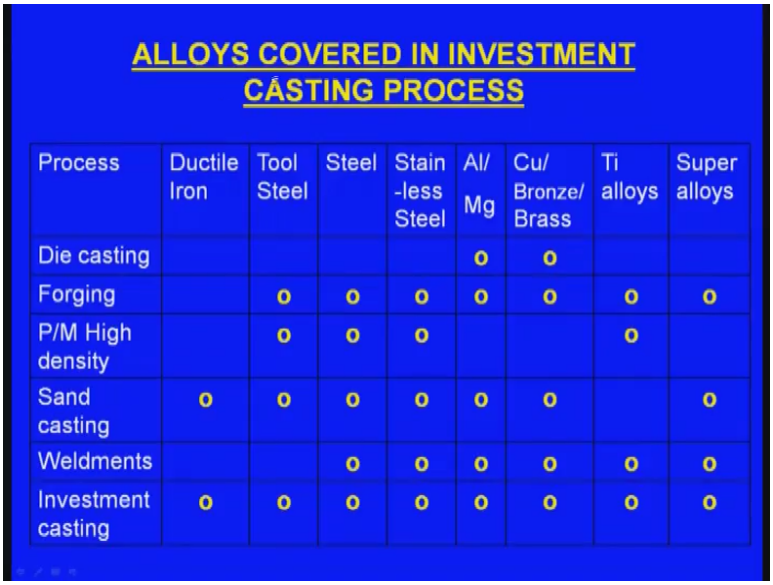

Process	Ductile Iron	Tool Steel	Steel	Stain -less Steel	Al/ Mg	Cu/ Bronze/ Brass	Ti alloys	Super alloys
Die casting					o	o		
Forging		o	o	o	o	o	o	o
P/M High density		o	o	o			o	
Sand casting	o	o	o	o	o	o		o
Weldments			o	o	o	o	o	o
Investment casting	o	o	o	o	o	o	o	o

If you see in this table we can see alloys covered in investment casting process. So, here we can see along with this we can also see alloys covered in the other casting process and other manufacturing process and if we see, say here, these are all the different to what say casting and manufacturing process and here, these are all the different cast alloys and other alloys which can be manufactured by different casting process or manufacturing process.

If you see the die casting process we see ductile iron cannot be cast using die casting whereas, tool steel also cannot be cast. Steel cannot be cast; stainless steel it cannot be cast only aluminum, magnesium, copper, brass and bronze alloys can be cast using die casting process. What about titanium alloys, super alloys? Those also cannot be cast using die casting process and if you see this forging it say one of the important manufacturing process. Ductile iron cannot be forged you see here whereas, tool steel, steel, stainless steel, aluminum or magnesium alloys, copper and what say bronze and brass, titanium alloys, super alloys can be forged, but ductile iron cannot be forged.

Now, this is another process that is the powder metallurgy process; in this we can see ductile iron cannot be done produced using powder metallurgy whereas, tool steel, steel, stainless steel and titanium alloys can be produced. Parts can be produced using powder metallurgy now let us come to the sand casting process. In this process yes ductile iron can be ductile iron parts can be produced, tool steels parts can be produced, steel parts can be produced, stainless steel parts can be produced and aluminum magnesium, copper, bronze, brass, alloys can be produced using sand casting process whereas, titanium alloys cannot be produced using sand casting process whereas, again super alloys can be produced.

Now, let us see the another manufacturing process that is the weldments. Now here, we can produce only steel, stainless steel, aluminum, magnesium, copper, bronze, alloys, titanium alloys and super alloys in this welding ductile iron and tool steels cannot be welded. Now let us consider the topic of our interest that is the investment casting. Now in the investment casting you see ductile iron can be cast, tool steel can be cast, steel can be cast, stainless steel can be cast, aluminium, magnesium, alloys can be cast, copper, bronze, brass alloys can be cast, titanium alloys can be cast and finally, super alloys also can be cast. Virtually, all the metals and alloys can be cast using investment casting process.

So, these are the special features of investment casting process. So, among all the casting process and manufacturing process investment casting gains this unique importants that every alloy and every metal can be cast using investment casting process.

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Now, before going to this subject let us see the history of investment casting process right.

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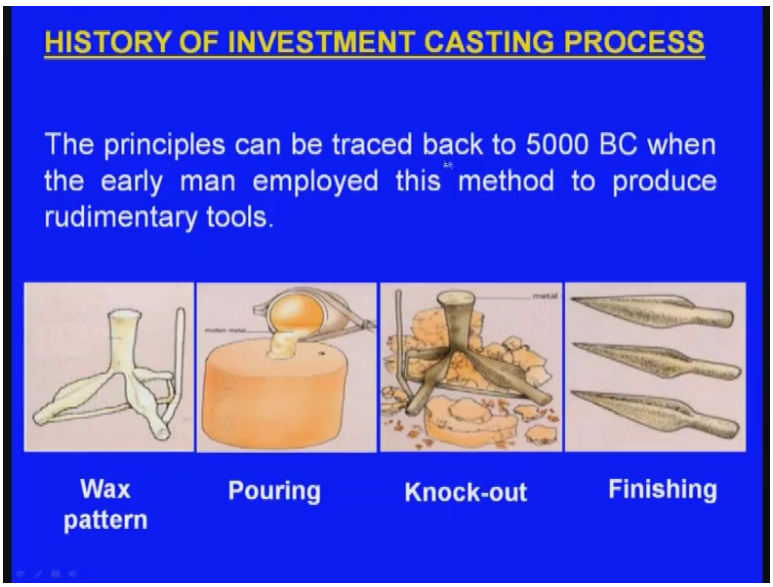

The principles can be traced back to 5000 BC when the early man employed this method to produce rudimentary tools. So, this method was in practice even 5000 BC by the ancient man to produce the rudimentary tools. So, those days if a war has to takes place on both sides there will be two groups will be there and they will be throwing the spears. So, these are the spears. So, this is the metallic of cast component and here there will be

a wooden handle will be there. So, they will be holding this spear and they will be throwing to the other group.

So, this is how they used to do the wars those days. Now, these a spear heads were manufactured by the ancient man using the investment casting process how? Initially the ancient man has made wax models of the sphere heads, you can see here so, this is the one wax model for one spear head. So, this is another wax model for another spear head and this is another model for another spear head. So, these three were joined together.

Now, there is a central tree was there. So, now, again these are all joined here, and here also, we can see another virtual projection. So, this entire structure entire assembly is made up of wax. Now, the next step done by the ancient man was, he has compacted the sand sticking sand around the this pattern wax assembly. You can see here he has compacted the sticking sand and it was dried. Now after that, he has what say heated this system hand moulding system then what happened. So, this because of the heat produced this wax pattern would melt and it used to drain out and inside there will be a cavity and whose shape is similar to this wax assembly or the pattern.

Now, he has melted the metal and he was pouring into this cavity you can see here his pouring is done. Now once the cavity is filled with the molten metal. So, there is another hole here. So, it would raise through this hole. So, then he will be realizing that the cavity is filled with the molten metal and he would stop pouring the molten metal. Now after some time the molten metal should face inside the sand mould then he was breaking this sand mould you see, now after the sand mould is broken it was looking like this now. So, these are the, this is the structure of the assembly of the 3 spear heads.

Now, he used to cut here, he used to cut here and he would cut here and he would cut here finally, 3 spear heads are produced. So, this is how the ancient man has produced the spear heads using the investment casting process. So, we can conclude that a investment casting is the most ancient process used by the ancient man.

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Now, we can see some more history. So, later this process was used for making art castings for several centuries. So, here we can see the bronze what say statues of important personalities and the kings. So, these bronze statues were made by investment casting mean means, initially they used to make the face of the face of that personality by wax model. They used create a wax model around that they would make a sand mould they used to compact this sand mould and they used to heat that sand mould and the wax would drain out and then they would pour the molten bronze.

Now, here we can see these are the again art castings bronze castings. So, these are made by investment casting process.

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Now, let us see the developments in India. In India again, this process was in use even during 2500 BC. So, those days a dancing girl was made you can see here. So, this is the what say dancing girl bronze girl. So, this dancing girl became very popular those days because this girl has several what say statue has got several artistic features. All this artistic features were a excellently cast using the investment casting process means initially they made a wax model of this dancing girl then they kept it inside a sand mould, they compacted sand around this wax model they heated it, then the wax has drained out then they poured the molten bronze into that mould.

So, this is this bronzing what say statue dancing girl is still in there in Mohenjo-Daro. So, now, it is in Pakistan.

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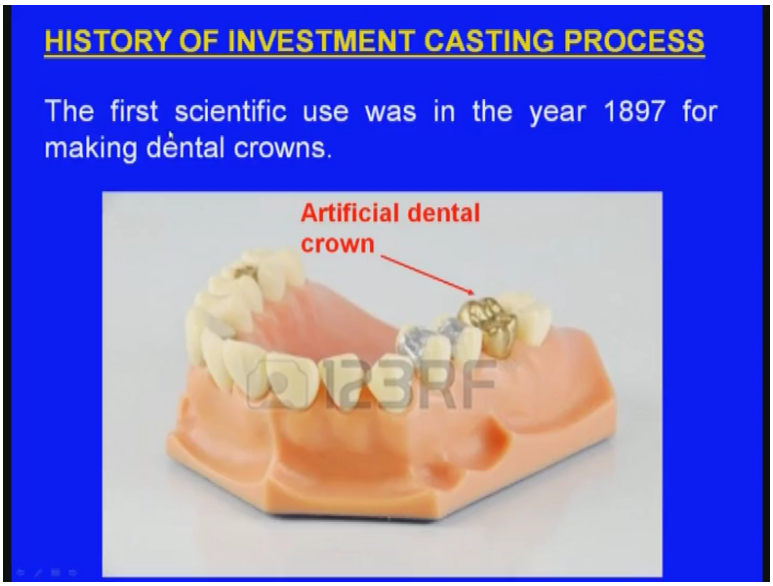

Now, again we continue the history, the first scientific use was in the year 1897 for making dental crowns; here we can see, so this is the dental crown. Again this dental crown was manufactured and it is still manufactured using the investment casting process.

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Now, the technology had a great evolution in the United States during the world war, Second World War.

Now, there was a great need for making precision components with complex geometry such as turbine blades for aircrafts engines and so on. So, here we can see these are the turbine blades and they have very complex what say geometry and these are manufactured by investment casting process. With excellent surface finish and with excellent dimensional accuracy we are able to get these complex featured cast components.

Now, let us see the developments. So, for we have seen the what say history in a what say nutshell now let us see the developments during the 20th century. What are the developments?

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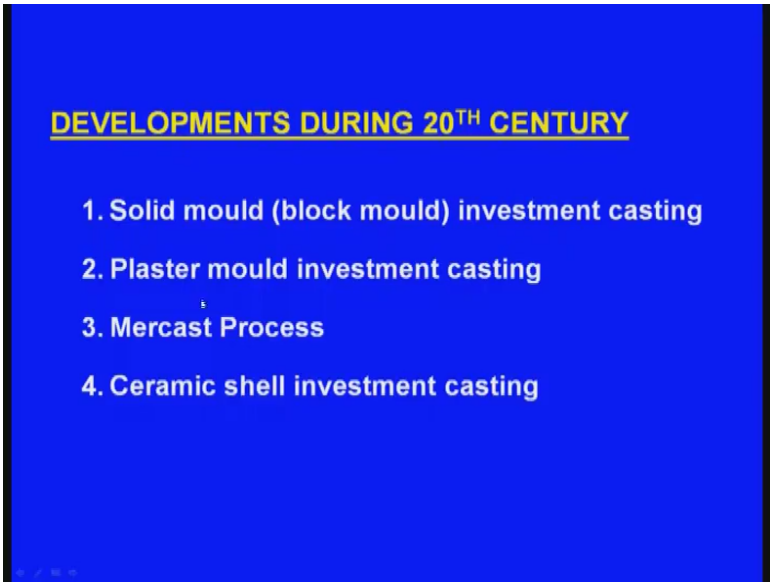

So, these are the what say different phases of the developments of the investment casting process. The first is the solid mould or block mould investment casting, next one plaster mould investment casting, next one mercast process and next one ceramic shell investment casting process.

Now, let us see all these one by one. First let us see the solid mould or the block mould investment casting process.

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Now in fact, this is the principle used by the ancient man. What the ancient man has done to produce the what say spear heads. Initially made the wax model of the spear heads, then he compacted moulding sand around this wax model and he heated that. Then it got drained, then he poured the molten metal into that mould.

So, solid mould what are block mould investment casting is same as the method used by the ancient man to produce the spear heads. Now here we can see, so these are all the jewellery components; several jewerelly components we can see rings. So, several such rings are wax patterns are assembled together here you can see. So, these this is the assembly of the wax pattern for several rings, jewellery rings.

So, several such patterns are assembled here you can see here. So, this is the central tree now around which say they used to make a ceramic slurry. So, the ceramic slurry this is kept inside a flask now, the ceramic slurry they used to pour inside. So that the ceramic slurry would fill the entire flask and the ceramic slurry would go around each and every pattern and it used to take the shape of the extreme fine details then, in such a state the ceramic slurry would be dried out of this ceramic slurry is dried out then they used to heat this system then what will happen? The wax would melt and it used to drain out then they will pour the molten metal into the mould.

Then after solidification they would break that mould then finally, they get a casting like this. So, this is the solid mould or block mould investment casting process.

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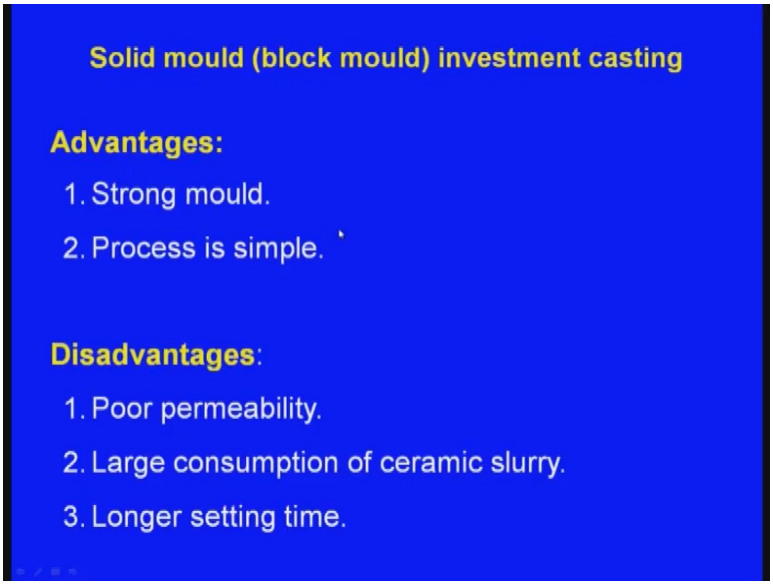

Now, what are the advantages of solid mould or block mould investment casting process? One is mould is very strong why because around the patterns we are what say completely filling the ceramic slurry inside the flask. So, the mould is very strong; next one the process simple, next one what are the disadvantages of this process. Poor permeability every where there is what say ceramic slurry is filled. So, during pouring of the molten metal if some aid or heart vase are trapped it is very difficult for the heart vases to escape from the mould because every where the ceramic slurry is filled.

Next one large conception consumption of ceramic slurry everywhere we are filling right. So, that a way we have to consume lot of ceramic slurry. So, that increases the cast of production. Next one, longer setting time. So, once we pour this ceramic slurry around the assembly of patterns inside the flask. So, that would take several hours for setting after that we have to dry it, again after that we have to drain the fax wax. So, that way the elite time they will be increasing abnormally. So, that increases the cost of production as well. So, these are the advantages and disadvantages of block mould or the solid mould investment casting process. Next one, so we have completed this one solid mould investment casting process.

Now, let us see the plaster mould investment casting process.

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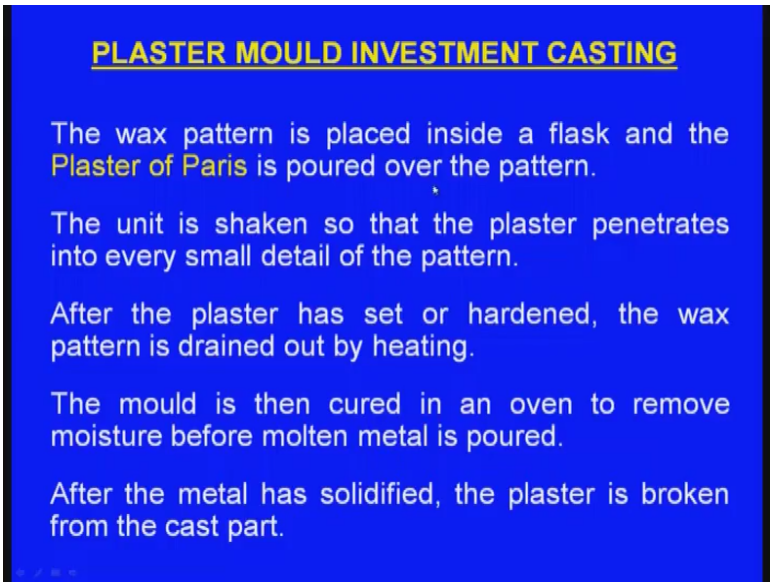

The wax pattern is placed in a flask and the plaster of paris is poured over the pattern. So, the process is similar to the first one, the solid blowk block right investment casting process. It is similar and plaster moulding investment casting process is similar to the solid mould investment casting process. The only difference is instead of the ceramic slurry, plaster of paris is poured over the pattern. So, that is the difference.

The unit is shaken so that the plaster penetrates into every small detail of the pattern. The system will be shaken so that, plaster of paris will be going all around the extreme details fine details of the pattern. Now, after some time it will be set and it will be hardened the wax pattern is drained out by heating. Again same thing then the mould is then cured in an oven to remove moisture before molten metal is poured. Sometimes some moisture will be present. So, this moisture is to be removed. So, before pouring we need to heat the what say this mould, plaster mould.

Now, then we pour the molten metal after the metal has solidified, the plaster is broken from the cast part and the casting is taken out. So, these are the advantages.

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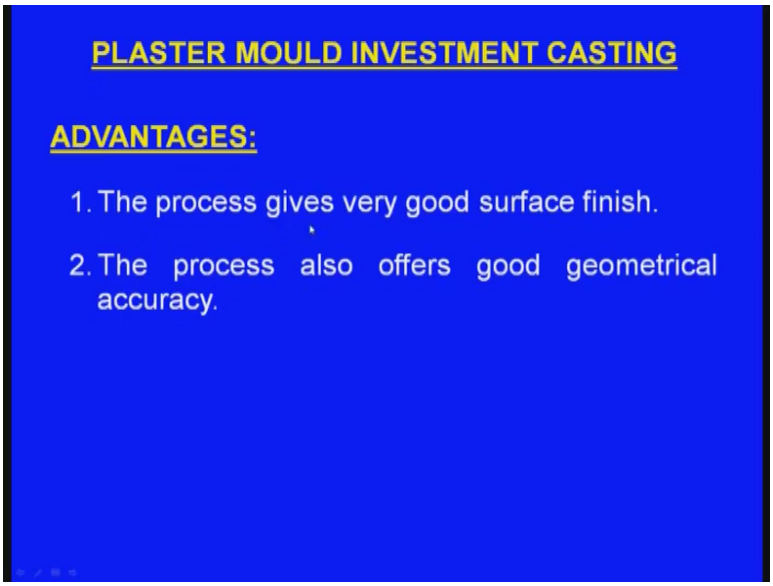

The process gives very good surface finish because plaster of paris is a very what say fine slurry. So, because of that even the casting will have a very fine surface finish. The process also offers good geometrical accuracy. So, these are the advantages of plaster mould investment casting process.

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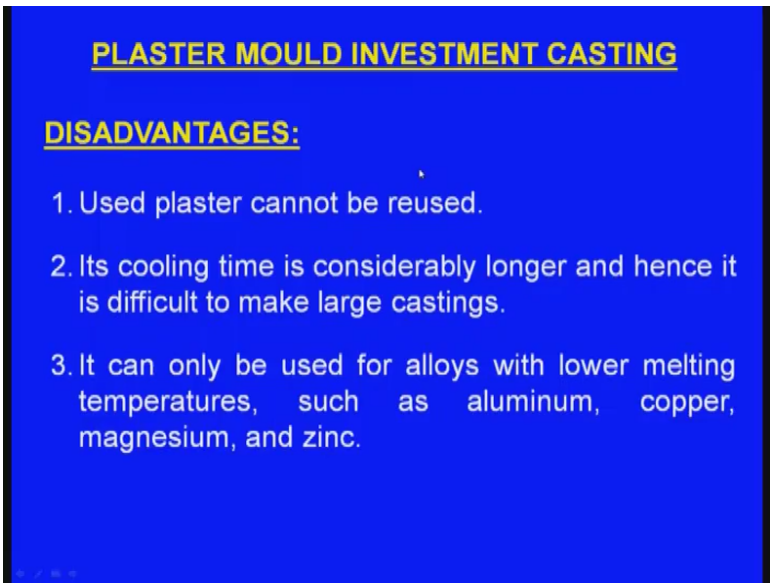

Now, these are the disadvantages; used plaster cannot be reused. So, this plaster itself is not cheap this is expensive. Now, when you have used this costly plaster the drawback is it can be used only once. Once it is used once we break that what say plaster of

solidification it cannot be reused. Its cooling time is considerably longer and hence it takes longer time for setting. So, that is how large castings cannot be made using this process, it can be used only for small castings and medium size castings.

Next it can only be used for alloys with lower melting temperatures such as aluminum, copper, magnesium and zinc. #We cannot produce castings of higher melting temperatures. So, that is another limitation.

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So, this is the typical plaster investment mould. We can see here this is a cylindrical flask and here inside we can see plaster, plaster of paris we can see and after sometime it would be hardening then they used to what say melt the wax and they used to drain out the wax.

Next one, mercast process that is the third process, which was used in the investment casting process what is this mercast process?

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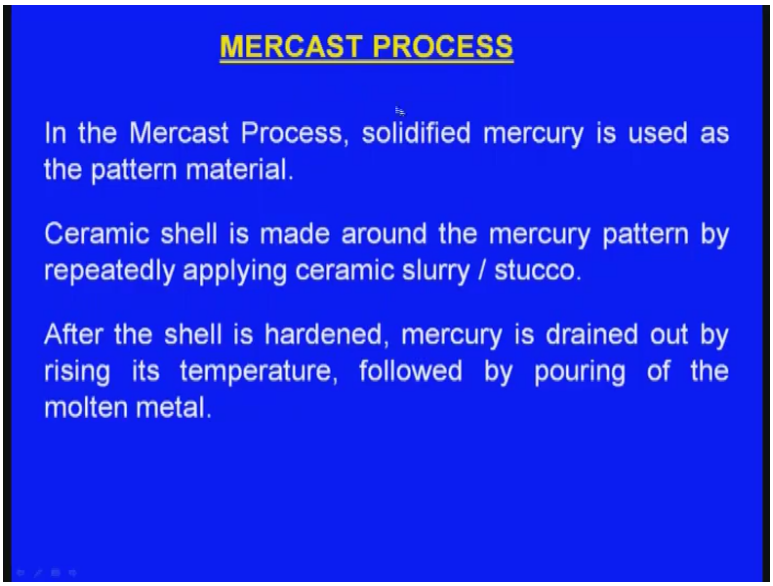

In the mercast process solid mercury is used as the pattern material, generally wax is used as the pattern material in investment casting process. In fact, in the first to two processes we have discussed wax was used as the pattern material, but here this solidified mercury is used as the pattern material. So, that is the unique feature of mercast process even the name implies the same mercast means mercury is used in this casting process.

Now, then after that initially we have to make the mercury pattern solid mercury pattern then what is the next step? Ceramic shell is made around the mercury pattern by repeatedly applying ceramic slurry and stucco. There will be a fine ceramic slurry will be there. So, this will be. In fact, the solid what say mercury pattern will be dipped inside the ceramic slurry and it will be taken out, then stucco will be sprinkled over the pattern then it will be dried again. The pattern will be dipped inside the ceramic slurry. It will be taken out then fine stucco will be sprinkled around the pattern likewise dipping inside the ceramic slurry applying this stucco and drain. So, this cycle goes on far at least 5 times. 5, to 6 times then a ceramic shell is created around the what say mercury pattern.

Now, after this shell is hardened, mercury is drained out by rising its temperature. At room temperature one must remember that mercury will be in liquid state. Now, this making the ceramic shell around the mercury pattern is done below the room temperature. Now once the shell is created now the temperature will be raised. Now

mercury is drained out by raising its temperature followed by pouring of the molten metal. Once we raise the temperature or at least when we bring it to the room temperature, the mercury will be melting and it will be drained out from the shell. Then we can pour the molten metal into the shell.

So, this is how the mercast process is carried out.

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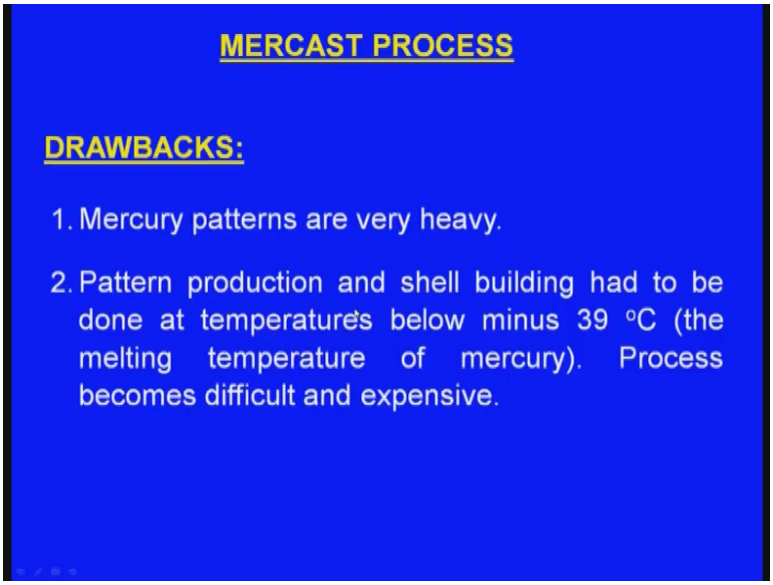

What are the drawbacks of this process mercury patterns are very heavy, next one pattern production and shell building had to be done at temperatures below minus 39 degree centigrade. So, at this temperature the mercury would be in solid state. The melting what say temperature of the mercury process becomes difficult and expensive means, we have to create that what say environment we have to control the temperature of the working area, we have to create such a temperature where the temperature will be maintained below minus 39 degree centigrade, at such temperature only mercury will be in solid state. So, the entire process right dipping the mercury pattern into the ceramic slurry taking out sprinkling the stucco, drying it again dipping into the ceramic slurry, the whole process has to be carried out below minus 39 degree centigrade.

So, that way the process becomes expensive. Not only that, the mercury pattern itself is costly mercury itself is costly, that way the whole process becomes costly. So now a days, this process this mercast process is no more in use. Next one, ceramic shell investment casting process. So, this is the what say ceramic shell investment casting

process and this has been developed in the recent years and it has gained popularity and it is in use all over the world today.

Now, what is this ceramic shell investment casting process?

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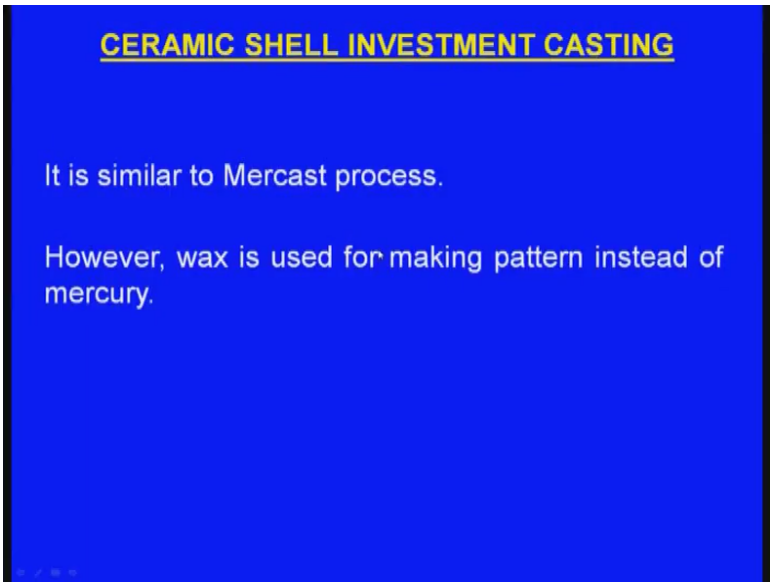

It is similar to mercast process in the mercast process what we are doing? We are making a mercury pattern and we are what say making a solid mercury pattern, that pattern we are dipping inside a ceramic slurry, taking out and sprinkling stucco, drying it again dipping inside the what say ceramic slurry take out, sprinkle, stucco, dry it like that we used to do 5-6 times. The same way we used to do in the ceramics shell investment casting also, but where is the difference? Here there in the case of the mercast process mercury is the pattern material, but here in the ceramic shell investment casting process, wax is the pattern material. However, wax is used for making the pattern instead of mercury.

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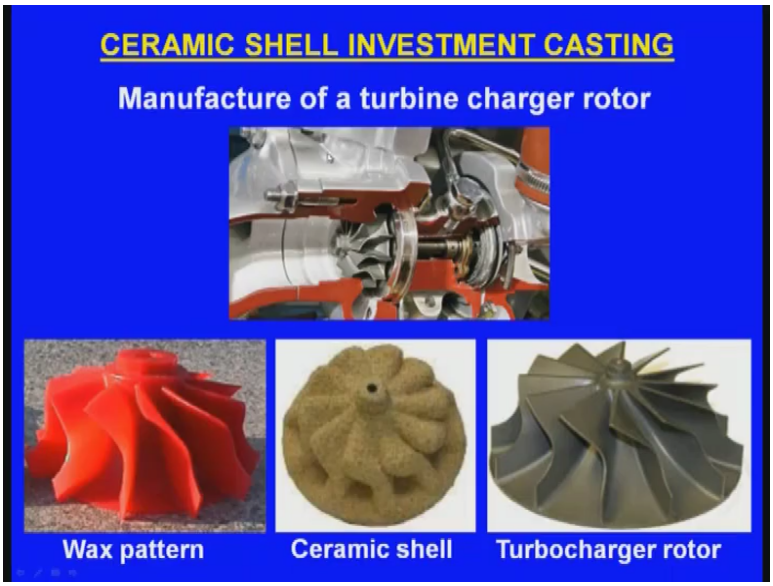

Now, here we can see a case study manufacture of a turbine charger rotor. So, here we can see this is a turbine charger rotor and here we can see this is the what say blades of that rotor this one. So, this what say rotor it is manufactured by ceramic shell investment casting process. How? Initially a wax pattern of the rotor is made, you see this is the wax pattern. Now after making this wax pattern, it will be dipped inside a ceramic slurry, fine ceramic slurry then it will be taken out, stucco will be sprinkled around that it will be dried again it will be dipped inside ceramic slurry stucco will be sprinkled over that and it will be dried, again it will be dipped in the ceramic slurry likewise, 5-6 times it will be dipped in the ceramic slurry and stucco will be applied and it will be dried, but one must remember that in the beginning the generally there will they used to take two types of ceramic slurries.

In the beginning, there will be a fine slurry will be there as the may be after 3 or fourth coating there will be coarse slurry will be there. So, first three coats it will be dipped inside the fine ceramic slurry, after third coating there will be a coarse slurry will be there. So, and even they stucco will be coarse are one. So, that as we going what say to the outwards the permeability of the shell will be increasing. So, here we make the ceramic shell in this way by dipping into the what say ceramic slurry and applying this stucco finally, you see a shell is created, then we heat it the wax pattern inside this shell will be melting and it will be drained out then molten metal will be poured into this shell after solidification we can break that shell finally, we are getting the turbocharger rotor

you see. So, this is the shape of the pattern gaps pattern and this is the final metallic what say part we are getting.

So, this is the simple principle of the ceramic shell investment casting process.

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Now, let us see the advantages applications and limitations of investment casting process.

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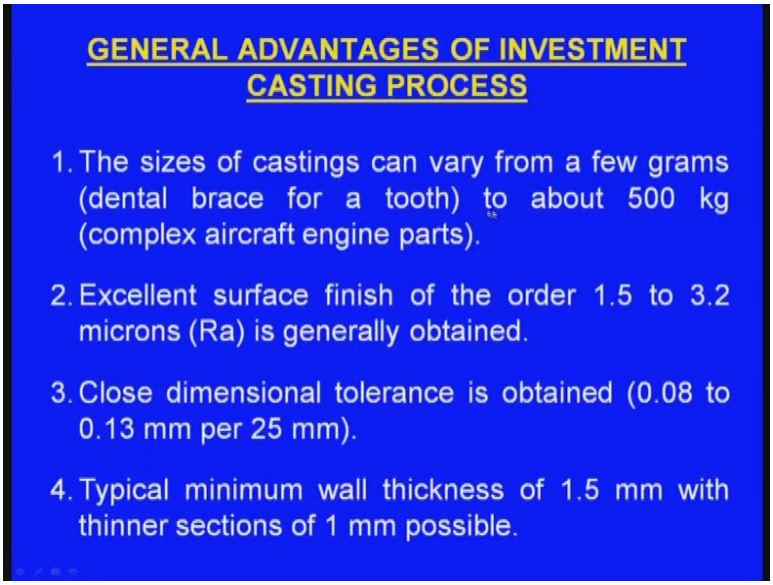

The size of castings can vary from few grams like dental brace for a tooth or to about 500 kgs complex aircraft engine parts we can make very small castings like jewellery components or a dental brace and their weight will be few grams we can make by investment casting process whereas, the complex what say aircraft engine it weighs about 500 kgs that also we can make using investment casting process.

Now, second benefit advantage is the excellent surface finish of the order 1.5 to 3.2 microns r a is generally obtained very good surface finish, excellent surface finish can be obtained using the investment casting process. Next one, close dimensional tolerance is obtained, you see the order 0.08 to 0.13 mm per 25 mm size of the part such a close dimensional accuracy can be obtained using investment casting process. Next one typical minimum wall thickness of 1.5 mm with thinner sections of 1 mm is also possible. In the casting what is the difficulty? Say if we want to produce thin sections it would be very difficult especially in the case of the sand casting process, but in the investment casting process even if the thickness of the section is 1 mm we can successfully cast that component. So, that is another benefit of investment casting process.

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Next one very fine details can be produced in small castings like jewellery castings very very fine details which may not be possible with other casting process can be possible using the investment casting process. Next one complex shapes can be made sometimes we come across certain castings there will be. So, many complex features especially in

the case of the jewellery ornaments now, such complex shapes can be produced only by investment casting and not by any other casting process. No or negligible finishing operations are needed sometimes no finishing no machining is required after the part is produced sometimes minimum machining is required.

Next one any alloy can be cast that we have seen in the beginning itself any alloy can be cast which is not possible with other casting process including ones that are impossible to forge or too difficult to machine. Any hard alloy, any soft alloy can be produced using investment casting process. Next one, castings are free from usual defects that are encountered in sand casting process.

In the sand casting process we used to get several defects like what say blow holes cracks so, these kind of defects will not arise in the case of the investment casting process. So, these are the advantages of investment casting process.

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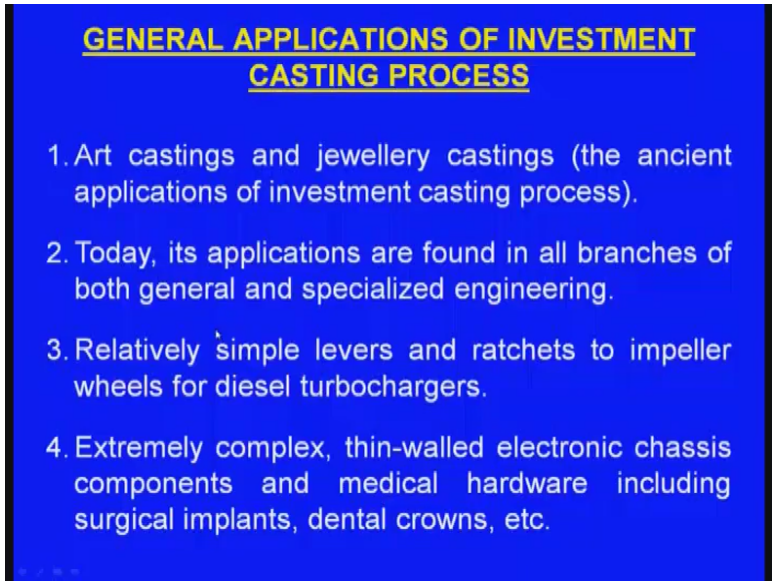

Now, these are the general applications of investment casting process art castings and jewellery castings the ancient applications of the investment casting process is it is still going on art castings and jewellery castings are still produced using the investment casting process. Today, its applications are found in all branches of both general and specialized engineering.

In general castings we can produce and in the specialized engineering like turbine blades rotors we can produce using investment casting process. Relatively simple levers and ratchets to impeller wheels for diesel turbochargers very simple levers can be produced and also very complex parts like diesel durbo turbochargers also can be produced using investment casting process. Next one, extremely complex thin walled electronic chassis components and medical hardware including surgical implants, dental crowns can be produced. So, this is another unique feature of investment casting process extremely complex details can be produced.

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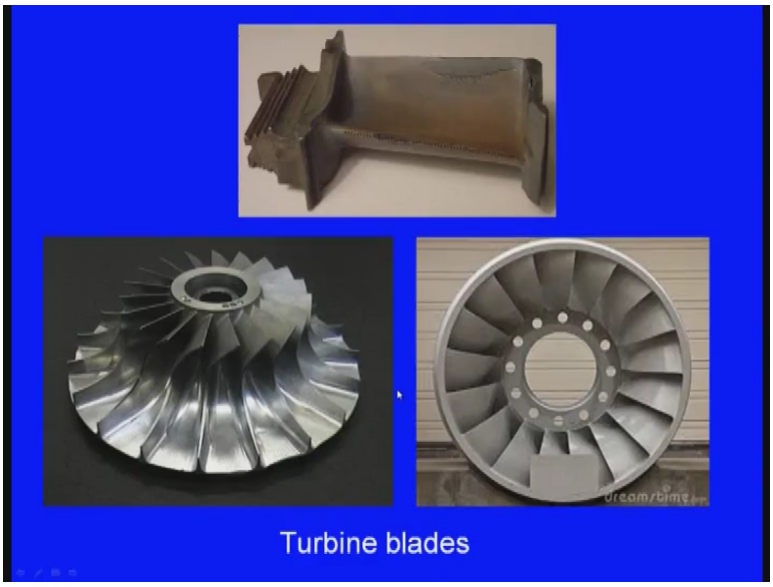

Now, here we can see a some applications of investment casting process. So, these are the turbine blades. This is the turbine blade and this is the rotor of turbocharger and these are produced by investment casting process and some more examples.

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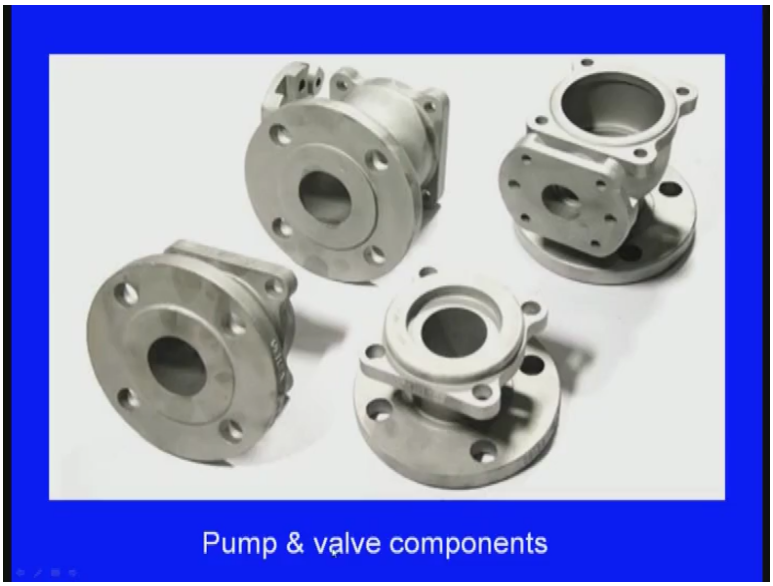

Pump and valve components.

We can see here, they have excellent surface finish and they have several complex features all these are produced using investment casting process.

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And here we can see these are the medical implants. So, these are the titanium cast parts now a days, these what say titanium cast parts are used in the surgery. So, these implants are made by investment casting process now these are the jewellery components.

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So, these jewellery cast components are produced by investment casting process

Now, here we can see.

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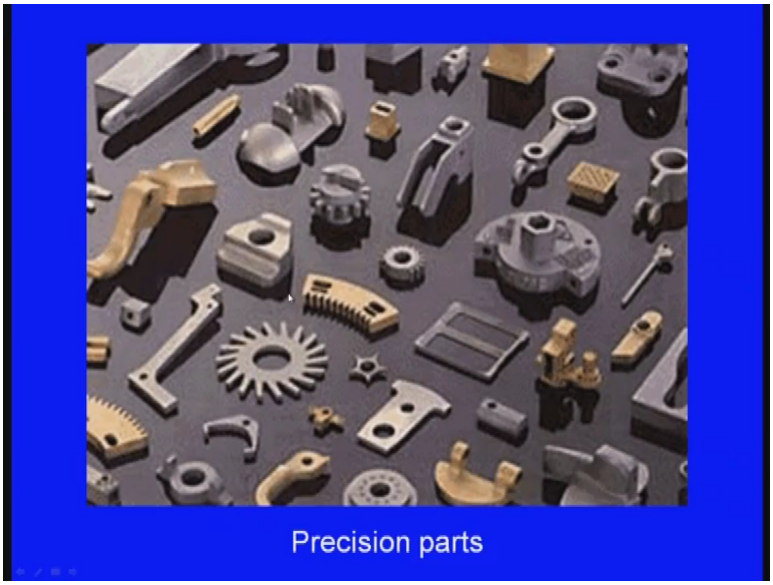

These are several tiny and precision components. So, these are also made by investment casting process.

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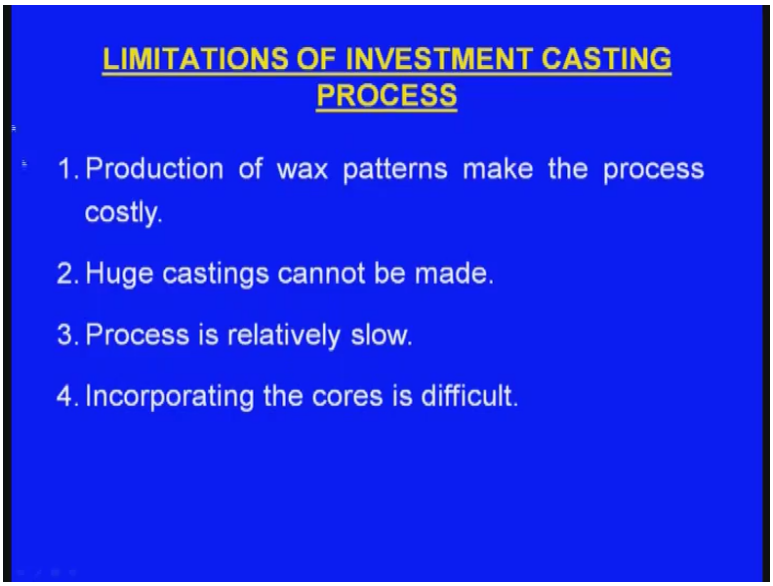

Now, let us see we have so far we have seen the advantages and limitations of investment casting process. Now, let us see the lim advantages and applications we have seen now let us see the limitations of investment casting process.

Production of wax patterns make the process costly. Wax itself is costly, now that wax has to be blended with several waxes some fillers how have to be mixed then we have to melt them sometimes some shrinkage defect used to come in the wax pattern. So, we need to reject it which is lot of care one has to produce the wax pattern. So, production of wax patterns make the process costly.

Next one huge castings cannot be made. See in the case of the sand casting process even 5 times casting can be made, but here today the limit is 500 kgs beyond 500 kgs it may not be possible using investment casting process. Now the process is relatively slow. Why it is slow? In the case of the sand casting process what will happen, we initially we make a metallic pattern are wooden pattern. So, the same pattern we can use for several castings and yes bring the pattern you put it inside the moulding box and dup the moulding sand and there will be moulding machines will be there and those moulding machines will make the mould within few minutes and if the molten metal is ready and we can pour the molten metal.

So, making a casting using green sand casting process is not so much time consuming whereas, in this process lot of time is consumed the process is relatively slow. Initially

we have to make the wax patterns; we have to makes the wax blends. 2 or 3 waxes along with the fillers we have to make that is the blend that we have to melt under careful environment then we have to make the pattern wax pattern remember 1 wax pattern can produce only 1 part for each pattern we have to produce 1 wax pattern.

Now, what is the next step? Then we have to make the ceramic slurry this wax pattern has to be dipped inside the ceramic slurry then take out and apply the stucco and let it right again dip it inside the ceramic slurry take out apply the stucco again dip then we will go to the next towards a chamber where coarser slurry is present dip inside the coarser slurry take out apply coarser stucco likewise 5-6 times we have to dip and apply the stucco and dry that way the process takes lot of time.

Ceramic slurry has to be prepared 2 to 3 days it has to be what say mixed inside a investment mixture then say 5-6 times we have to dip. How much time it takes each time it has to dry per head about how 1 hour means making the ceramic slurry itself takes a 7 to 8 hours. Then we have to melt it and we have to drain the wax then we have to fire the shell finally, we can pour the molten metal. That way the process is relatively slow compared to other casting process. On the other hand, die casting process means within no time we get the casting within few seconds also we get the casting, but investment casting takes several hours to produce one part. Next one, incorporating the cores is difficult in this process.

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Now, we will go for the. So far we have seen that the investment casting has been developed in four stages. One is the solid block investment casting process, second one is the what say plaster mould investment casting process, third one is the mercast process and fourth one is the ceramic shell investment casting process. Now let us study this fourth one in detail. Ceramic shell investment casting process.

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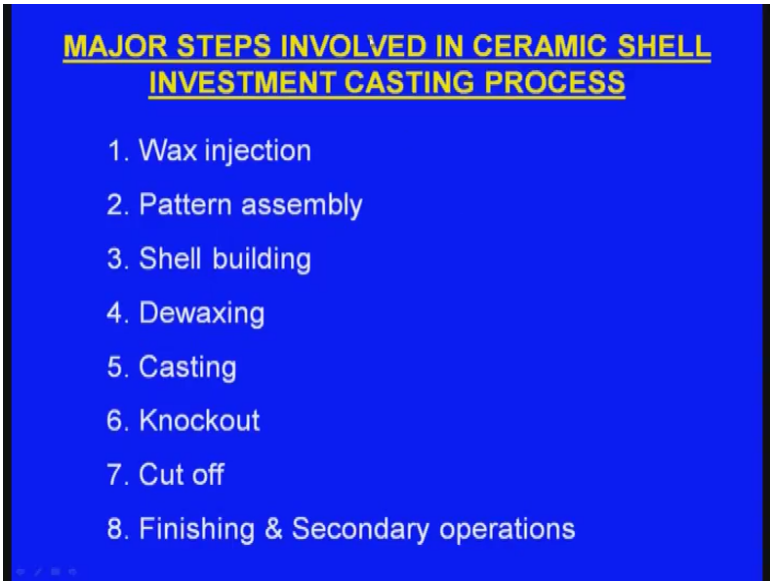

Now, major steps involved in ceramic shell investment casting process. So, these are the several steps involved in this ceramic shell process that is how the process becomes longer it takes lot of time.

What is the first step wax injection, second one pattern assembly, third step shell building, next one dewaxing, next one casting, next one knockout, next one cut off, next one finishing and secondary operations. So, these are the several steps involved in the investment casting process. Now we will see all these steps one by one. First one let us see the wax injection now you can see here,

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This is the wax injector pattern is prepared by injecting molten wax along with resins, fillers and right resins into a metallic die. So, this is the what say wax injector and here there will be two metallic dies will be there. So, these are the detachable dies as per our requirement we can change these dies. So, when we close this two dies inside there will be a cavity. Means, this dies similar to the die casting process right. So, in the case of the die casting process we get a what say metallic component, but here a, we get a wax pattern. So, when we close this two dies inside there will be a cavity and that cavity resembles the cast component which we are going to produce.

So, this two dies will be closed and wax will be injected into these dies and it will be taken out it will be cool down and it will be taken out. So, that is the first step first we produce the wax patterns.

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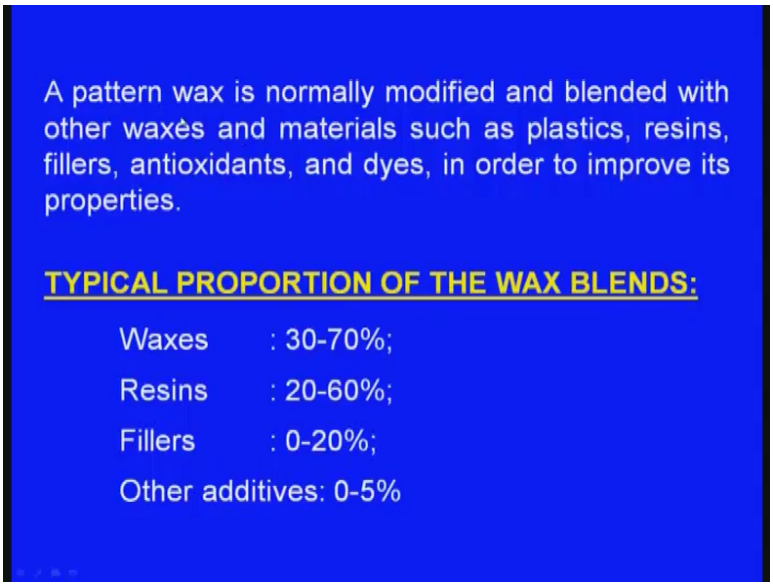

Now, a pattern wax is normally modified and blended with other waxes and materials such as plastics, resins, fillers, antioxidants and dies in order to improve its properties. So, normally a single wax is not used for making the pattern because no single wax posses the what say all the properties. For example, what say paraffin wax is there, it is soft, but its fluidity is very good so we take the advantage of the fluidity, but it is very soft we have to improve it is what say hardness. We mix some other wax so that it would become hard. So, we also mix the what say fillers and dies to improve the properties of the wax pattern generally 2-3 waxes will be mixed it in certain proportions along with the certain fillers.

So, that it will develop required fluidity required hardness and minimum what say shrinkage. Typical proportion of the wax blends you can see here waxes will be 30 to 70 percent. Resins will be 2 to 60 percent, fillers up to 20 percent and other additives up to 5 percent. So, this is the typical proportion of the wax blends. So, one must remember that a single wax is never used to produce the wax pattern always a blend made up of several components like waxes, resins fillers and additives is used to make the pattern.

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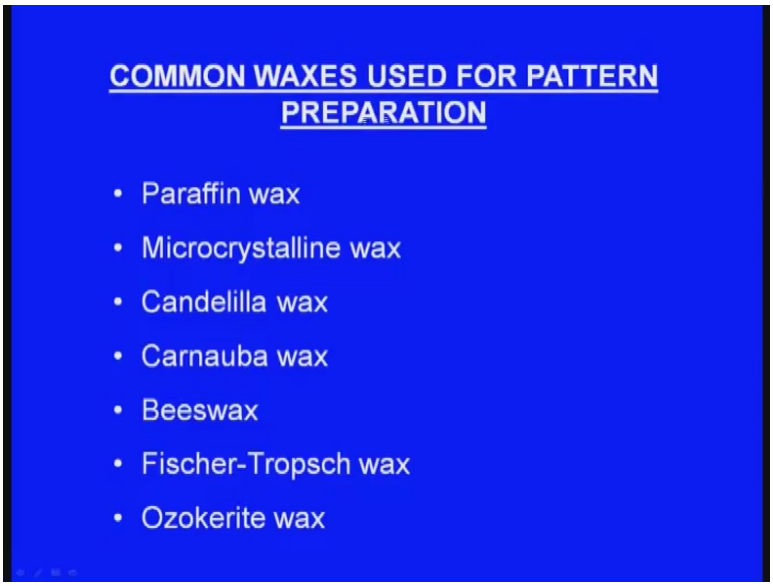

So, these are the common waxes used for pattern preparation. One is the paraffin wax, the most widely used wax. Next one, the microcrystalline wax, next candelilla wax, next one carnauba wax, next one beeswax, next one fischer tropsch wax, next one finally, ozokerite wax. So, these are the waxes which are commonly used and we make a blend out of these waxes.

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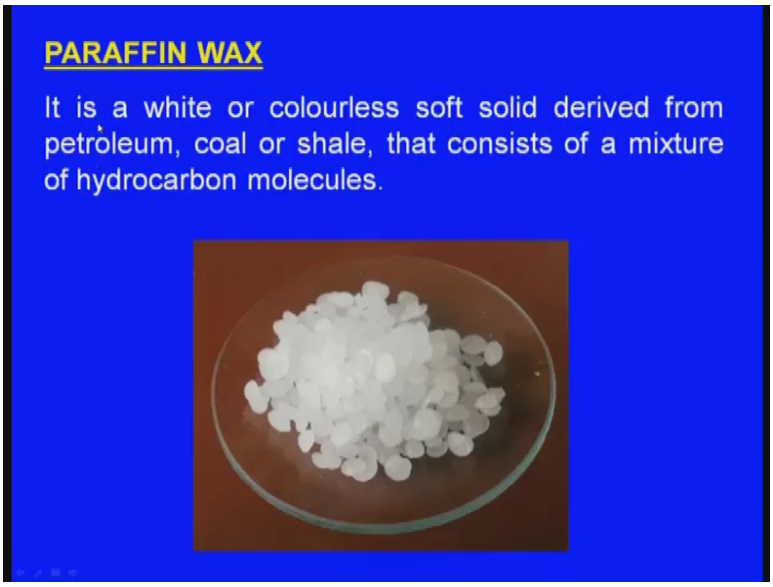

So, let us little about this waxes. First one is the paraffin wax. It is a white or colourless soft solid derived from petroleum, coal or shale that consists of a mixture of hydrocarbon molecules.

So, paraffin wax is white in colour and it looks like this. So, it is a what say petroleum product second one is the.

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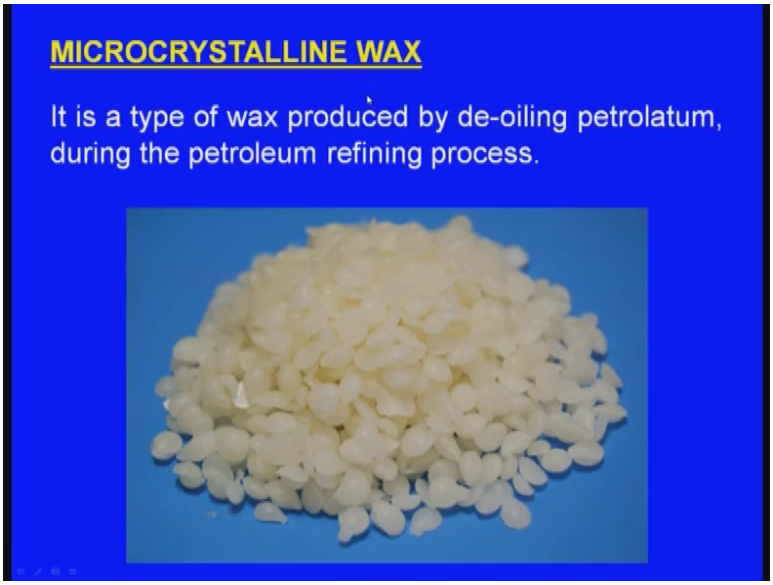

Microcrystalline wax, it is a type of wax produced by de oiling petrolatum during the petroleum refining process. So, this is a byproduct of petroleum. So, this is the microcrystalline wax.

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Next one, candelilla wax. Candelilla wax is a wax derived from the leaves of the small candelilla shrub native to northern Mexico and the southwestern United States. So, this is obtained from the candelilla shrub leaves.

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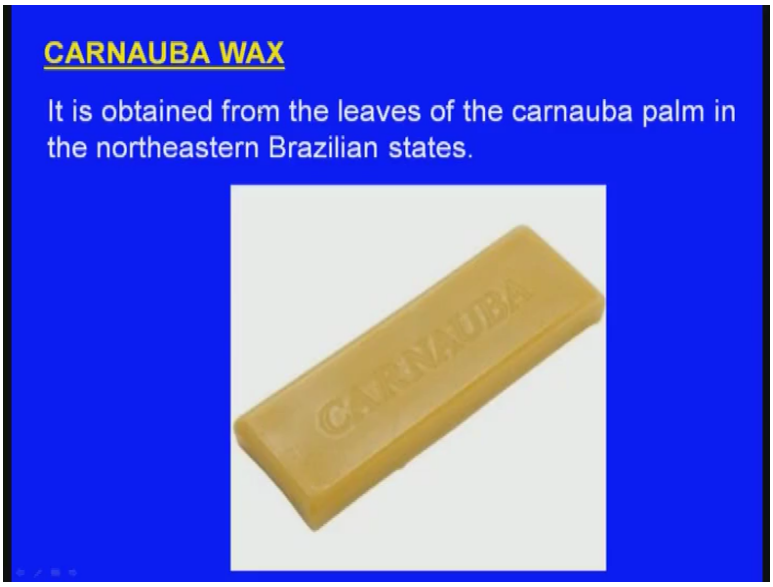

Next one carnauba wax, it is obtained from the leaves of the carnauba palm in the northeastern Brazilian states. Carnauba wax colour is different you can see here, so somewhat brown colour and it is somewhat hard compared to the paraffin wax next one beeswax.

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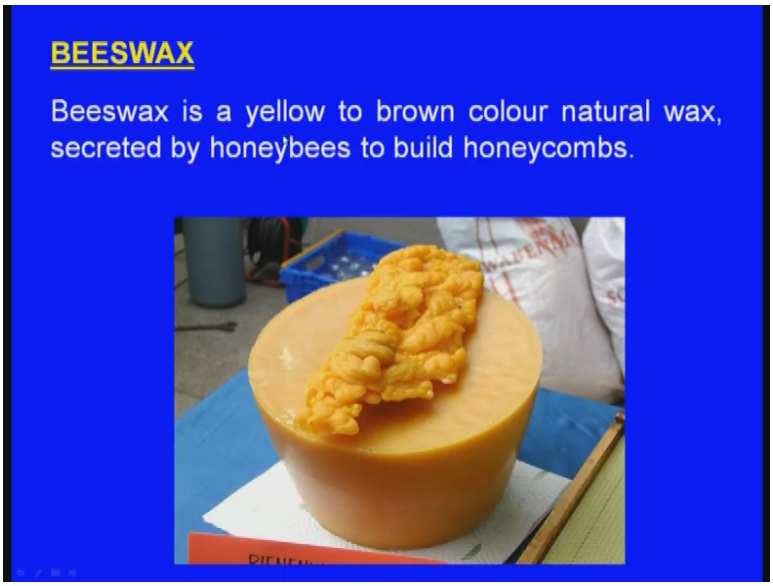

Beeswax is a yellow to brown colour natural wax secreted by honeybees to build honeycombs. So, to me we all know the honeycombs. So, to make the honeycombs. So, these bees beeswax there will go and make the honeycombs. So, these honeycombs is made by the beeswax. So, this beeswax is what say a secretion coming out of the beeswax. So, this secretion will be a wax it becomes a wax.

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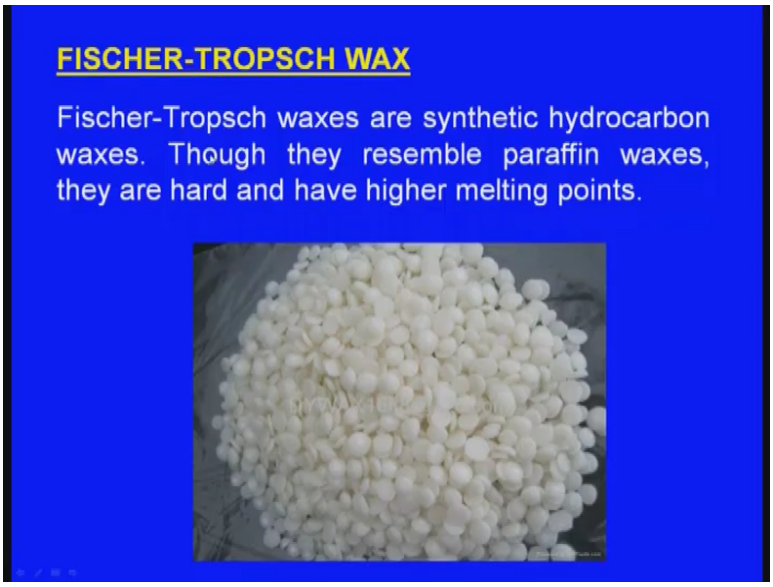

Next one Fischer-Tropsch wax. So, these waxes are synthetic hydrocarbon waxes. Though they are resemble paraffin waxes they are hard and have higher melting points.

So, colour wise it looks like paraffin wax, but paraffin wax is very soft, but whereas, this wax is hard.

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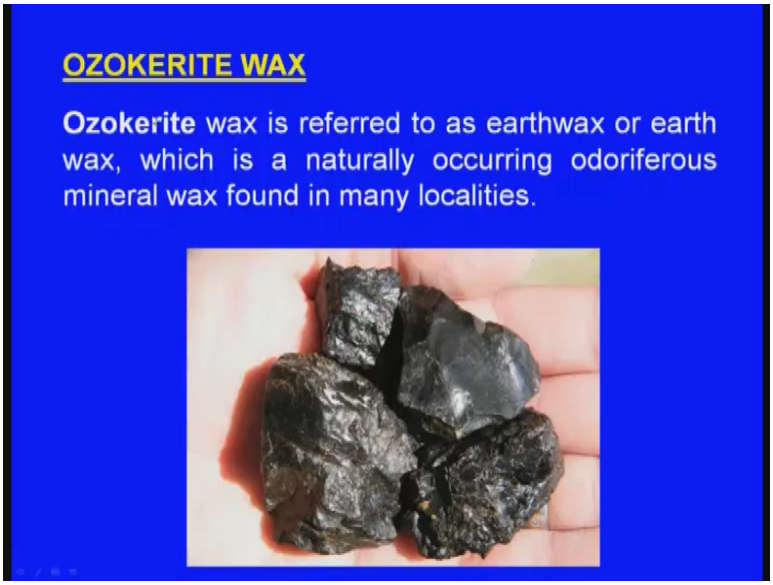

Next one Ozokerite wax, ozokerite wax is referred to as earthwax or earth wax which is a naturally occurring odoriferous right mineral wax found in many localities. So, it its appearance is somewhat different from the previous ones. So, its colour is black.

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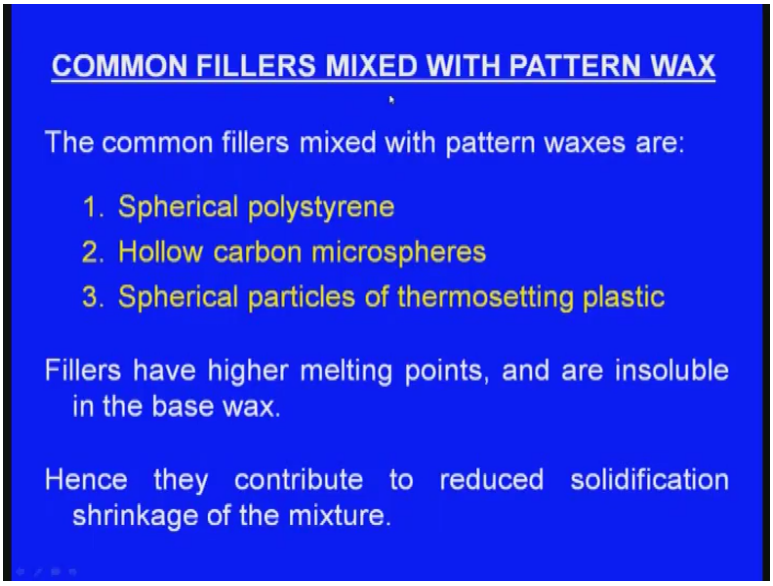

So, these are the common fillers mixed with the pattern wax. So, we will when we are making a wax pattern we take 2 or 3 waxes and we make a blend along with a 2-3 waxes we also mix certain fillers.

So, these are the common fillers mixed with the pattern waxes. One is the spherical polystyrene; second one is hollow carbon microspheres, next one spherical particles of the thermosetting plastic. Fillers have high melting points and are insoluble in the base wax hence; they contribute to reduced solidification shrinkage of the mixture. So, most of the times when we produce a pattern say we inject the liquid wax into the dies. So, there is a cavity between the two dies we inject the liquid wax.

So, liquid wax there is solidifies inside the metallic dies. Now during this solidification generally, sometimes a shrinkage cavity will arise in which case that pattern wax pattern is of no use again we have to melt it. So, because we are adding these fillers what will happen, when we add these fillers there will be lesser shrinkage. So, to reduce the shrinkage we will be mixing the fillers. Friends we will continue this in the next lecture.

Thank you.