Manufacturing Processes - Casting and Joining
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Lecture – 10
Expendable Mould Casting Processes

Hello and welcome back to the course on Manufacturing Processes - Casting and Joining. Let me remind you that in the casting section, we have discussed a lot of things. I have shown you some video clips of various kind of foundry practices, how the mould is made, how the molten metal is poured and so on.

Then, we discussed some design problems namely, how to properly design a riser, how to properly design a gating system and why it is important. Then, we discussed the theory behind the total solidification time, how to determine it as per the Chvorinov's rule.

We have seen that the total solidification time is directly proportional to the mould constant; some C_m we have taken if you remember. And, that multiplied by the ratio of the volume, V and the area, A square. Now, that means, that there are two factors which mostly decide the total solidification time.

Mould constant actually remains constant for a particular metal, and for a particular mould. There are three factors on which the mould constant will depend; then we have the $\left(\frac{V}{A}\right)$, volume to area ratio. So, this Chvorinov's rule gives you a very important message about how the riser should be solidified.

Now, how you can manipulate the riser design so that it could solidify later than the solidification taking place in the mould cavity. This is, once again, because we have to depend on the molten material remaining in the riser so to feed the shrinkage cavities in the casting.

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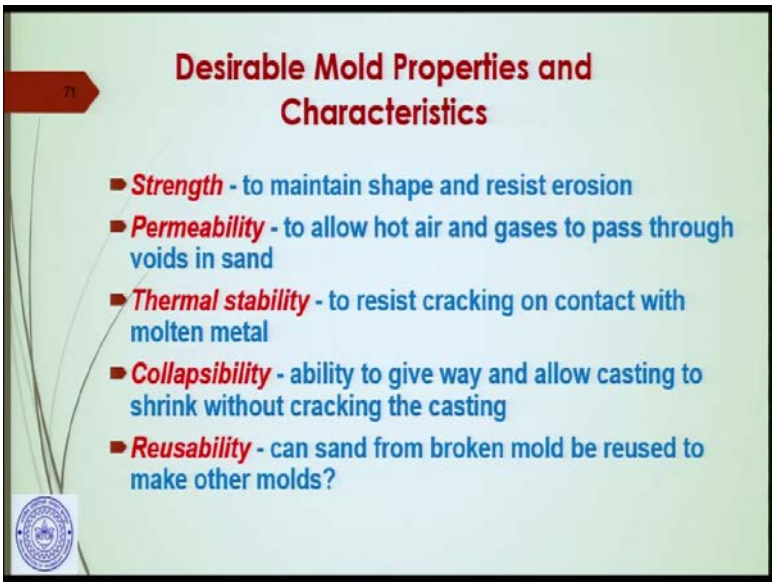

These are the important points that we have discussed; then, we said that there are desirable mould properties and characteristics, if we see the slide. We have said that there are five properties: strength permeability, thermal stability, collapsibility, and the reusability.

All these five properties and the characteristics should be adhered to so that a proper mould is made. Once the mould is proper, you understand that on this the quality of the casting will depend greatly.

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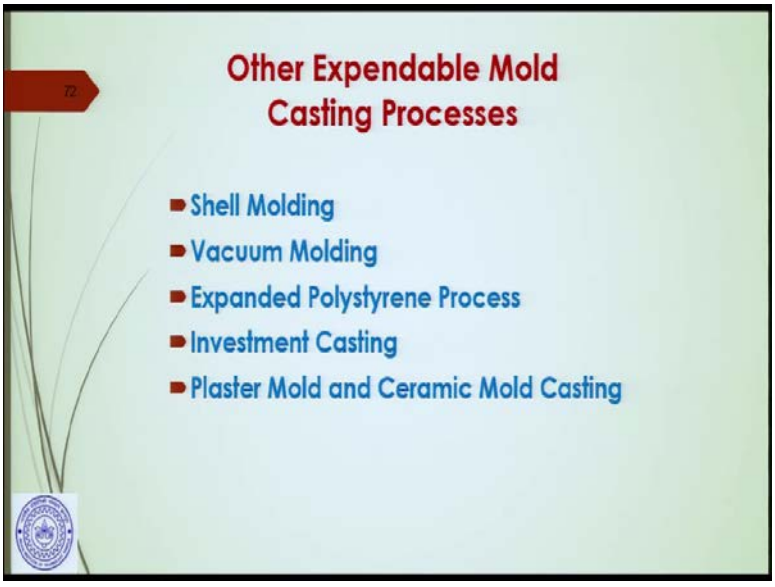

Now, there are other expendable mould casting processes; these are the other five different other expendable mould casting processes namely, shell moulding, vacuum moulding, expanded polystyrene process, investment casting, and the plaster mould and ceramic mould casting.

Shell moulding, I said something about the shell moulding in my earlier lectures, that here a shell is formed and I will show it to you right now, how the shell moulding process is performed; that means, the mould cavity is made inside a shell and the molten metal is poured inside the shell. That shell is broken after the molten metal has solidified inside it to obtain the final casting.

The shell is strong enough to resist the force that is exhorted by the molten metal. Also, it can resist the high temperature, of the molten metal and it is not destroyed. Hence, the shell material should be appropriately chosen.

Now, the vacuum moulding; inside the mould, there is a vacuum created so that the intricate shapes can be moulded properly, can be casted properly so that to all the intricate corners the molten metal can reach. That is the purpose of having the vacuum, so that it can suck the molten metal.

Next is the expanded polystyrene process. In Expanded polystyrene process, polyester is taken as the material of the mould. I will tell you in more details about the investment casting as we go along.

Next is the plaster mould and ceramic mould casting meaning that, when the mould material is made of plaster of Paris or ceramic material. It is like in case of the shell moulding, we have a special refractory material for the shell. Here also we have the material, which is the plaster of Paris or the ceramic material for making the mould and, inside that the molten metal can be poured.

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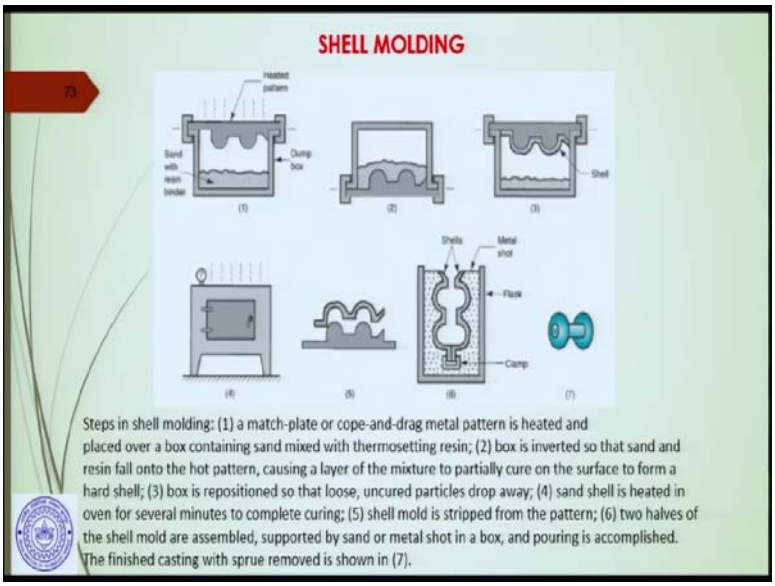

So, let us see what is the shell moulding and how the shell moulding process is performed. It is an interesting process, if you see there are six steps shown here. In the first step, there is a box; inside the box, the sand with the resin binder is kept dry.

As a cover of this box, on the top of the box there is a pattern which is the match plate or cope and drag metal pattern, this pattern is heated up and it is kept at the top; and, it is tightly fixed on the top of the box. Then, the entire box along with that match plate or the cope and drag metal pattern is inverted.

The box is inverted so that the sand can actually fall on this surface of the pattern and it can get melted and form a shell, form a layer because, this is the sand along with the resin, so, at that high temperature at which the pattern is heated up, it will melt the resin and it will bind the sand particles. Then it will form a kind of a shell on top of this.

Now, again the box is repositioned, it is again rotated and repositioned like this as it was earlier so that loose uncured particles drop away. So, only a certain layer of sand adjoining to this pattern, will create a layer on top of this match plate pattern.

The rest of it, which has not been participated, let us say to this layer, will actually drop off. So, what will be remaining on this match plate pattern is a shell. And, that shell consists of the sand and the resin which was kept inside the box. It is now kept inside an oven. Sand shell is heated in oven for several minutes to complete curing.

This match plate pattern along with the shell that is formed, is removed from the top of the box and the match plate pattern along with the shell is kept inside the oven for further curing. It is kept inside the oven for about 5 to 10 minutes normally.

That time depends of course, on the type of the shell that you are creating. Now, the shell mould is stripped from the pattern; this is the match plate pattern and here the shell has been formed and cured. When it is cooled off, then it can be separated out, it is stripped off, two halves are now connected together with the clamp. And, it actually forms a cavity, when they are joined together.

So, the two halves of the shell mould are assembled. And, the remaining portion is supported by the sand or metal shot; that means, small metal balls or the sand. This gap is filled up by sand or the metal shot, this will be the support to the shell and then this is the complete mould which has been made.

Then, the molten metal is poured inside this cavity, and it is kept for solidification for sometimes like in case of the sand mould. After pouring the molten metal, the metal has to be solidified. So, certain time elapses for the solidification of the molten metal and, then it is cooled off; it is kept for some time for cooling off. Then the mould is separated and the final casting is taken out.

The finished casting with sprue removed as it is shown in the step 7, meaning that this sprue which will remain attached to the final casting has to be sheared off to segregate from the final product. So, the final product will be like it is shown here.

Once again, this process is quite simple. Like, we have a match plate pattern; on the match plate pattern, we are making a shell. And, that shell is made by means of sprinkling the sand and the resin, which is kept initially at the bottom of a box. If the match plate pattern is heated up and when the box is turned around, inverted then this sand with the resin will cover the match plate pattern and the shell will be formed, because the pattern is heated up.

Then, it is again reversed in the initial position, shell is taken out after it is baked, cured. And, these two halves are joined together, supported by the sand or the metal balls, metal shots. Then the cavity is prepared. Into this cavity the molten metal is poured. Given

some time for solidification of the molten metal and the shell is broken or segregated and then the final product or the final casting is taken out.

This is the entire process which is simple and effective. Of course, here the production rate is not very high and that we already said that it is valid for almost all expendable moulds. When the casting is made using the expendable moulds, the production rate is not very high; this you have to keep in mind because of the preparation of the mould every time you make the casting.

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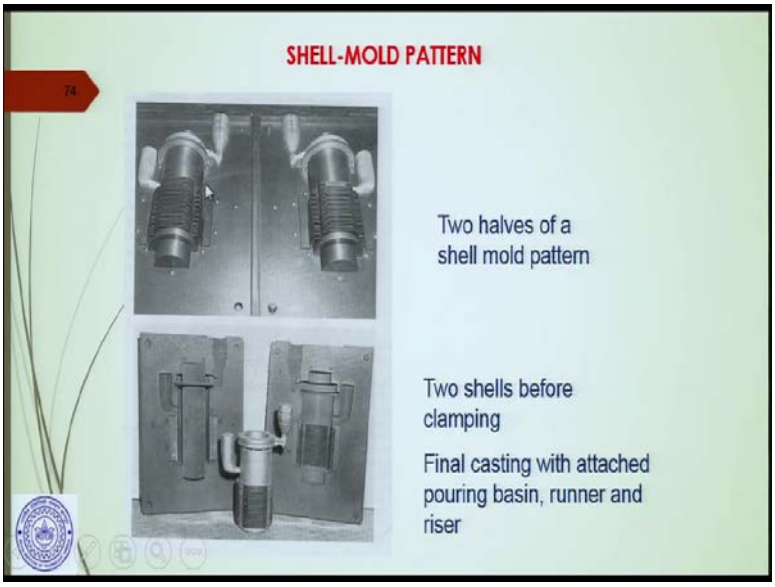

Now, these are the different kind of shell mould patterns. These are the two halves of a shell mould pattern. And, this is how the final casting is made. This is the mould cavity that you are making; two shells before clamping, final casting with attached pouring basin, this is the pouring basin which has to be segregated along with the runner and the riser.

This is the riser that has to be segregated; runner, pouring basin, riser have to be segregated from this casting and the final casting is made. So, when the final casting is taken out, further machining may be required, I mean after the casting. So, to get the final dimensions and the accuracy, the machining process has to be performed on the casting.

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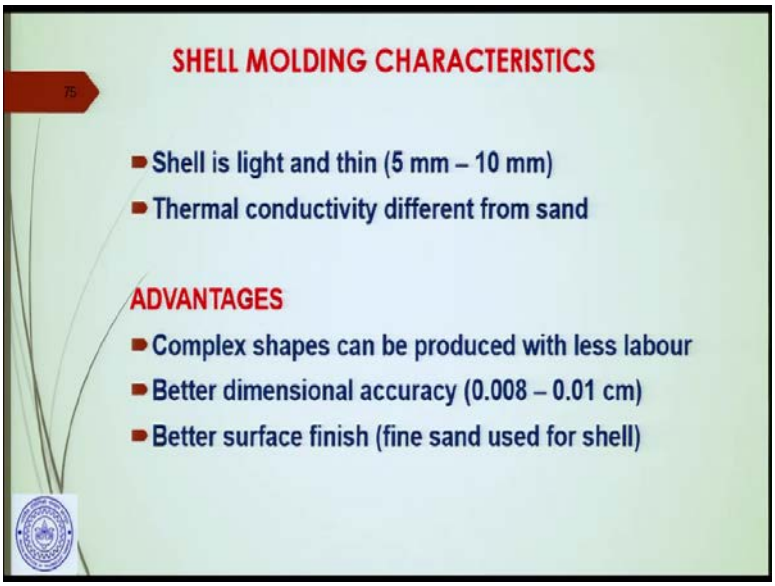

Now, the shell moulding characteristics are the following - that shell is light and thin. So, the shell thickness is about 5 to 10 millimetres. As you can see that with the material being sand and the clay and with 5 millimetres to 10 millimetres thickness, the shell itself will be very light.

Thermal conductivity is different from the sand, because it has been mixed up with the resin and it is baked further; so, the thermal conductivity will be different, thermal conductivity will be more than the sand itself. Advantages are - that the complex shapes can be produced with less labour, than in case of the sand mould. Better dimensional accuracy and the dimensional accuracy can go up to 0.01 centimetre, from 0.008 to 0.01 centimetre.

And, better surface finish than at least the sand moulding. In sand moulding, because the inside of the mould cavity will be rough since it is made of the sand. So, the small sand particle marks will be there. In case of shell moulding, inside walls of the shell mould can be smoother and therefore, the surface finish can be better. So, fine sand used for shell that is another reason. And, then the sand is mixed with the resin and it is baked. So, it is smoother because of the finer sand.

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Significant reduction in the cleaning, machining, and finishing; therefore, because the surfaces are smoother than in case of the sand moulding; so, the cleaning process, machining process, finishing process are reduced. Disadvantages are there. First of all, the lower permeability than the sand mould, because the sands are closely packed here in case of the shell moulding, than in case of the sand moulding.

Therefore, the permeability is less, meaning the voids between the sand particles will be less in size than in case of the sand moulding. And, therefore, the capability of permitting the evolving of the gas will be less. So, less gas will be evolved from the shell mould.

Decomposition of shell sand binder produces high volume of gas, requiring good venting system. So, anyway permeability is less, but on top of that there are shell sand binder, which gets decomposed, because of the very high heat of the molten metal. So, the gas will be evolved more and therefore, a good ventilation will be required. The ventilation holes are made specially for ventilating such gas.

Products can be gear housings, cylinder heads, connecting rods, where more accuracy is required. And as far as possible so that it could be used as a readymade product and without any further machining or finishing. So, these kinds of housings, gear housing, cylinder heads, connecting rods are made with the help of the shell moulding.

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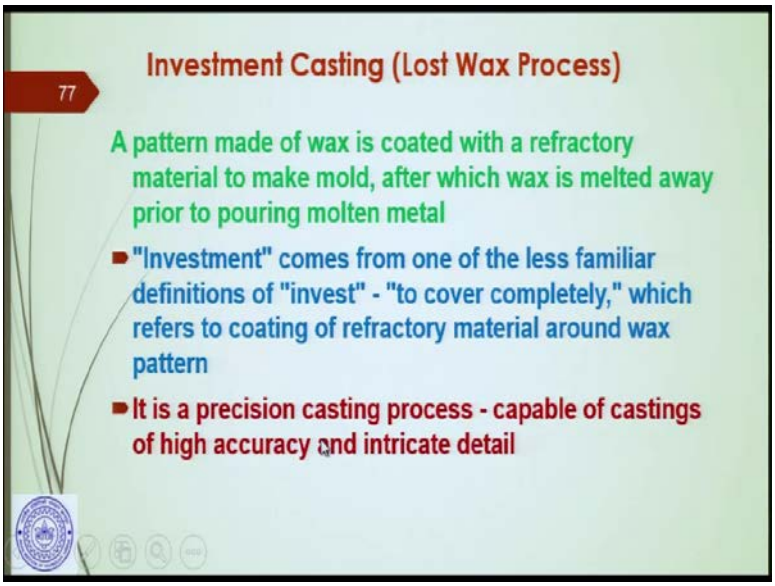

Let us now discuss the investment casting; as, I said that investment casting is called the Lost Wax Process. Now this is one of the oldest processes, a pattern made of wax is coated with a refractory material to make the mould, after which the wax is melted away prior to pouring molten metal.

So, pattern is made of wax. That pattern is coated with the refractory material. Therefore, there will be a kind of a shell around that wax pattern and then inside that shell, if we pour molten metal, then the wax will be melted, and it will be taken out.

“Investment” comes from one of the less familiar definitions of investment, “invest” normally we say invest in a business or something. So, here the investment means to cover completely. Therefore, the name came as the investment casting, which refers to coating of refractory material around the wax pattern.

So, it is covering the wax pattern completely. It is a precision casting process, capable of castings of high accuracy and intricate detail. Now, here since the wax pattern is made, so any intricacy is possible.

If, the casting has to be very complicated in shape and that is possible, because it is made of wax, pattern is made of wax. And, second point is that it is very precision because, shell is made accurately. So, that makes it more precise. By the way the investment

casting is one of the very few casting processes, where the net shape castings are produced.

Net shape castings mean that casting, which is taken out from the investment casting and it can directly go for the assembly, without any machining or finishing process. And, particularly this process was widely used for making ornaments. Ornaments can be very complicated and to make those complicated ornaments this kind of an investment casting can be very suitably used. I will show you how this process can be performed.

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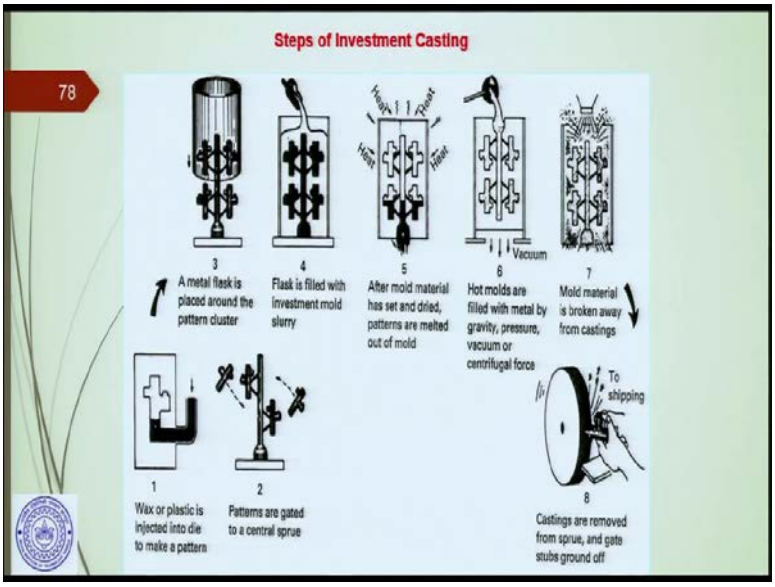

And, let us see this. First of all, the wax or plastic is injected into the die; this is the die as you can see. Wax is injected to this die, that pattern is kept in a particular container and the liquid wax is injected into the die. When it is solidified, this is taken out, and these patterns are gated to a central sprue meaning, that each of them will be mounted around that central sprue, and the molten metal is poured inside.

So, through this and the gating system, which will be connected to each of these patterns, molten metal will flow inside.

For example, this one is already fixed, this one is already fixed, to this central sprue. And, this is the gating system connected through the central sprue to the pattern and so on. So, there could be few of them at the same time. You can see that this pattern is ready. Now, this is the central sprue, this is the gating system.

And, around the central sprue there are few of those patterns mounted. Now a metal flask, this is the metal flask, this metal flask is placed around the pattern cluster. And, the flask is filled with the investment mould slurry. Once this flask covers the entire pattern cluster, then from top investment mould slurry will be poured.

By that we mean that there will be sand along with the resin and it will be mixed with the water to make a kind of a slurry, to make a kind of a paste, more like semi solid, semi liquid kind of paste. So, it will be poured inside the flask so that the entire cluster is covered by that slurry, but that is not yet hot.

Therefore, it will just make a layer on top of it; then after mould material has set and dried, patterns are melted out of the mould. Then it will be heated up, after this it is dried up, the investment mould slurry will cover all the patterns and it will be dried up after some time.

Then it is heated up so that from each of these moulds the wax can be melted away and it can be taken out from the central sprue through this, because as you understand that these are the gating systems. These are connected to the cavities of the moulds. So, the wax inside this shell will be coming out through this.

Next, hot moulds are filled with molten metal by gravity, pressure, vacuum or centrifugal force. So, there is a pouring cup made in the central sprue and this is pre-heated. So, to this central sprue the molten metal will be poured. The molten metal will flow to each of these shells through the gating system and the central sprue, it will fill up. So, the molten metal will fill up each of these cavities.

Now, the filling can be, of course, either through gravity or vacuum or centrifugal force by rotating at a higher speed and so on. Then mould material is broken away from casting and the castings are removed from the sprue and gate stubs are ground off.

Now, if it is broken then you will get the entire stuff that is all of these along with the central sprue because, the metal will be solidified along the central sprue as well and inside the gating system. So, the entire gating system along with the sprue which will be attached to each of these castings after the metal is solidified inside the cavities, inside the shells.

Then the gating system and the sprue will be segregated, it will be ground, and the parts are ready for the shipment. This is also a kind of a simple process as you can see, that it is the shell moulding kind of making the shell and it is very important and very widely used process.

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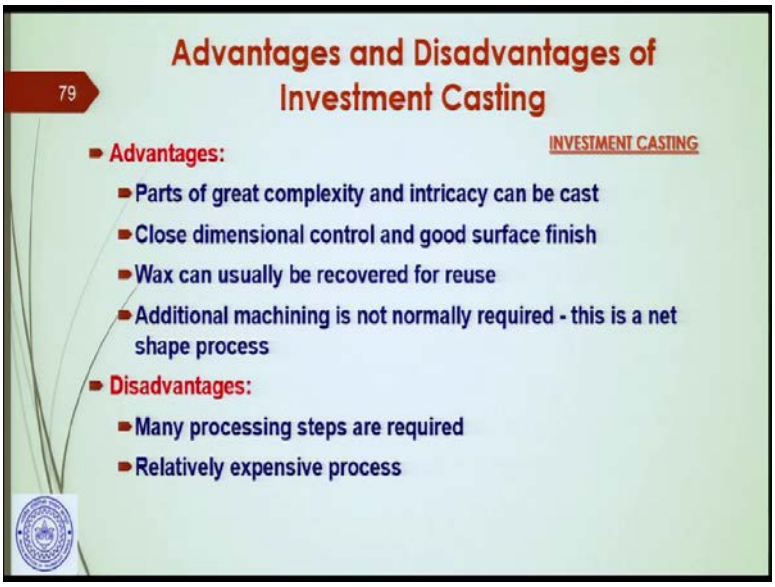

But this process has certain advantages and certain disadvantages. Advantages are that the parts of great complexity and intricacy can be cast. This I already told you, particularly I gave you the example of the ornaments, golden or you know the copper ornaments in Egypt that we have seen in the historical background, in Mesopotamia, which has been excavated. So, great complexity and the intricacy can be cast.

Second advantage is that close dimensional control and good surface finish can be obtained. After the investment casting, in most of the cases, it is the net shape casting that can be obtained. There is no further machining or any kind of machining or the cleaning will be required.

Wax can usually be recovered for reuse that is another advantage, that it can be reused. Because lot of wax will be required for each shell. So, when it is melted out, it will be taken out and it will be again used after melting. And, finally, the additional machining is not normally required, this is already said, this is a net shape process.

So, these are the four advantages, very important advantages that the investment casting will have. However, the investment casting also has certain disadvantages. If you see here many processing steps are required, the processing steps are here 1, 2, 3, 4, 5, 6, 7. So, first you are making the patterns, putting the wax, then making the shell, taking out the wax, then pouring the molten metal and so on.

So, there are a lot of steps involved. Therefore, the processing time is very high. And, the second disadvantage is that it is a relatively expensive process because the wax is required and then you have to form the tree; by “tree” I mean to say that this kind of a tree you have to make with the pattern cluster all around and so on. So, it becomes relatively expensive.

In my next session, I will show you a small video clip of the investment casting where the entire process will be shown to you.

Thank you very much for your attention.