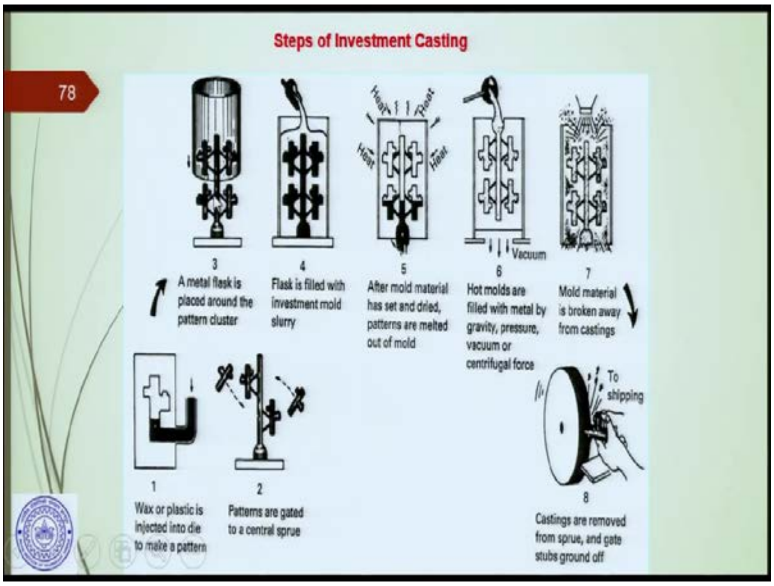
Manufacturing Processes – Casting and Joining
Prof. Sounak Kumar Choudhury
Department of Mechanical Engineering
Indian Institute of Technology Kanpur

Lecture – 11
Permanent Mould Casting

Hello and welcome back to the lecture series of Manufacturing Processes Casting and Joining. Let me remind you that in our last discussion session, we started discussing the investment casting process. We discussed the shell casting, shell molding and the investment casting.

In the investment casting, we said that it is quite a lengthy process; but the accuracy could be very high and almost the net shape products can be produced, and a lot of steps are involved there. It is also called the lost wax method because the patterns are made of wax;

(Refer Slide Time: 01:12)



Let me once again tell you that these are the steps. If you look at the slides, first of all the wax or plastic is injected into the die; by the way it can be also plastic, because it is easily melted. Patterns are gated to a central sprue, then the metal flask is placed around the pattern cluster.

Then the flask is filled with the investment mold slurry, it is heated up; then the wax is taken out and the the molten metal is poured. Afterwards it is broken, and the parts are taken out.

As you can see that the process is really lengthy, there are quite a few steps involved; but at the same time here the greatest advantage is that almost net shape products can be produced. Castings can be made with very high accuracy and very intricate shapes can be produced, like ornaments, for example.

(Refer Slide Time: 02:21)

Let me show you a small video clip, where it will be clear to you how this investment casting process is performed.

(Refer Slide Time: 02:34)

(Refer Slide Time: 02:37)

Thank you for your interest in Niagara investment castings and your interest in learning more about the investment casting process.

(Refer Slide Time: 02:41)

(Refer Slide Time: 02:44)

(Refer Slide Time: 02:47)

(Refer Slide Time: 02:49)

These precision castings are sometimes referred to as near net shape castings; since they can often be used with little or no subsequent finishing operations.

(Refer Slide Time: 02:52)

(Refer Slide Time: 02:56)

(Refer Slide Time: 03:03)

The entire manufacturing process starts with wax patterns produced from injection dies. The defining characteristics of an investment casting including its smooth surfaces, dimensional accuracy, and high degree of detail attainable can be attributed to these dies.

(Refer Slide Time: 03:11)

(Refer Slide Time: 03:22)

(Refer Slide Time: 03:35)

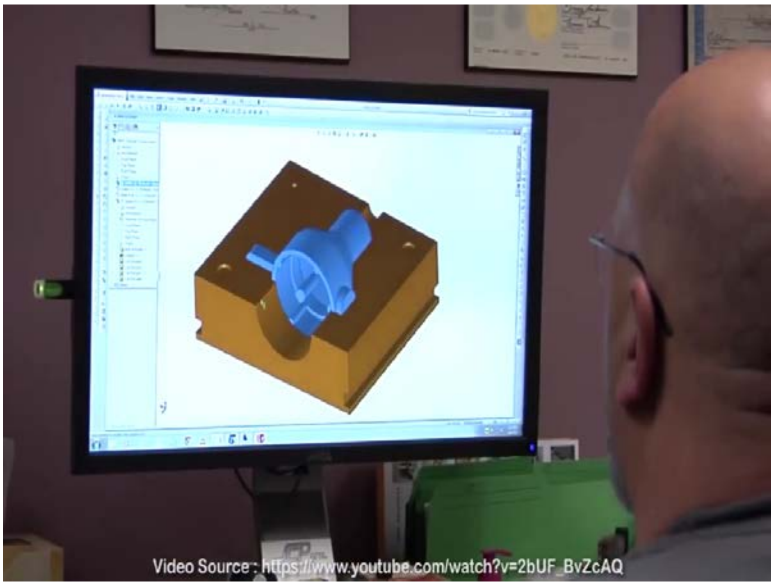
Each casting requires a wax pattern, which is a disposable replica of the casting to be produced. To produce the wax patterns, the dies are loaded into a wax press and filled via injection ports with a special pattern wax melted into a paste form. The wax quickly solidifies in the die; the die is opened, and the wax pattern removed, this process is repeated for every part that is required.

(Refer Slide Time: 03:37)

(Refer Slide Time: 03:40)

(Refer Slide Time: 03:43)

(Refer Slide Time: 03:46)



However, multiple cavity tools are used for high volume jobs to help with costs and increase productivity. The degree of internal detail possible with an investment casting is one of its most versatile characteristics.

(Refer Slide Time: 03:55)

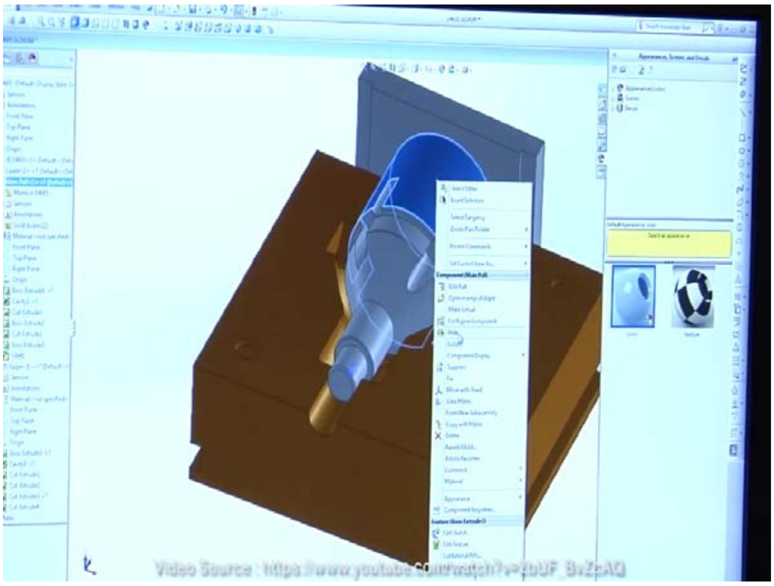
(Refer Slide Time: 04:04)

This detail is formed using either simple poles in the tooling or by using soluble wax or ceramic coring techniques for more complex internal detail. For prototyping or very short runs, purchasing of production oriented tooling is not always economical.

(Refer Slide Time: 04:10)

So, we offer the option of special printed patterns produced using stereo lithography from 3 D CAD data.

(Refer Slide Time: 04:15)



(Refer Slide Time: 04:18)

Once the wax patterns are produced, they must be assembled to a feed system called a sprue. The sprue is made from reclaimed wax and designed to not only hold the wax patterns; but also engineered to form a sufficient pathway.

(Refer Slide Time: 04:29)

(Refer Slide Time: 04:32)

(Refer Slide Time: 04:43)

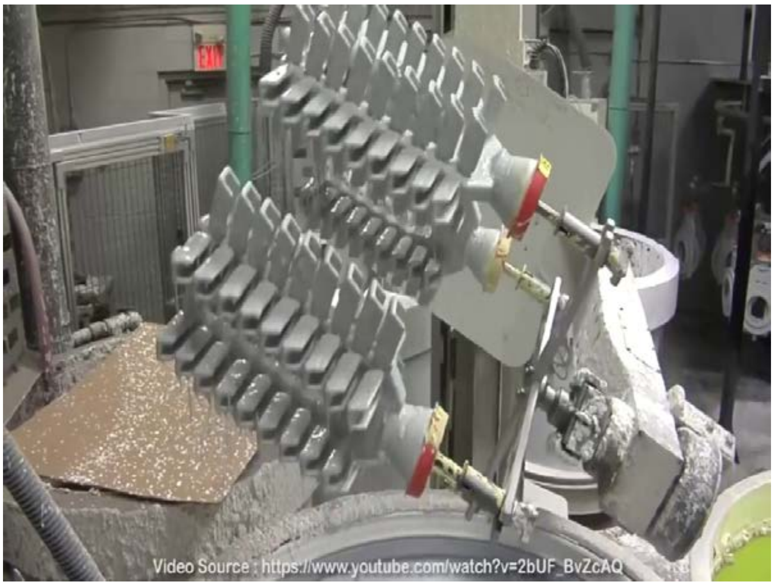
Metal flows through the mold during casting to produce a sound of defect free component during solidification. With the wax is now assembled to the sprue, we have completed what is called a tree.

(Refer Slide Time: 04:46)

(Refer Slide Time: 04:54)

To transfer the exact detail of the wax pattern to the casting, the trees are encased in a seamless ceramic shell mold. It is formed by robots dipping or investing the wax into a slurry, drying the tree and repeating.

(Refer Slide Time: 05:01)



(Refer Slide Time: 05:03)

This builds up three eighths to one half inch of ceramic around the tree. It is this ceramic shell or mold, which will receive the molten metal during casting.

(Refer Slide Time: 05:13)

(Refer Slide Time: 05:20)

The first coat is called the primary; it forms the internal surface of the mold. For that reason, it must be carefully applied in very controlled conditions to ensure the quality. Gradually additional layers of increasingly coarser secondary ceramic layers are added, and the completed shell takes form.

(Refer Slide Time: 05:34)

The next step is to remove the wax patterns and sprue. We do this by inverting the shell into either a steam autoclave or flash fire de waxing furnace. The wax melts and runs out and the shell is now complete and fully self supporting.

(Refer Slide Time: 05:50)

(Refer Slide Time: 05:57)

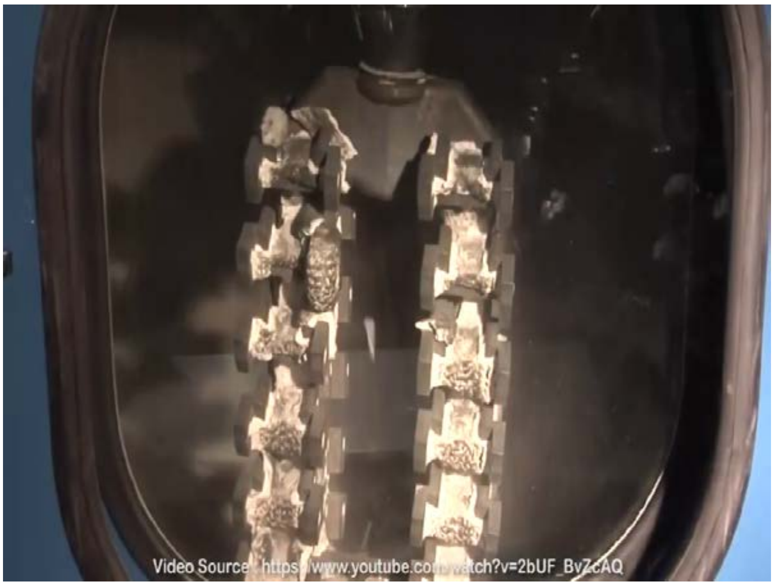
When the shells are scheduled to be poured, they are reheated to approximately 1700 degrees to further condition and strengthen the ceramic shell. They are now able to withstand the thermal stress they must endure during the next stage.

(Refer Slide Time: 06:12)

While the shells preheat, we prepare and melt the metal to be cast. When at the proper pouring temperature, the chemistry of the alloy is checked, and the molds are filled with the molten metal. The metal completely fills the cavities of the mold taking on the geometric shape, which will form the outer detail of the cast component. Inside the cavity, the molten metal also surrounds any cores, which will impart the same detail to the internal geometry of the casting.

(Refer Slide Time: 06:36)

(Refer Slide Time: 06:44)



(Refer Slide Time: 06:50)

The metal is allowed to cool into its solid form, and the ceramic shell is now ready to be removed from the castings using a variety of cleaning methods including blasting, vibration or chemical cleaning. The castings are cut from the sprue and the ingate is removed by grinding.

(Refer Slide Time: 06:55)

(Refer Slide Time: 07:03)

Finally, the individual castings are given a final cleaning to expose the smooth and detailed surface. If heat number traceability is requested, this identification is directly engraved onto each of the castings.

(Refer Slide Time: 07:12)

(Refer Slide Time: 07:20)

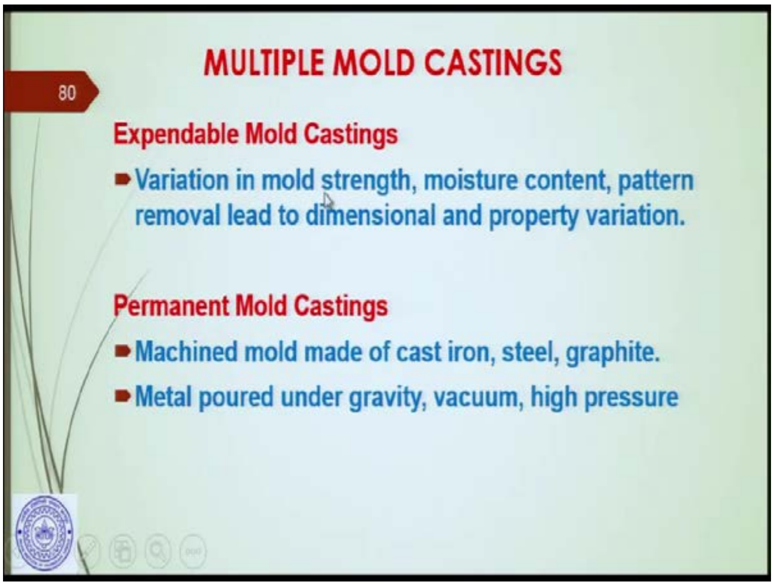
The castings are now ready for final processing to the customer’s requirements including heat treatment, NDT testing, machining, plating, or other value added processes.

(Refer Slide Time: 07:24)

The investment casting process is an economical manufacturing method that offers many benefits and advantages over competing processes. We hope this video has been informative and helpful, and thank you for your interest in Niagara investment castings .

So, I hope it is clear to you how the steps are performed in the investment casting. And as you have seen that the castings are of very high quality and they are used as a net shape castings or the net shape parts.

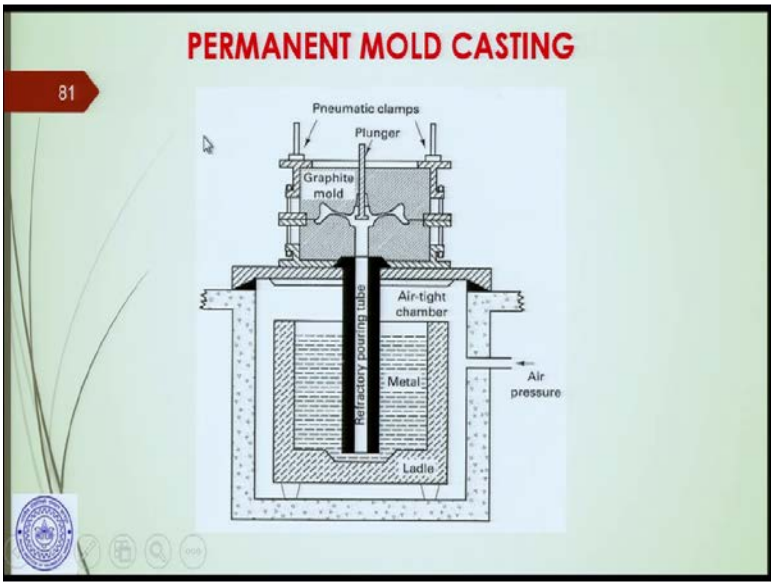
(Refer Slide Time: 07:59)



Now, the multiple mold castings , can be expendable mold castings like variation in mold strength, moisture content, pattern removal lead to dimensional and the property variation .

In case of permanent mold castings, machine mold made of cast iron, steel, graphite; metal poured under the gravity, vacuum or the high pressure . So, these are the characteristic features of the expendable mold castings and the permanent mold castings.

(Refer Slide Time: 08:42)



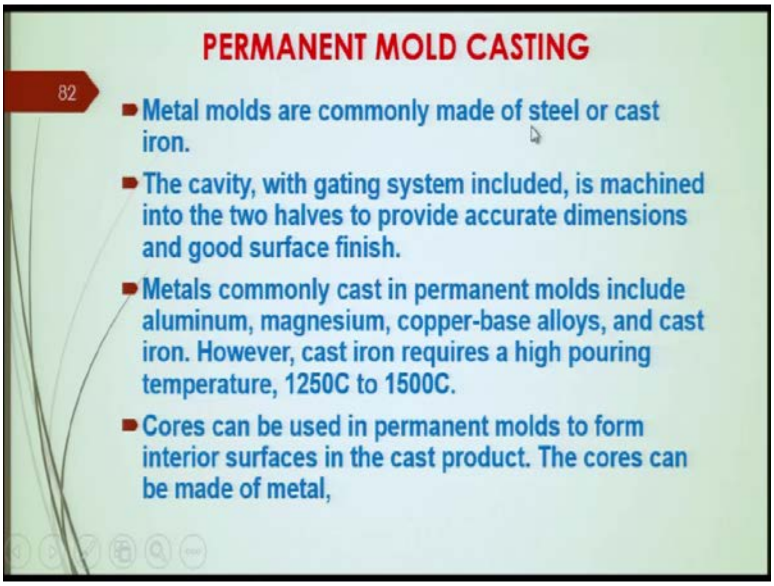
Now, let us see an example of the permanent mold casting; how the permanent mold castings are made? Here we have the mold cavity; mold cavity is made by the graphite mold.

These are the two halves; both are made of the graphite, this is the mold and when these two halves are joined together, this cavity is formed . And this is the sprue through which the molten metal will go to the cavity. Here these are the pneumatic clamps, which will actually clamp the two halves of the graphite mold, and there is a plunger.

This plunger will actually suck the metal from the box, let us say ladle . This is the refractory pouring tube and through this the molten metal which is melted in the air tight chamber and here is the molten metal; the molten metal will be sucked and it will be taken to the cavity.

This plunger is kind of a syringe or injection syringe when the medicine is taken inside the syringe; same way this plunger will take up the metal, and the molten metal will come through this tube and it will fill up the mold cavity. So, this is the entire process. As the mold cavity is filled up, the plunger stops moving and then it is given some time to solidify; after that the graphite molds two halves are separated and the casting is taken out from the mold cavity.

(Refer Slide Time: 10:42)



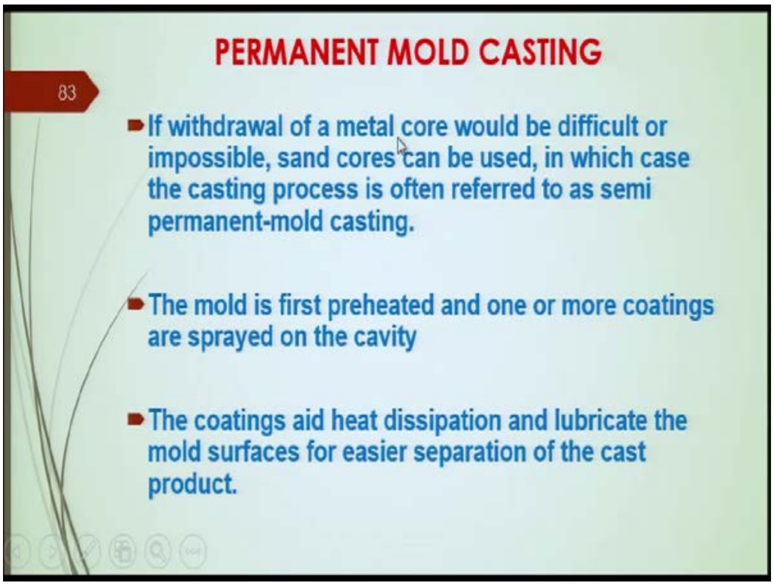
Metal molds are commonly made of steel or cast iron . The cavity includes the gating system. The gating system we are now familiar with; it can be the well, runner, sprues, cup - the entire thing is the gating system. Now, the cavity with gating system included in the machine within the two halves to provide the accurate dimensions and good surface finish.

Metals commonly cast in permanent molds include aluminum, magnesium, copper-base alloys, and the cast iron. However, cast iron requires a very high pouring temperature; this is about 1250 degree centigrade to 1500 degree centigrade .

So, at this high temperature, we have to take care of this metal; if the mold is made of metal, so that it does not melt, so that it can withstand that high temperature. This is always difficult and expensive of course. Cores can be used in permanent molds to form interior surfaces in the cast product; the cores can be also made of metal.

Now, the metallic cores you have seen earlier in the video clips, you have seen how cores are utilized for making the internal hole or the internal cavity. And in this case, that is, in the permanent mold also the cores can be used which are made of metal, instead of the sand as in case of the sand molding.

(Refer Slide Time: 12:25)

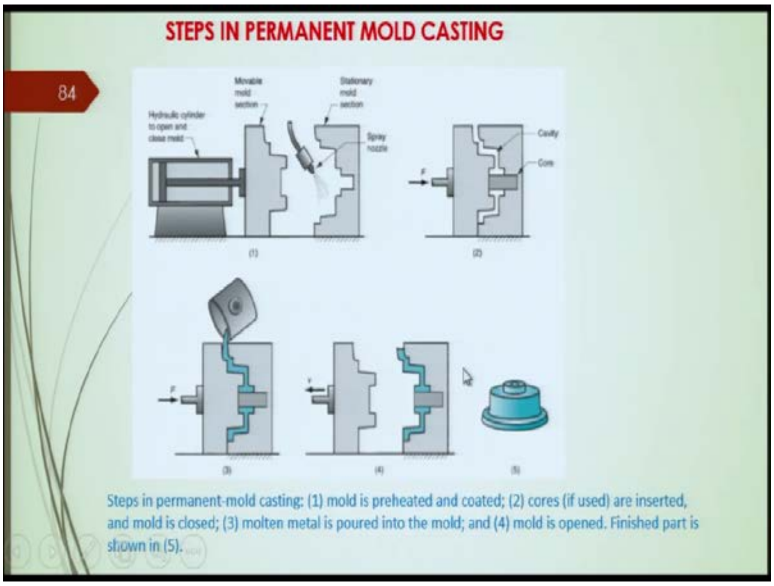


If withdrawal of a metal core would be difficult or impossible, sand cores can be used; because there are sand cores which can withstand very high temperature, special sand. I mentioned about that - mixed with molasses binder, in which case the casting process is often referred to as semi-permanent mold casting.

Semi-permanent means that, it has the mold made of metal; but the core made of sand, that is the semi-permanent. The mold is first preheated, and one or more coatings are sprayed on the cavity; this coating, spraying of the coating you have seen in the video clips. This is particularly to withstand high temperature; it is a refractory coating normally.

The coatings aid heat dissipation and lubricate the mold surfaces for easier separation of the cast product. When the two halves are separated and the casting has to be taken out from there; so, it should not stick to the inside wall of the mold cavity. Here also because the layer, I mean the spraying of the coating helps.

(Refer Slide Time: 13:47)



Here is an example of the permanent mold casting; here you see that this is the hydraulic cylinder. The hydraulic cylinder and the piston here, this is used to open and close the mold half, one half of the mold. The other half of the mold is rigidly fixed; it is not moveable.

This is the spray nozzle. Spray nozzle sprays the coating in the inside wall of the mold; then the hydraulic cylinder gets activated, piston moves towards this side, so that the movable mold section can move towards the stationary mold section.

If there is a core required; for example, here you need the internal shape. So, here the core is required, this is for the core print; so it is made for the core to be installed. Let me go ahead and show you the final casting.

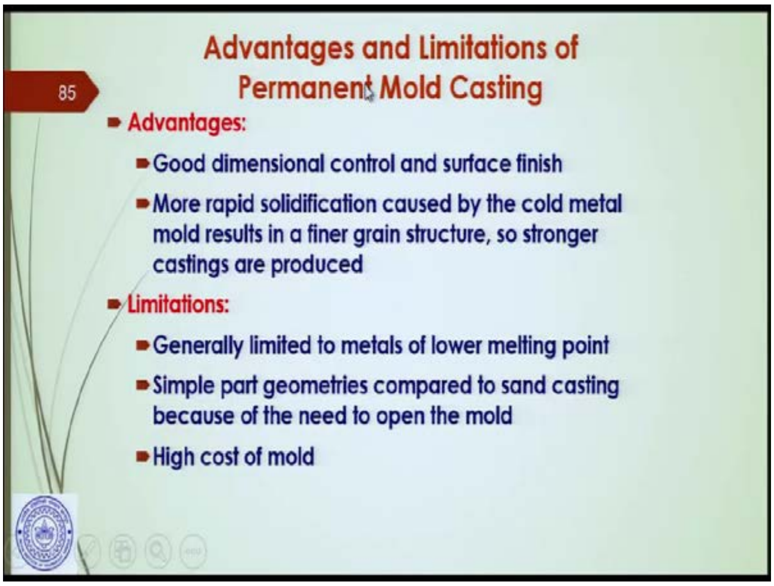
In the final casting if you see, there is an internal hole. For making that internal hole, you understand that there is a core required. As I said earlier that, core can be made of metal or it can be made of sand. That core is fixed, then both of these halves are joined together to form the cavity.

In this cavity, the molten metal will be poured and then some time is given to solidify the molten metal. After the molten metal is solidified, depending on the shape of the internal cavity, you will get the final product. The final product is shown here and then after it is solidified, the moveable section of the mold is again taken out. This is by activating the hydraulic cylinder and the piston moves to the left side now and then the casting is taken out.

These steps are written here; first, mold is preheated and coated. Cores, if used, are inserted and mold is closed. Third step is the molten metal is poured into the mold and the mold is opened, finished part is taken out as shown in this position. As you can see that these steps are very simple steps.

Only difficulty is that you have to make the permanent mold and then these two halves have to be joined together. How accurately you are joining them, how accurately the cavity is made, depending on that you will get the accuracy of the final casting.

(Refer Slide Time: 17:02)



The advantages and the limitations of the permanent mold casting are the following; advantage is that, because it is a permanent mold casting, so as in case of all other permanent mold casting the good dimensional control and the surface finish, that is one characteristic feature of all the permanent mold castings.

More rapid solidification caused by the cold metal mold results in a finer grain structure; so stronger castings can be produced. The solidification is very rapid; if you remember, we also told about this rapid solidification in case of the sand mold.

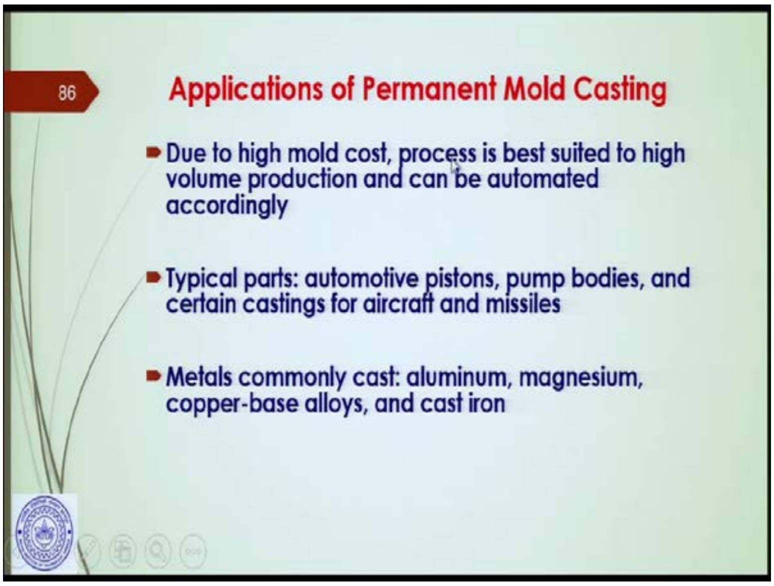
When the molten metal is poured into the cavity, immediately when it comes in contact with the cavity walls, adjoining to the cavity wall, the cooling is very fast. And at that thickness within that layer; the grain size is very small, because the cooling is very rapid.

Here also as soon as the molten metal is poured into the permanent mold, that is the metal mold, as it is coming in contact with the walls or overall, because it is a metal mold, rapid solidification takes place, caused by the cold metal mold resulting in a finer grain structure. So, stronger castings can be produced. As you know the final grains meaning, the casting strength is higher; so the stronger castings can be produced.

Limitations are that, generally limited to metals of lower melting point. Simple part geometries compared to sand casting, because of the need to open the mold. I am again repeating that, when you need to open them without destroying the mold, you cannot make that casting very complicated, very intricate, because otherwise the mold cannot be opened.

Here since you have to open the molds and molds cannot be destroyed and one and the same mold can be used multiple times; so, parts are simple. The part geometries are simple compared to sand casting, because of the need to open the mold and of course, finally, it is the high cost of mold. These are the three limitations because of which the permanent mold casting cannot be used in all the cases.

(Refer Slide Time: 20:03)

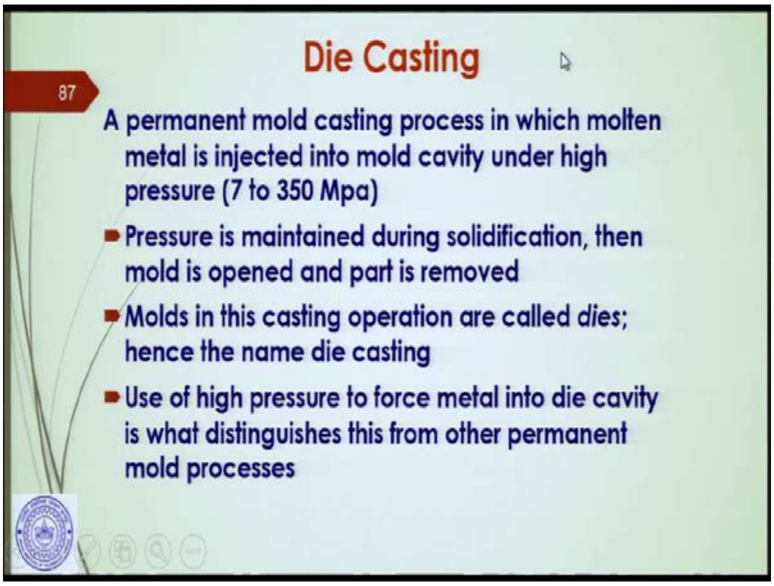


Applications of the permanent mold casting however is quite wide; because the permanent mold casting production rate is also very high. So, where the high production rate is required, the permanent mold comes in very handy. The applications are - due to high mold costs process is best suited to high volume production, where you need a very large number of parts and can be automated accordingly.

The automated process you have seen in the video clips that, those are not manually done; but the dipping of the tree in the case of investment casting, the heating up, putting it in the oven everything is done by the manipulators, by robots. So, it is automated. Now, typical parts are automotive pistons, pump bodies, and certain castings for aircraft and the missiles; they are made using the permanent mold casting.

By the way, these parts you require at a very large volume; large number of parts are to be produced. So, it is better to use the permanent mold casting and it is economically feasible. Metals commonly used in case of permanent mold casting are aluminum, magnesium, copper base alloys, and cast iron.

(Refer Slide Time: 21:35)



Let us talk about the die casting which is one of the very important casting processes and used very widely. Permanent mold casting process in which molten metal is injected into mold cavity under high pressure. The pressure can go up to 350 mega Pascal, starting from 7 to 350 mega Pascal.

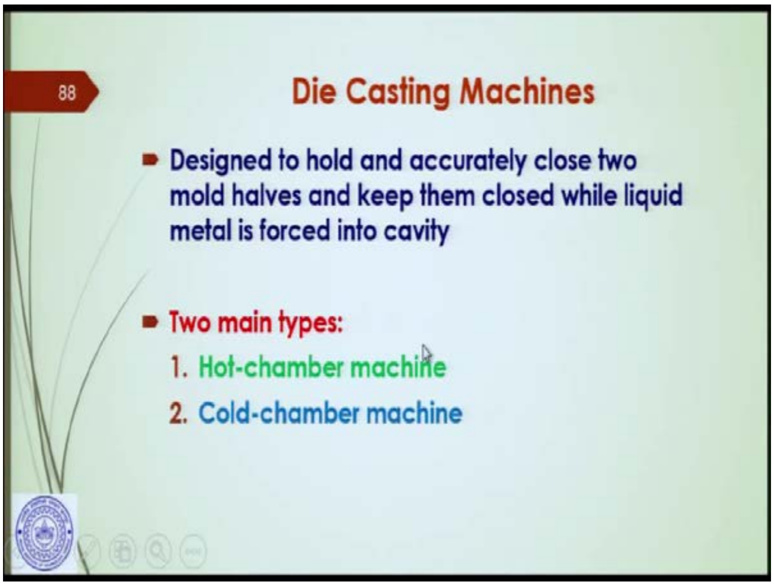
The die casting is a metal permanent mold casting; that is because the cavity is made or the mold is made from two halves of the metal mold as we have shown in here, as we have shown in the case of the permanent mold casting.

And inside the cavity, the molten metal is injected under high pressure. You can understand that many features will be now available in the die casting; because the metal is poured under pressure, so very intricate shapes can be produced. Pressure is maintained during the solidification; then mold is opened, and part is removed, when the molten metal gets solidified. Molds in this casting operation are called the dies, hence the name die casting.

In all these casting processes we kept telling that these are the molds. Here the molds are called the dies, and that dies are normally used in the metal forming process. Here, since they are called the dies, it is named as the die casting.

Use of high pressure to force metal into the die cavity molten metal is what distinguishes this from the other permanent mold processes. In all other permanent mold processes, you have seen that the pouring is by gravity; it is poured from the top normally by gravity, but in this case, it is under the high pressure. This somehow distinguishes from the other processes.

(Refer Slide Time: 23:51)



Die casting machines designed to hold and accurately close two mold halves and keep them closed while liquid metal is forced into the cavity. This machine is particularly similar to the one that I have shown you earlier; that there are two halves, one is permanent, one is movable, and the one which is movable is moved by the piston of a hydraulic cylinder.

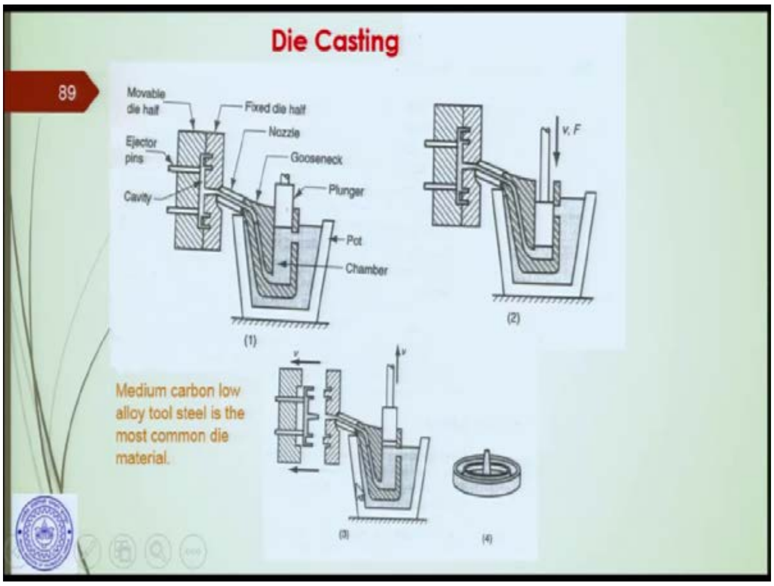
It can be a pneumatic cylinder, or it can be a hydraulic cylinder. When the hydraulic cylinder is activated, the moveable part of the mold can move towards the fixed mold or it can come away from that.

Now, the machines are designed to hold and accurately close two mold halves and keep them closed while liquid metal is forced into cavity. Mind it when it is forced into the cavity at a pressure of 300 up to 350 mega Pascal, within that pressure two halves have to be kept together. Therefore, the clamping force has to withstand that much force of 350 mega Pascal; that is why it has to be kept closed while liquid metal is forced into the cavity.

There are two main types of the die casting machines; one is the hot chamber machine, and second is the cold chamber machine. As the name says, now the chamber where the molten metal is poured, that is heated up in case of the hot chamber machine. And in case of cold chamber machine, it is not; that means the molten metal is poured in the cold chamber, but metal has to be molten.

Hot or cold only is concerned with the mold cavity; whether the mold is heated up or the mold is used as at an ambient temperature.

(Refer Slide Time: 26:00)



Here is the diagram, you can see; these are the three steps shown; these are the two halves. One is fixed at the right side and the movable die is here. These are the ejector pins, mounted through the movable die or the half portion of the movable die.

Now, when those two halves will be joined together; this will be the cavity formed. There is a nozzle here, that is coming from the setup; in this setup we have a chamber and the pot, where the molten metal is kept, or the metal is melted.

The molten metal from this chamber is pumped at a pressure of up to 350 mega Pascal as we said; it is pumped to the cavity through the gooseneck here and through the nozzle.

At this time, these two halves should be held together; that means these two halves should have some kind of clamping force, so to withstand this force of the up to 350 mega Pascal. Rest of the steps and the rest of the die casting methods, I will discuss in my next lecture session.

Thank you for your attention.