Advanced Manufacturing Processes
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Module - 2
Advanced Metal Casting Processes
Lecture - 2
Evaporative Pattern Casting Processes (EPC)

Welcome to this lecture on advanced manufacturing processes. I am Apurbba Kumar Sharma from the department of Mechanical and Industrial Engineering of IIT, Roorkee. Dear students, in this session we will discuss about the evaporative pattern casting process also known as EPC process.

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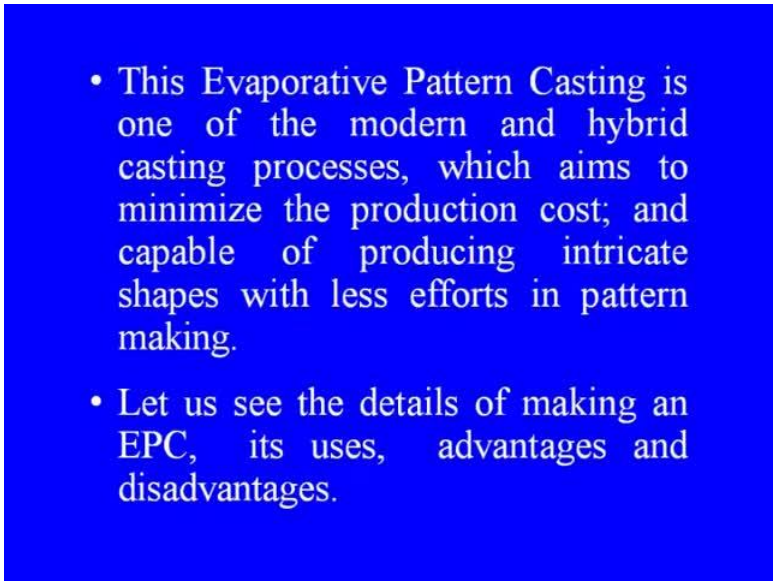

This evaporative pattern casting is one of the modern and hybrid casting processes, which aims to minimize the production cost, and is capable of producing intricate shapes with less efforts in pattern making. Let us see the details of making an evaporative pattern casting, its uses, advantages and disadvantages.

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The evaporative pattern casting process is also known by other names such as full mold casting process and lost foam casting process. It makes use of patterns made from evaporative materials like foam.

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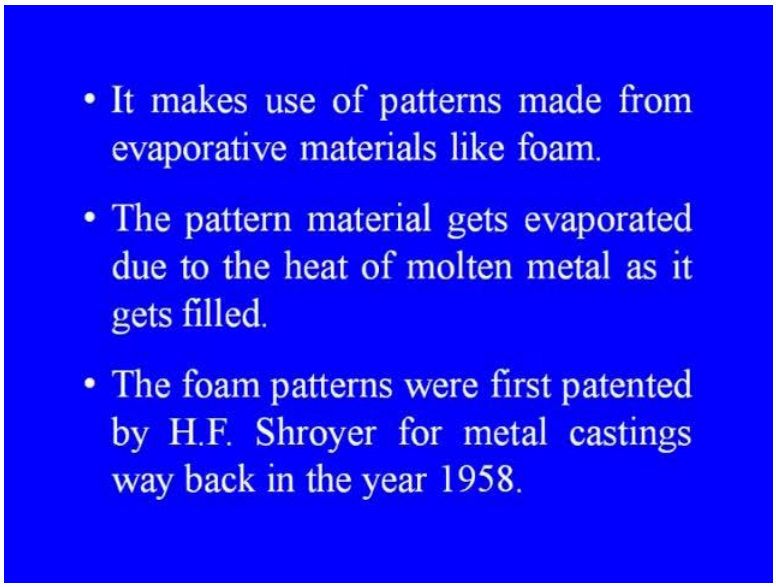

The pattern material gets evaporated due to the heat of molten metal as it gets filled. The foam patterns were first patented by H F Shroyer, for metal castings way back in the year 1958. Earlier expanded polystyrene also known as EPS blocks were used for measuring the patterns, bonded sand was used for support while pouring.

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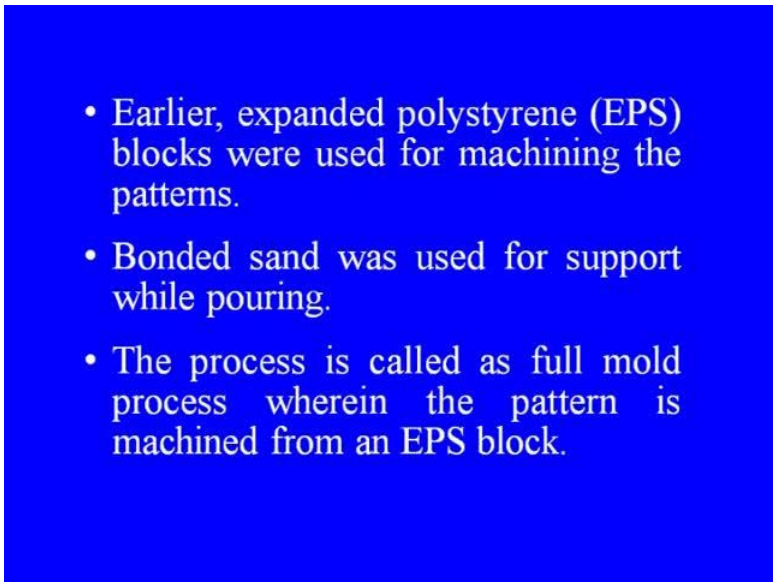

The process is called as full mold process wherein the pattern is machined from an EPS block. The process is primarily used to make large one of castings.

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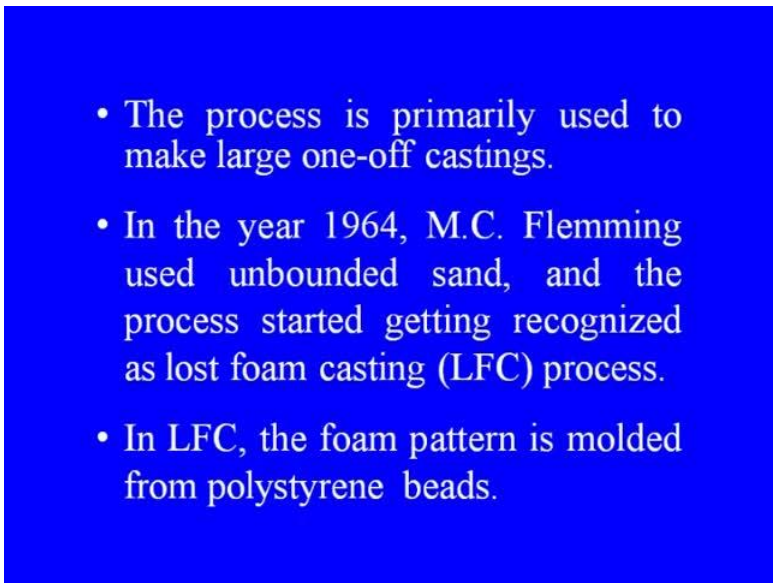

In the year 1964 M C Flemming used unbounded sand and the process started getting recognized, as lost foam casting process, also known as LFC process. In the LFC the foam pattern is molded from polystyrene beads. In full mold process on the other hand, bonded sand is used. In the LFC process, the bonded sand is replaced by unbounded

sand. The evaporative pattern casting process is a binder less process, wherein no physical bonding is required to bind a sand particles.

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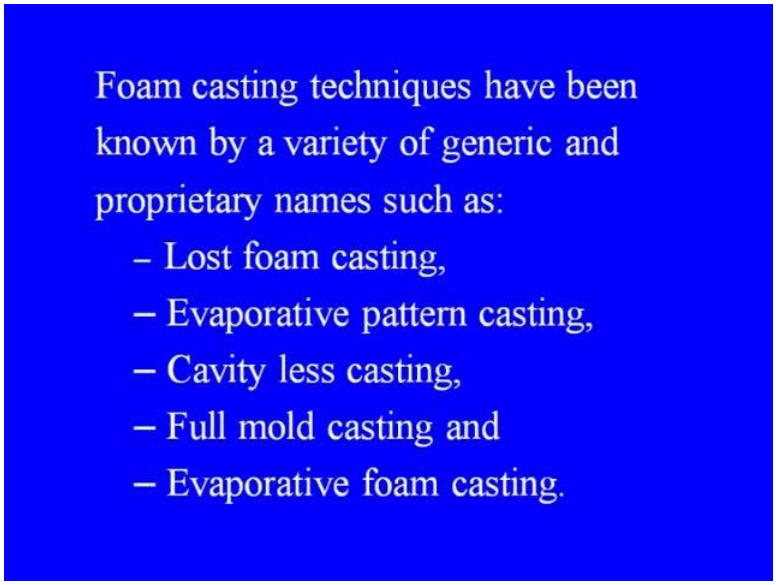

Foam casting techniques have been known by a variety of generic and proprietary names such as, lost foam casting, evaporative pattern casting, cavity less casting, full mold casting and evaporative foam casting. In foam castings evaporative polystyrene is used to prepare the complete pattern, including the gates and risers.

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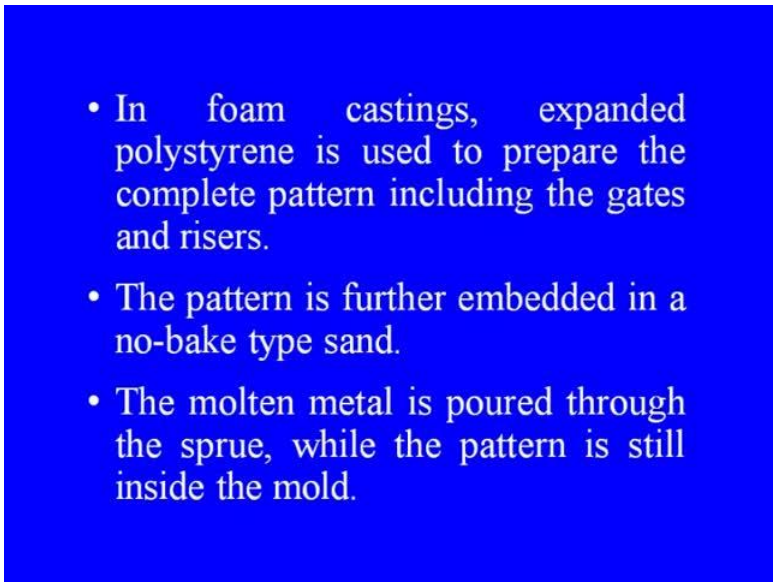

The pattern is further embedded in a no bake type sand. The molten metal is poured through the sprue while the pattern is still inside the mold. The heat of the molten metal is sufficient enough to gasify the pattern and the pattern progressively gates displaced by it. Using unbounded sand and expandable polystyrene pattern, the EPC process is a very economical method in producing complex and closed tolerance castings.

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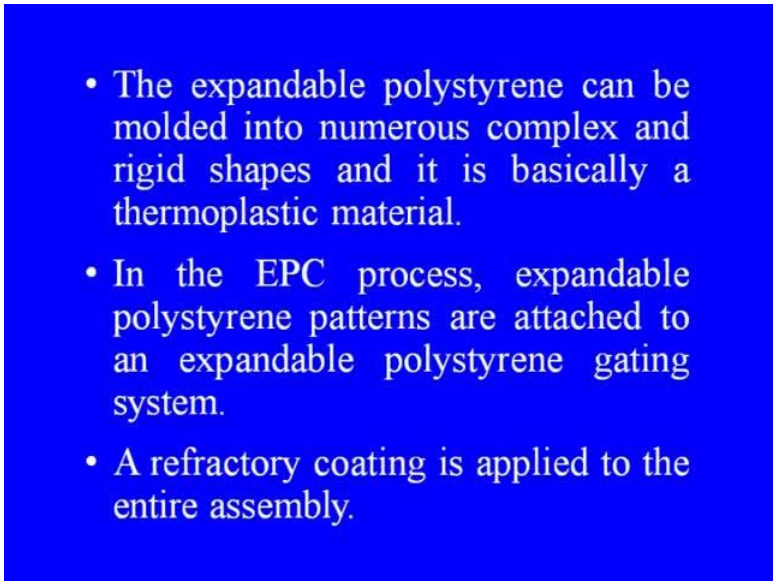

The expandable polystyrene can be molded into numerous complex and rigid shapes and it is basically a thermoplastic material. In the EPC process expandable polystyrene patterns are attached to an expandable polystyrene gating system. A refractory coating is applied to the entire assembly, once the coating gets dried, the entire foam pattern assembly is kept on loose dry sand in a vented flask. The flask is then vibrated and additional sand is added to it until the pattern assembly gets completely embedded in sand. Subsequently, molten metal is poured into the sprue, which further reprises the foam polystyrene. As soon as it enters inside the entered metal solidifies and reproduces the size and shape of the used pattern perfectly to get the desired casting in this process.

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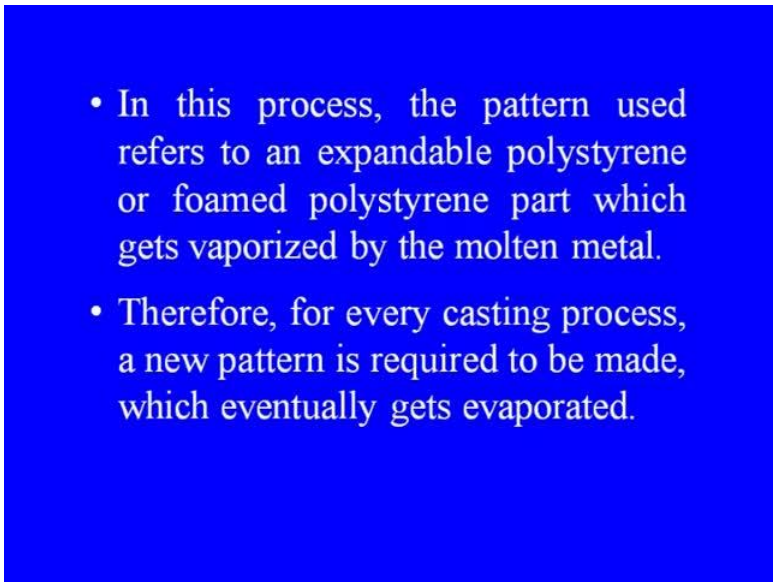

The pattern used refers to an expandable polystyrene or foamed polystyrene part, which gets vaporized by the molten metal. Therefore, for every casting process a new pattern is required to be made, which eventually gets evaporated. Now, let us see the advantages of the evaporative pattern casting process.

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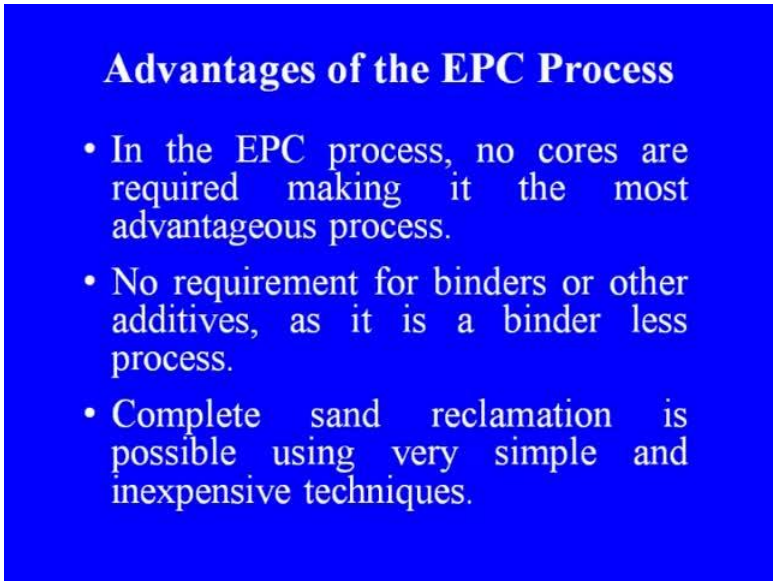

In the evaporative pattern casting process no cores are required, making it the most advantageous process. No requirement for binders or other additives, as it is a binder less process. Complete sand reclamation is possible using very simple and inexpensive

techniques. In this process sand shake out is easy as the sand is unbounded. Since, the pattern used in EPC process is one piece, hence no parting lines are required. Since, cores are eliminated, no core prints are required. Further due to this, there is no mismatch and problems due to the core sips are also reduced. This reduces the casting defects considerably improved casting quality is achieved in this process.

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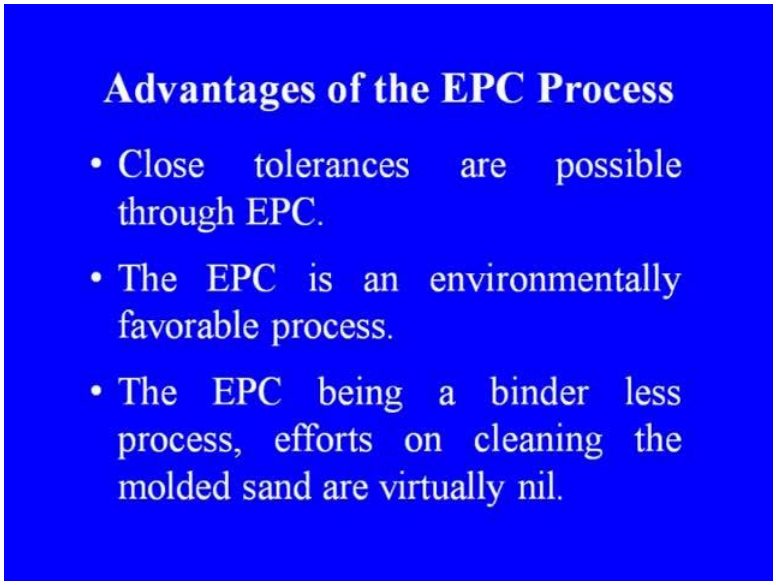

Close tolerances are possible the EPC is an environmentally favorable process. The EPC being a binder less process, efforts on cleaning the molded sand are virtually nil. The EPC process is viewed as a value added process, harder than a substitute for sand casting. The EPC is cheaper and much simpler than the investment casting process, as the foam is more readily available and cheaper as compared to wax.

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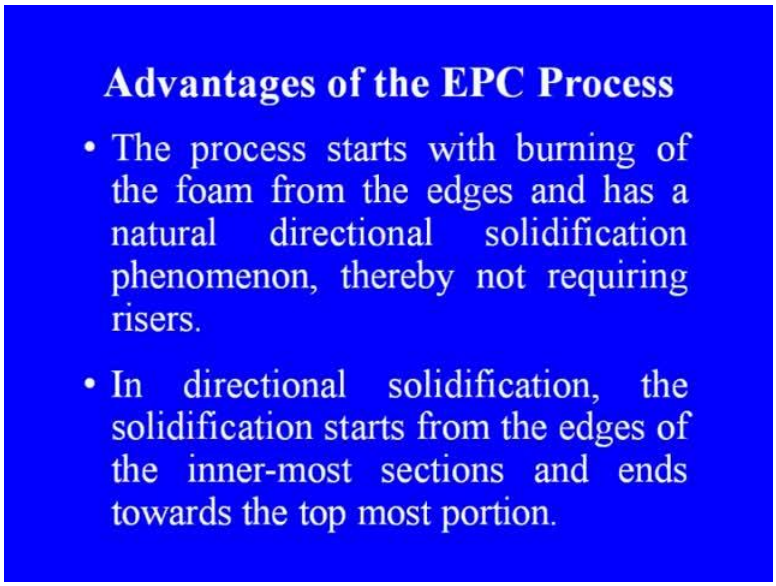

The EPC process starts with burning of the foam from the edges and has a natural directional solidification phenomenon, thereby not requiring risers. In directional solidification, the solidification starts from the edges of the inner most sections and ends towards the top most portion. Now, let us also see the disadvantages or limitations of the evaporative pattern casting process.

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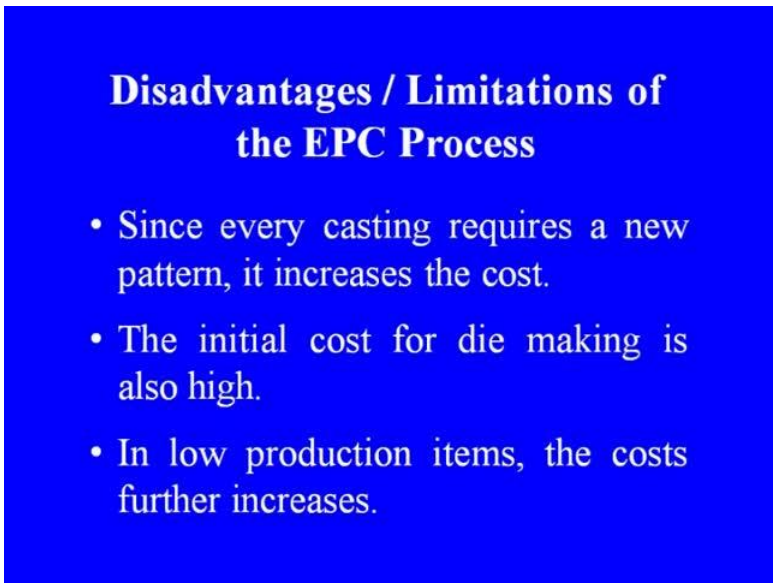

Since, every casting requires a new pattern, it increases the cost. The initial cost for die making is also high. In low production items the costs further increases. There is a

limitation on the minimum section thickness of the pattern. Due to lower strains of the patterns, they can get easily damaged or distorted. Quality of the casting fully depends upon the quality of the pattern.

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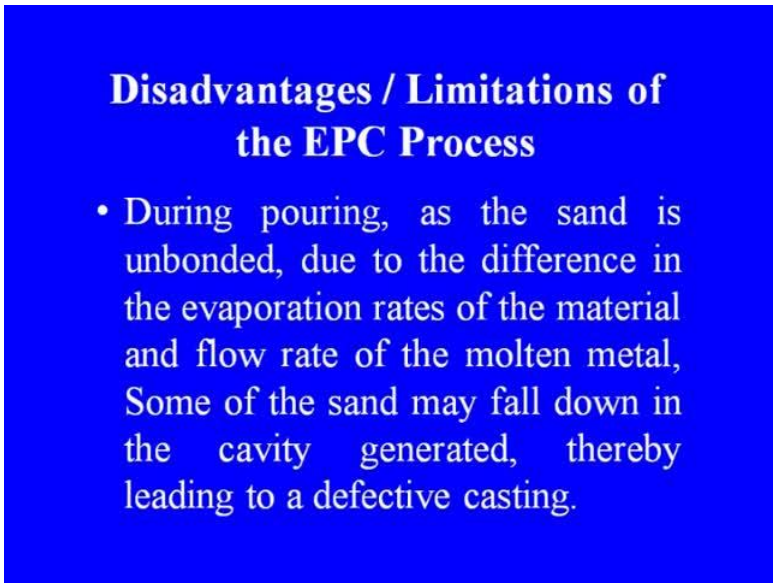

During pouring as the sand is unbounded, due to the difference in the evaporation rates of the material and flow rate of the molten metal some of the sand may fall down in the cavities generated, thereby leading to a defective casting. Now, let us also see the applications of the evaporative pattern casting process.

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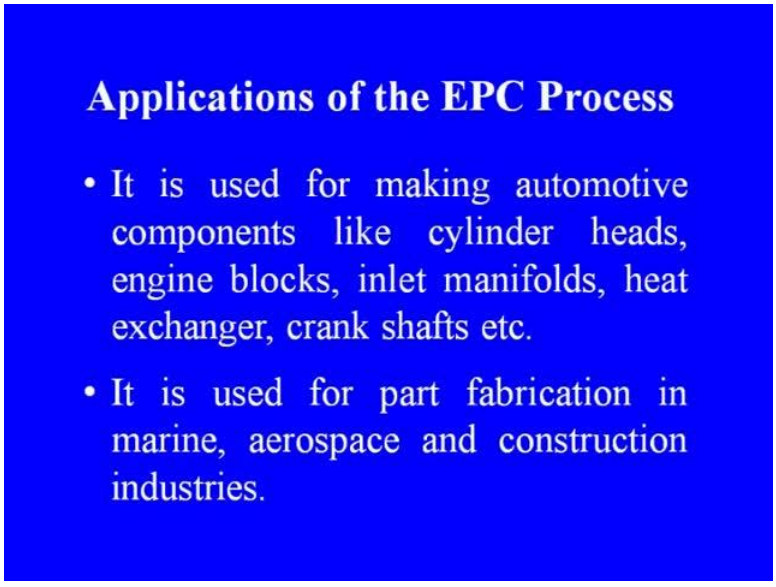

This process is used for making automotive components like cylinder heads, engine blocks, inlet manifolds, heat exchanger, crank shafts etcetera. It is also used for parts fabrication in marine, aerospace and construction industries. Now, let us see the evaporative pattern casting process.

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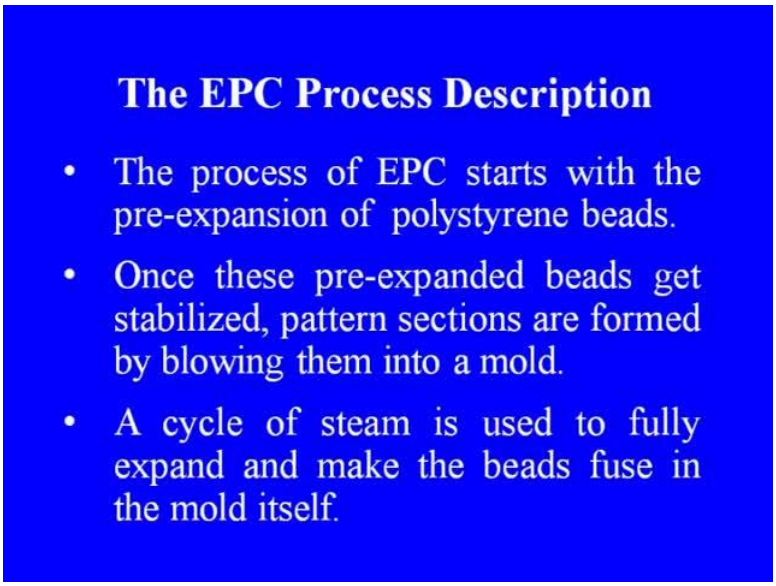

The process of evaporative pattern casting starts with the pre expansion of polystyrene beads. Once these pre expanded beads get stabilized, pattern sections are formed by blowing them into a mold. A cycle of steam is used to fully expand and make the beads fuse in the mold itself clusters are made.

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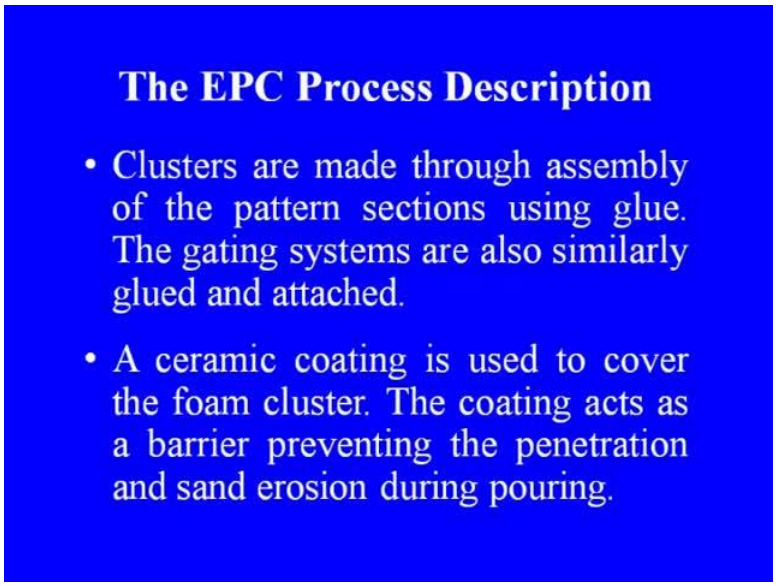

Through assembly of the pattern sections using glue, the gating systems are also similarly, glued and attached. A ceramic coating is used to cover the foam cluster. The coating acts as a barrier preventing the penetration and sand erosion during pouring. Once the coating gets dried, the cluster is placed in a flask along with backing of the bonded sand. Any suitable sand can be used as long as it resists the temperature of the molten metal being poured. Silica sand zircon sand olivine's sand and chromites are commonly used molding sands.

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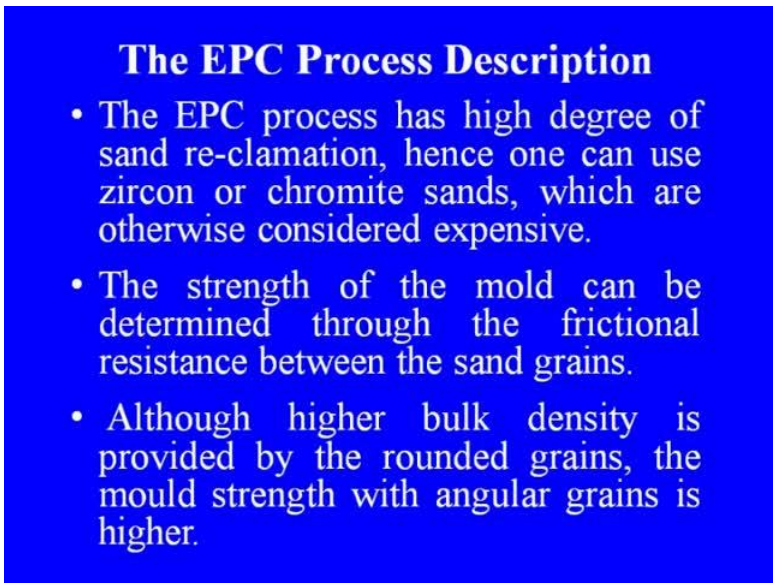

The EPC process has high degree of sand re-clamation, hence one can use zircon or chromites sands which are otherwise considered expensive. The strength of the mold can be determined through the frictional resistance between the sand grains. Although higher bulk density is provided by the rounded grains, the mold strength which angular grains is much higher. In order to ensure uniform and proper compaction, a vibrating table is used for the mold compaction. After completing this process, the cluster is packed in a flask and the mold is set ready for getting poured. A schematic sketch of the EPC process is shown in the figure one.

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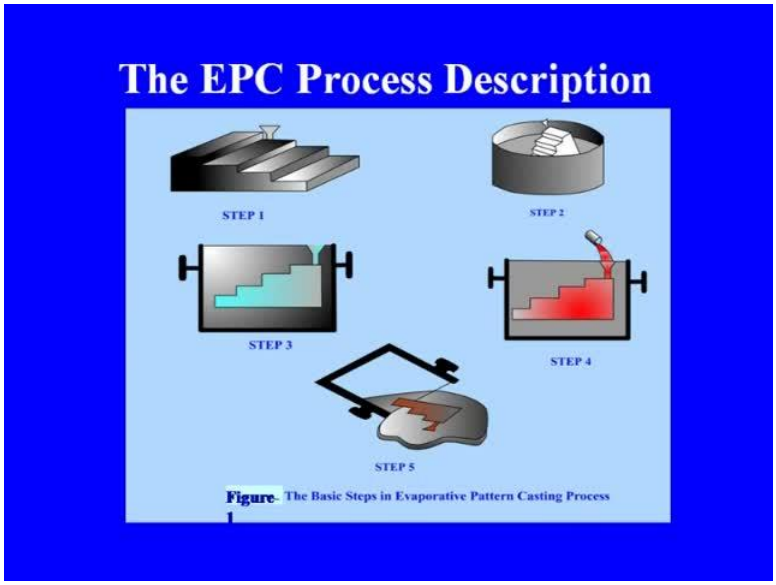

This is the pattern, the pattern is coated and then finally, the pouring is done, and the product is obtained. The patterns used in the EPC process are made of expandable polystyrene. A typical pattern is shown in the figure two, pattern fabrication starts with the pre expansion of polystyrene beads. They are blown into the die cavity to form pattern sections.

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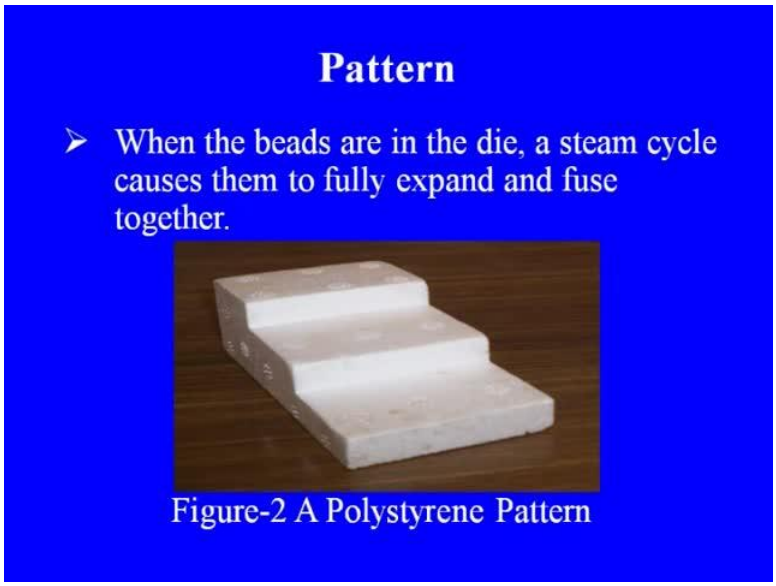

This is a typical polystyrene pattern. When the beads are in the die, a steam cycle causes them to fully expand and fuse together, forming the pattern as shown here. Ford fabrication of steamed pattern die and sprue a cavity, as per the pattern dimensions is prepared.

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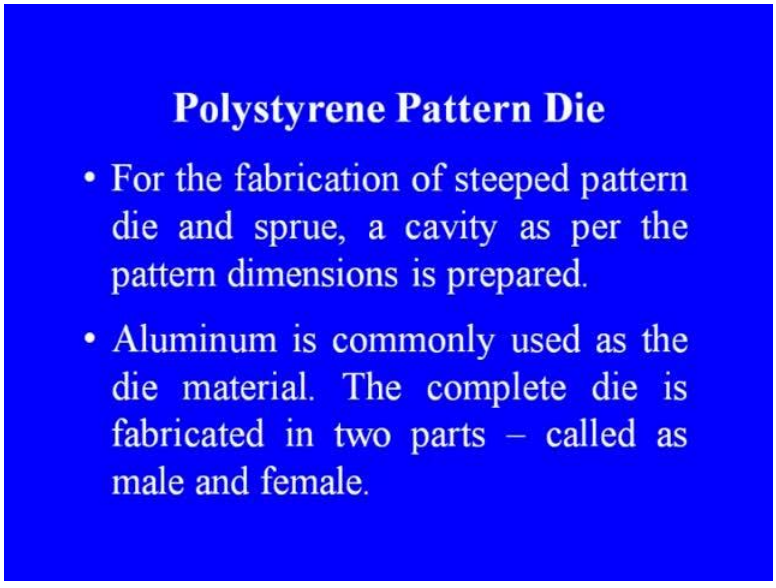

Aluminum is commonly used as the die material. The complete die is fabricated in two parts, called as male and female.

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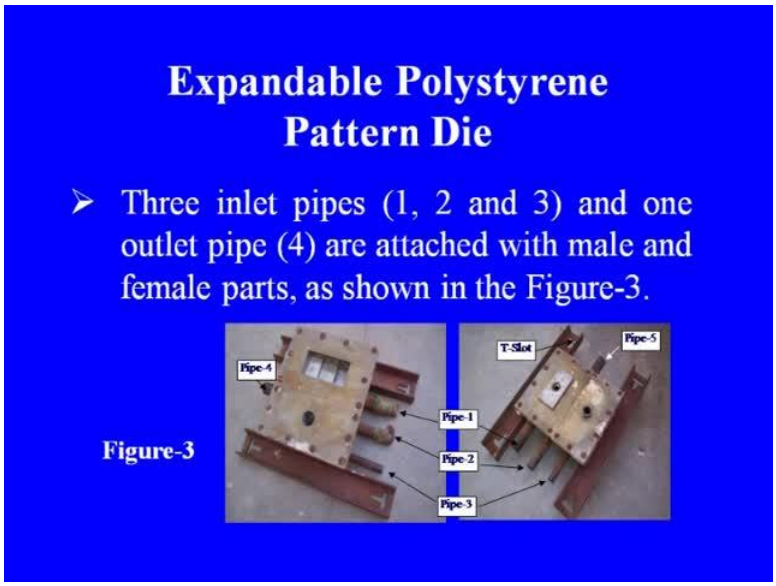

The the in three inlet pipes 1, 2 and 3 and one outlet pipe pipe 4 are attached with male and female parts, as shown in this figure. These are inlets this is the outlet. The function of all three inlet pipes was same in male and female parts. The two outermost pipes, number 1 and 3 were used to supply water as a cooling agent in the die. The middle pipe, which is pipe number 2 was used to supply the steam into the cavity through pin holes to soften and expand the beads.

Pipe 4 was used to throw water and steam from the die. Polystyrene beads were fed in to the die cavity through a pipe, which is connected at the top of the male part at the four corners of the die. These slots are fabricated to hold both male and female parts of the die in the phrase. Pattern density and bead size density and bead size play an important role in evaporative pattern casting process. In order to minimize the amount of gases evolved during evaporation of the pattern patterns with low density are generally used.

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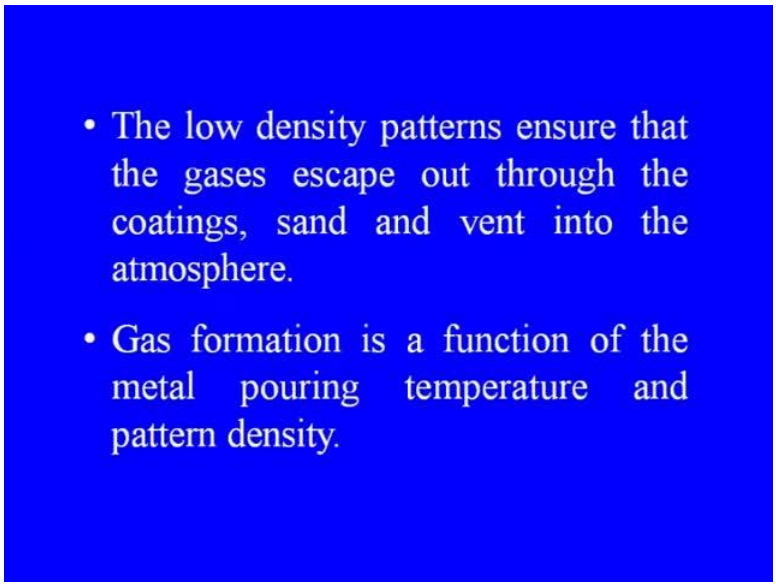

The low density patterns ensure that the gases escape out through the coatings, sand and vent into the atmosphere. Gas formation is a function of the metal pouring temperature and pattern density. If the gas forms faster than it can vent, a defective casting will be formed. If the pattern density is increased, then at a constant pouring temperature more gas is formed.

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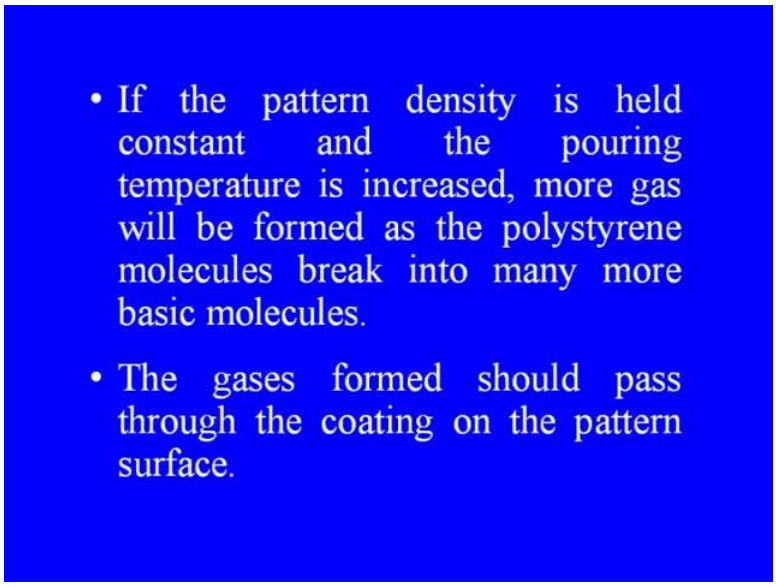

If the pattern density is held constant and the pouring temperature is increased more gas will be formed as the polystyrene molecules break into many more basic molecules. The gases formed should pass through the coating on the pattern surface. The pattern density generally varies between 1 and 1.5 PCF, which further depends on the geometry and metal, that is being poured. Small beads are required for obtaining relativity non beady smooth surfaces on the molded patterns.

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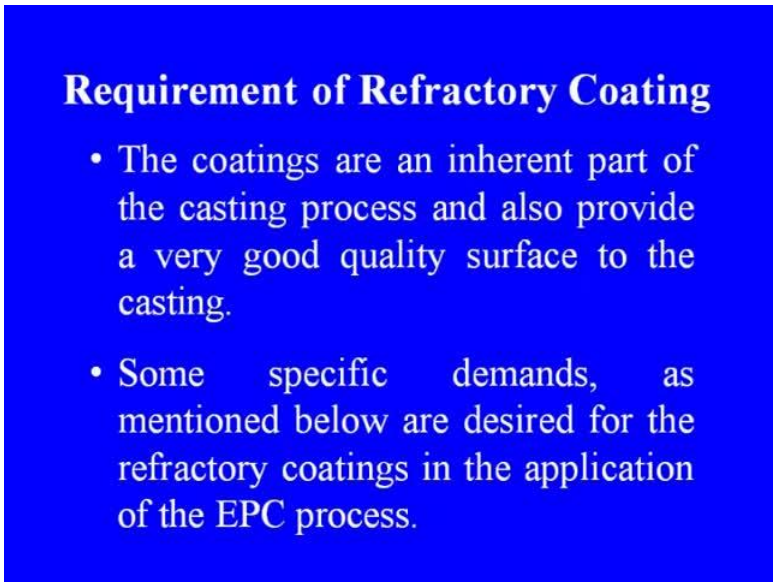

Requirements of refractory coating. The coatings are an inherent part of the casting process and also provide a very good quality surface to the casting. Some specific demands as mentioned below are desired for a refractory coatings in the application of the EPC process. Highly permeable coating is preferred for rougher sand while medium and low permeable coating is preferred for final sand. Quick drying is preferred coating should get easily stuck to the pattern and there should be provision of controlling and adjusting coating layer thickness.

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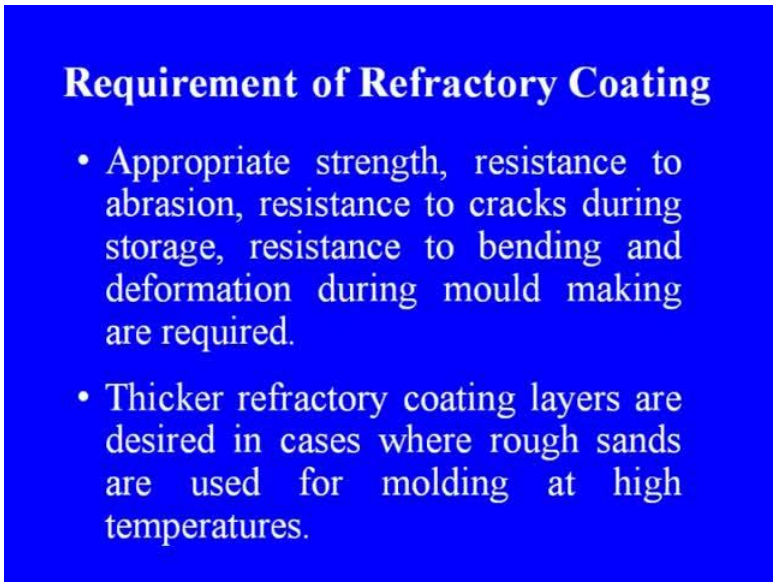

Appropriate strength resistance to abrasion, resistance to cracks during storage, resistance to bending and deformation during mold making are required. Thicker refractory coating layers are desired in cases where rough sands are used for molding at high temperatures. Coating material, the refractory coating materials play an intimate role in the EPC process. Its function is to provide a refractory protection and seal in penetration of metals.

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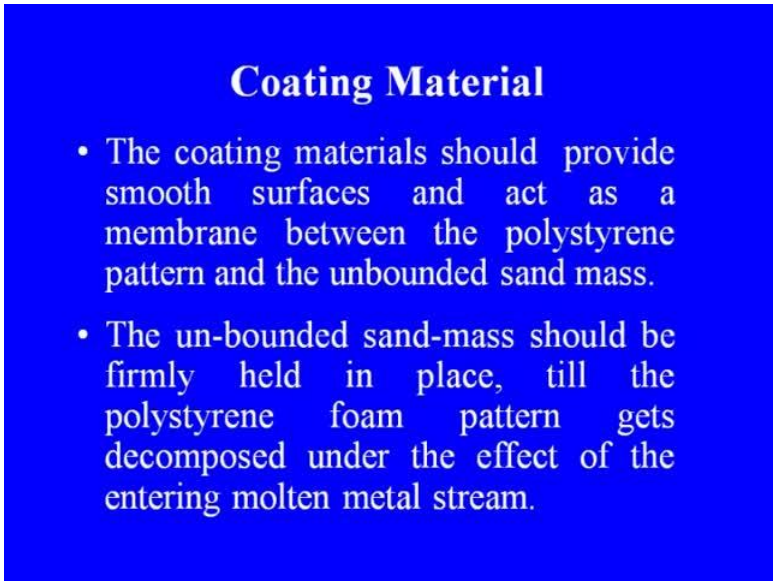

The coating materials should provide smooth surfaces and act as a membrane between the polystyrene pattern and the unbounded sand mass. The unbounded sand mass should be firmly held in place, till the polystyrene foam pattern gets decomposed under the effect of the entering molten metal stream. This is achieved by allowing the permeability of the refractory coating to restrict the free flow of decomposition gases and liquids through the coating into the unbounded sand mass. This causes a back pressure against the entering molten metal stream resulting in a pressure force, that holds the unbounded sand in place.

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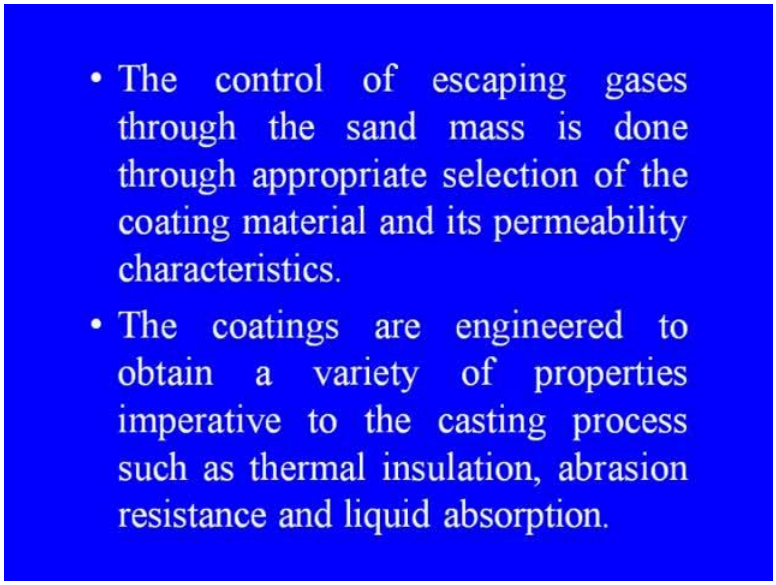

The control of escaping gases through the sand mass is done through appropriate selection of the coating material and its permeability characteristics. The coatings are engineered to obtain a variety of properties imperative to the casting process such as thermal insulation, abrasion resistance and liquid absorption.

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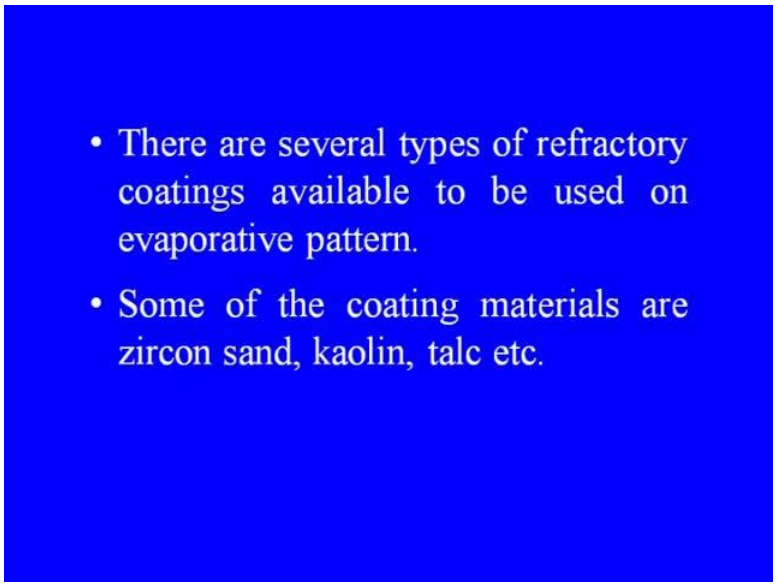

There are several types of refractory coatings available to be used on evaporative pattern. Some of the coating materials are are zircon sand, kaolin, talc etcetera. The coating generally recommended, in case of cast iron is iron powder, as it prevents the metal penetration. The siliminate quartz and aluminum silicate can be used as filler materials to make the coatings cost effective. Now, let us look into the process variables involved in the evaporative pattern casting process.

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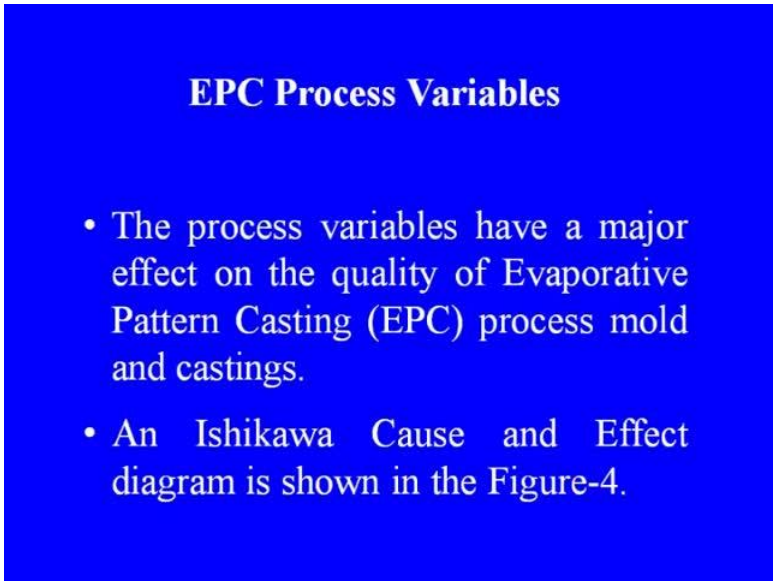

The process variables have a major effect on the quality of evaporative pattern casting process mold and castings. An Ishikawa cause and effect diagram is shown in the figure four.

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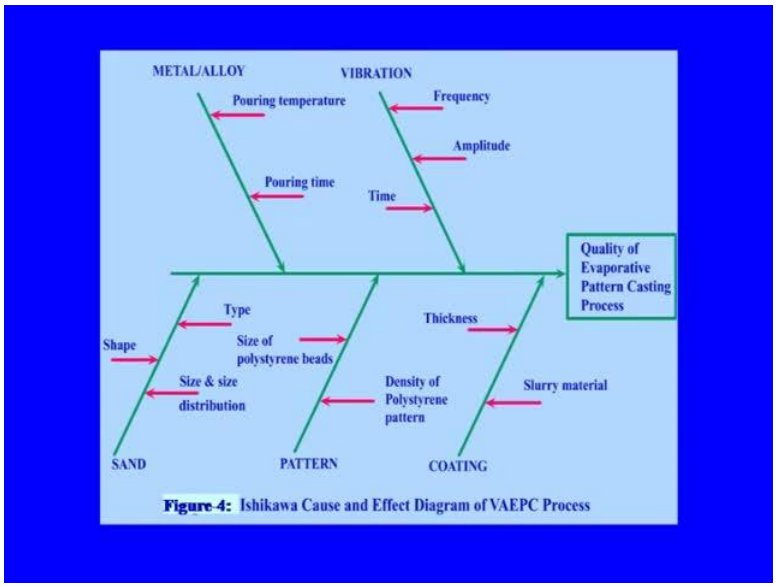

Figure 4: Ishikawa Cause and Effect Diagram of VAEPC Process

Here the major parameters involves the metals and alloys, the vibration, the sand used, the pattern and the coating. The parameters involved in this, affect ultimately the casting to be obtained as the product. The EPC process variables can be grouped in the following categories.

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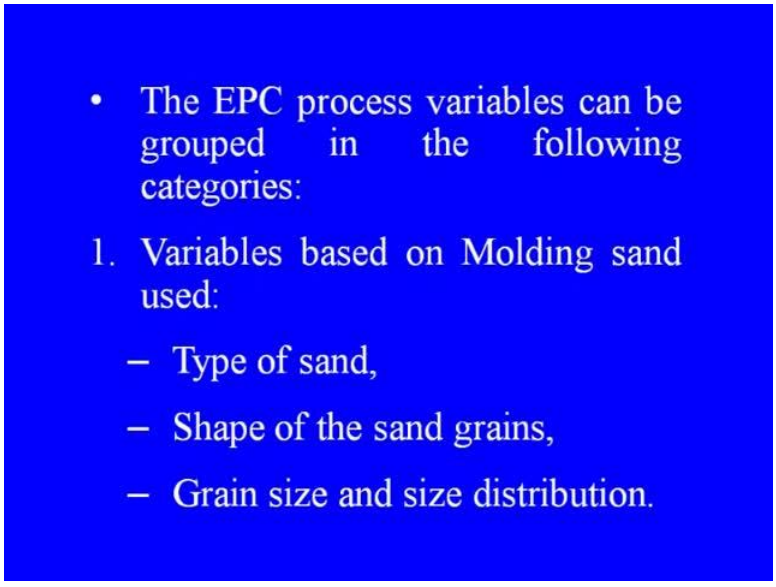

Number one, variables based on molding sand used, these are type of sand, shape of the sand grains, grain size and size distribution. Number two, variables based on pattern.

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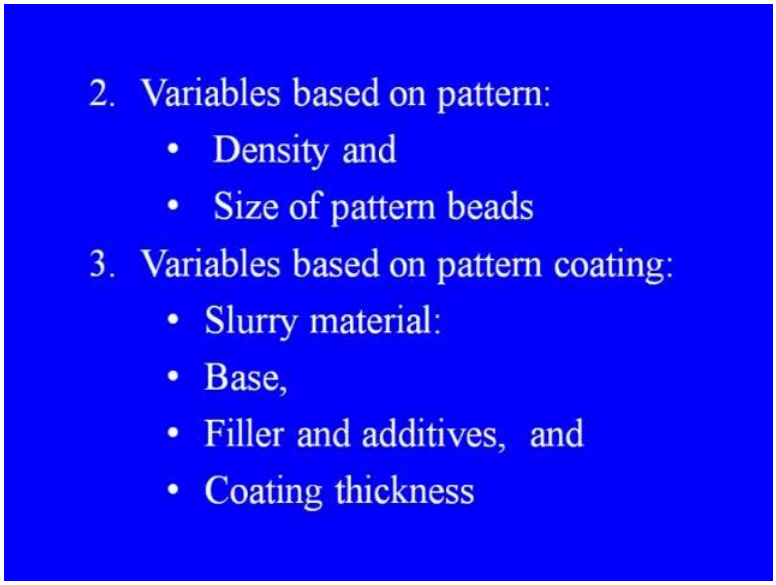

They are density and size of pattern beads. Number three, variables based on pattern coating the variables are, slurry material, base, filler and additives and coating thickness. The fourth category of variables are based on the vibration system.

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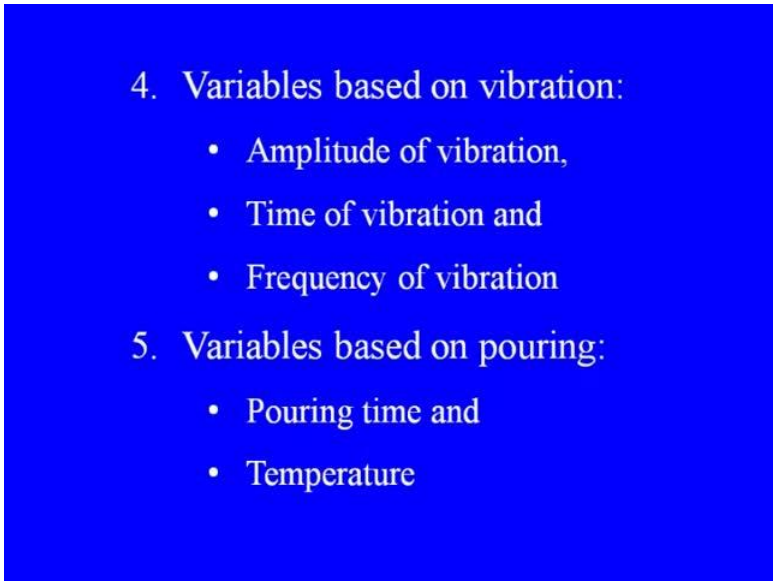

The variables are, amplitude of vibration, time of vibration and the frequency of vibration. The fifth category of variables are based on, pouring, the variables are pouring

time and pouring temperature. These are some of the product produced through evaporative pattern casting process.

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The products obtained from evaporative pattern casting need to be subjected to various tests to ensure its soundness. Few of them are discussed in this session, which are very commonly used.

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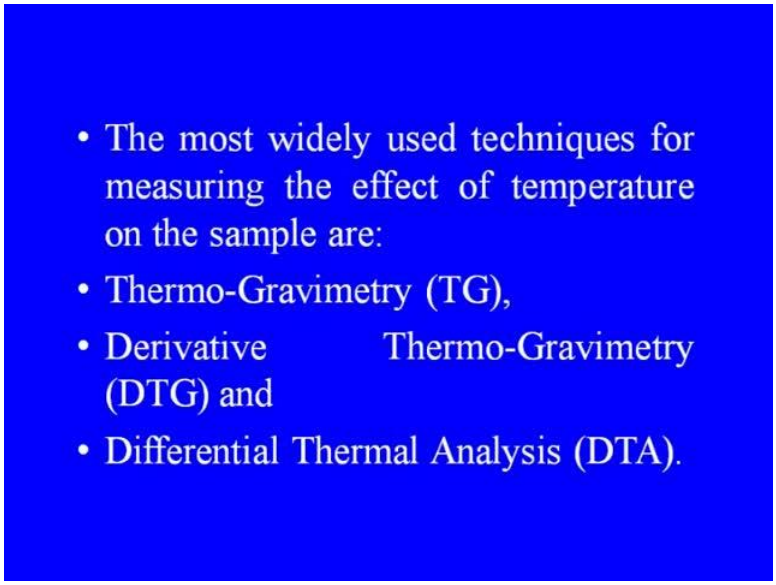

The most widely used technique for measuring the effect of temperature on the samples are thermo gravimetry also called TG test. Then derivative thermo gravimetry also called DTG test and differential thermal analysis called DTA test.

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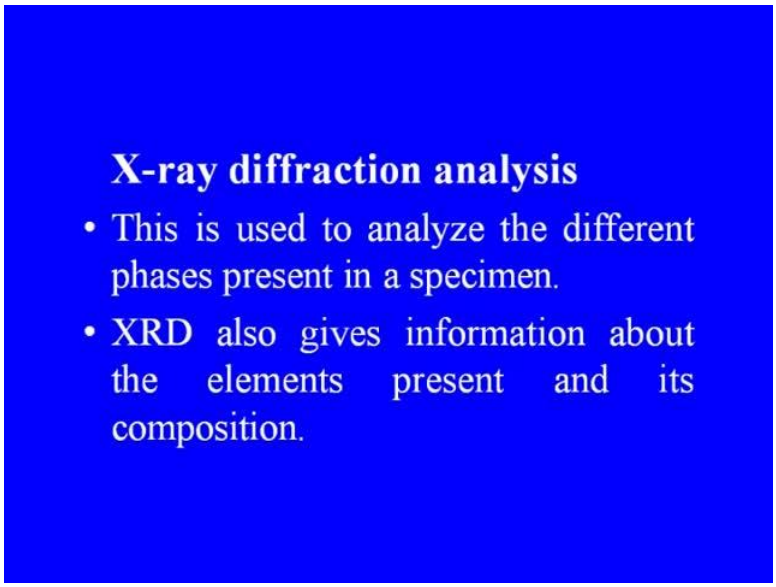

Then another very popular and very widely used technique is the X-ray diffraction analysis. This is quiet old process, but quiet comprehensive and quiet popular process. This is used to analyze the different phases present in a specimen. X-ray diffraction also gives information about the elements present and its composition. As we know different materials diffracts the light incident on it or we can say different electromagnetic radiation incident on heat depending on the structure. Therefore, this can be explained like this.

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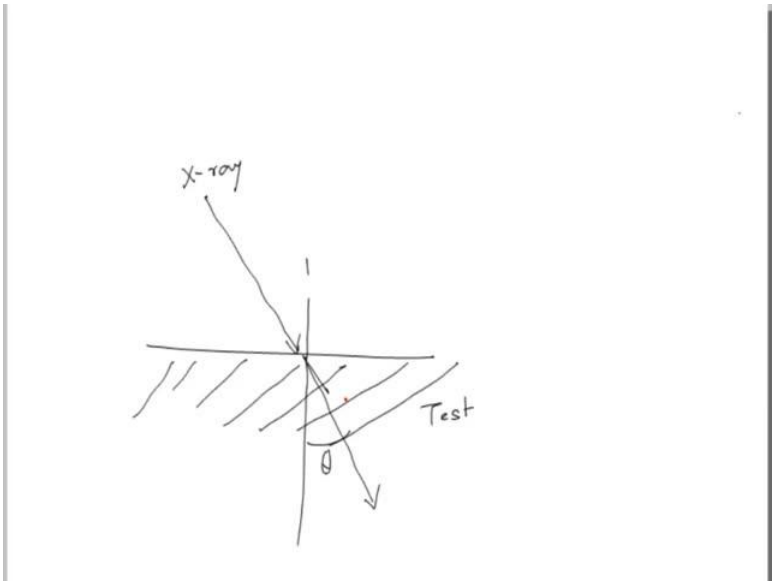

If this is the surface and if X-rays are falling on it, this is say X-rays, then this refracted x- rays inside this material, so this is the material, this is test material, this will be depending on the crystal structure of this material. Therefore, by measuring the angle of deflection, what is this angle? We can find out, what is the material in this because this can be correlated to its characteristic. That means this diffraction will be characteristic of the material or the crystal structure through which, X-ray incident X-ray is passing through.

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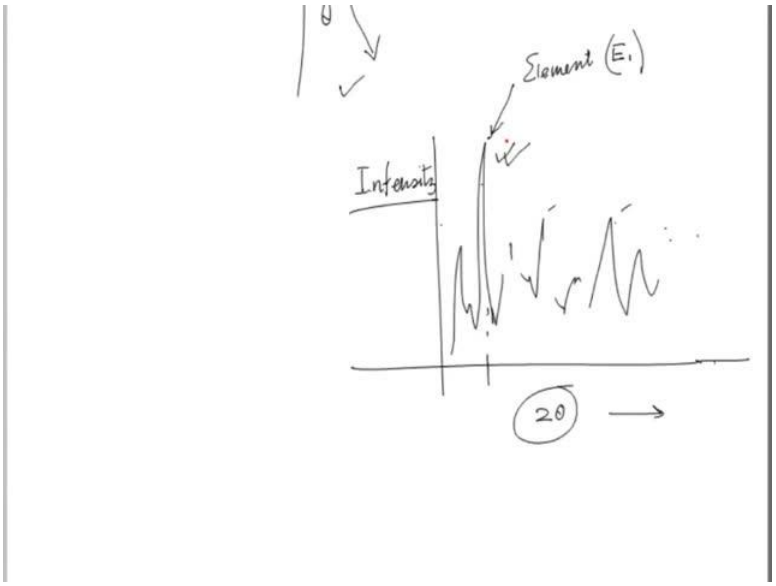

Therefore, we can get a signal like this. So, here so this is 2 theta and this is called intensity. Now, these different peaks, these peaks represents that one element some element say E 1 is present and that can be confirmed by subsequent detection of five peaks, five such peaks in this spectrum. This intensity is plotted as a function of 2 theta as we have indicated.

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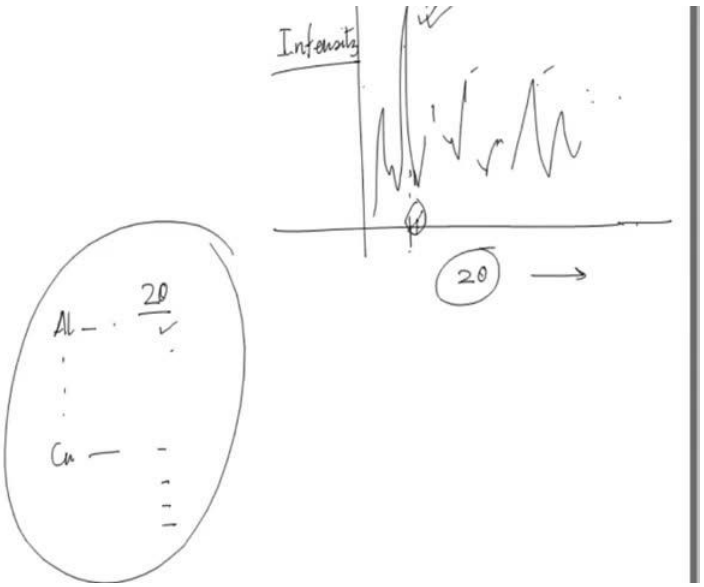

And by knowing this 2 theta, we can identify which element it is because this 2 theta for different materials say aluminum for different phases, this 2 theta is fixed. Similarly, for

copper different phases, this value is fixed. Now, by correlating these values, if we obtain these values here, then by identifying the peak corresponding to that particular 2 theta value, one can identify the element present in that material. So, this is a very important technique widely used technique, a very low cost technique and of course, this is a non destructive testing technique, which is very widely used even today under crystallographic labs. Of course for subjecting this particular test to a material, the material needs to be crystalline in nature. Amorphous materials like glass etcetera cannot be characterized by using this method.

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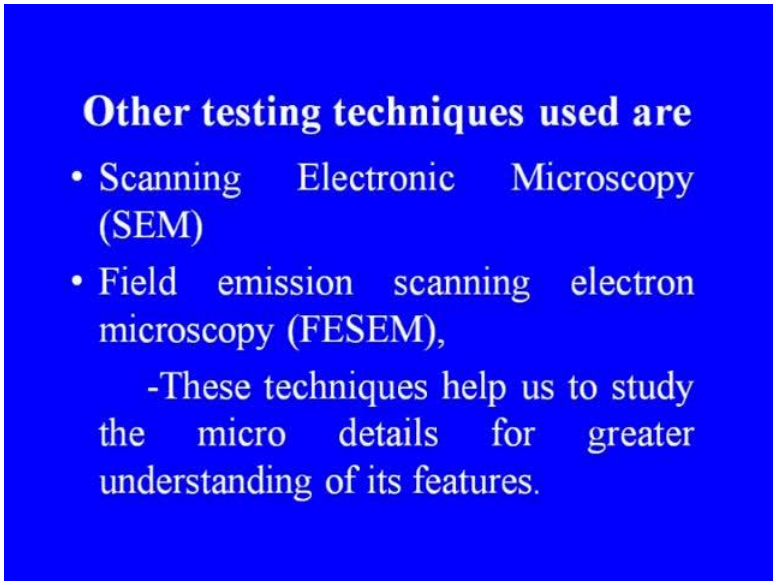

Other testing techniques used are scanning electron microscopy, field emission scanning electron microscopy. These techniques help us to study the micro details for greater understanding of the features. The field emission scanning electron microscopy can be used to obtain an information about to constitute, constituting elements as well. While scanning electron microscopy gives the micro structure as a whole, which help us to identify the phases to identify the micro structure how it is or to identify whether there is any crack, micro cracks or whether there is any porosity or any other defects at all?

In many a cases, micro structure changes with the temperature or in other words since, the casting is a thermal process and the cast product is nothing but a solidified molten material. Therefore, we can say the solidification leaves some foot print of the material to be examined later. Now, using these devices like scanning electron microscope or

field emission scanning electron microscope, we can study, what are the foot prints during the solidification process? Now, as per the heating rate or the cooling rate here in case of casting it will be cooling rate, the material micro structure the structure of the material will be changed and that can be identified using scanning electron microscopes.

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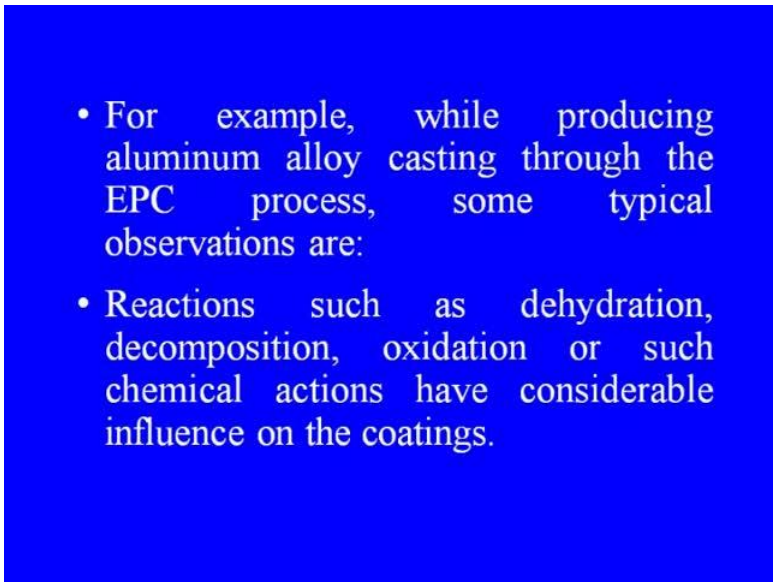

for example while producing aluminum alloy casting through the evaporative pattern casting process, some typical observations could be reactions, such as dehydration, decomposition, oxidation or such chemicals actions have considerable influence on the coatings. And this can be identified by easily, by using scanning electron microscopes.

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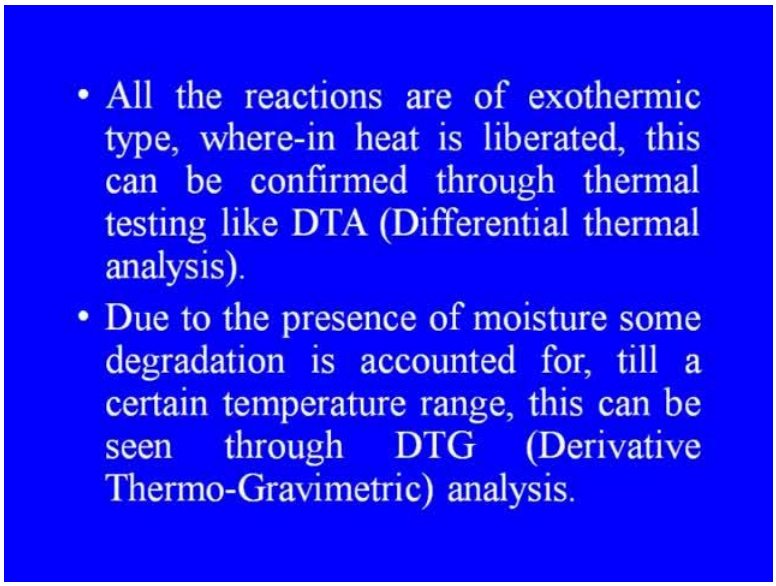

All the reactions are of exothermic type wherein heat is liberated. This can be confirmed through thermal testing like DTA or differential thermal analysis. Due to the presence of moisture, some degradation is accounted for till a certain temperature range. This can be seen through DTG technique or derivative thermo gravimetric analysis technique.

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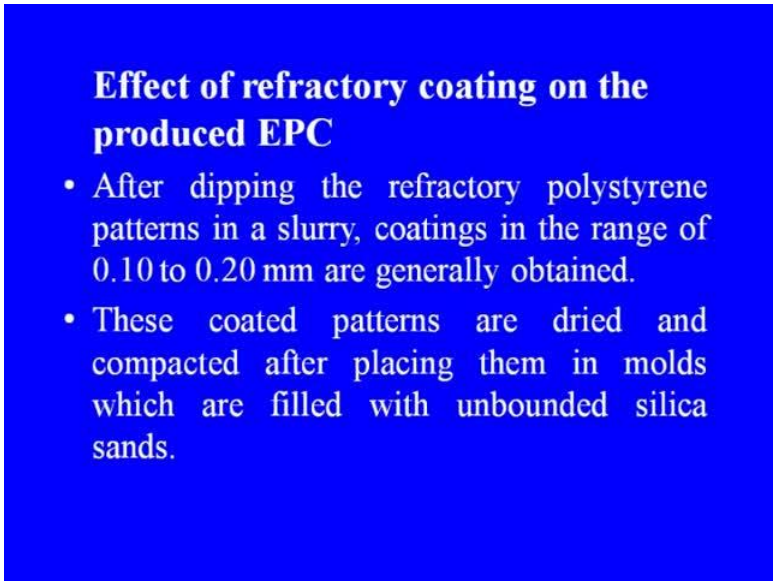

Now, we will see the effect of refractory coating on the produced evaporative pattern casting. After dipping the refractory polystyrene in a slurry coatings, in the range of 0.1

to 0.2 millimeter are generally obtained. These coated patterns are dried and they compacted after placing them in the molds, which are filled with unbounded silica sands.

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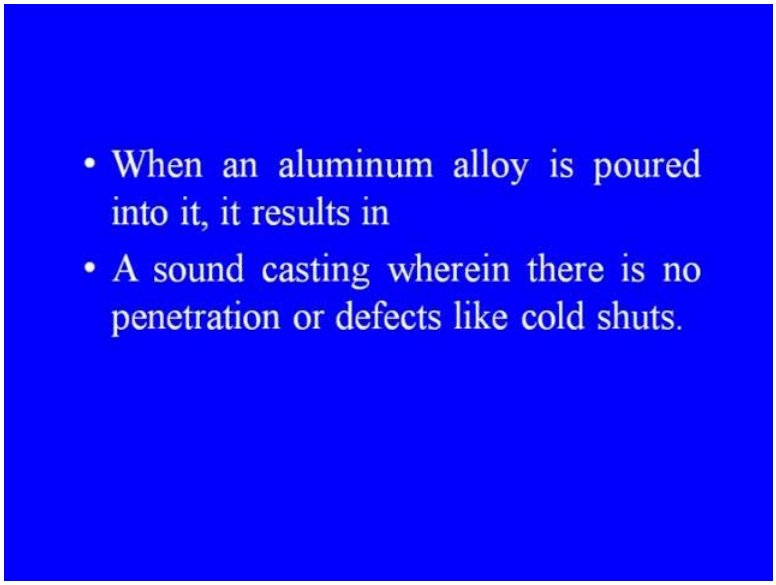

When an aluminum alloy is poured into it, it results in a sound casting wherein there is no penetration or defects like cold shots. As we know cold shot is a big problem associated with castings, this is considered to be a defect in casting and this can be identified with this.

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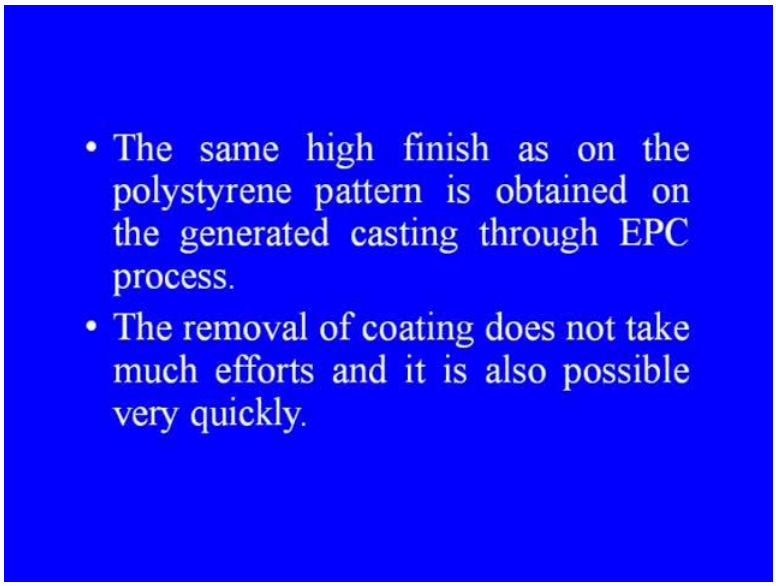

The same high finish as on the polystyrene pattern is obtained on the generated casting through evaporative pattern casting. The removal of coating does not take much efforts and it is also possible very quickly.

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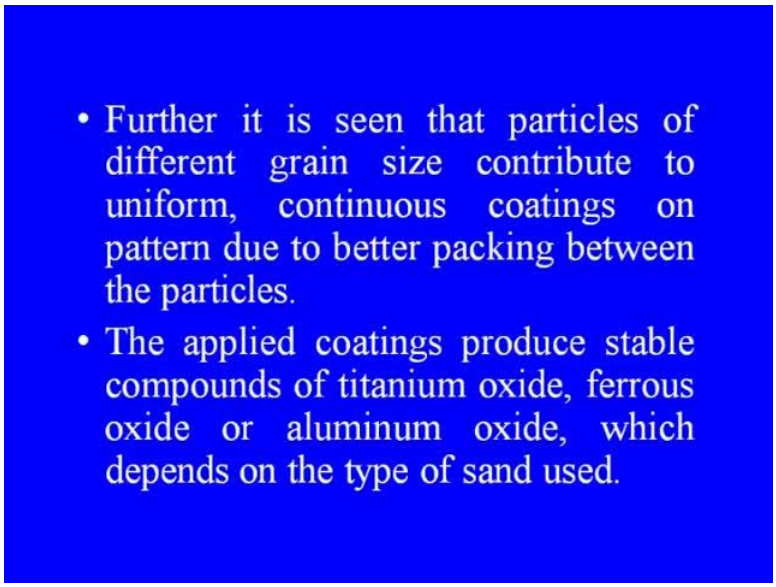

Further it is seen that particles of different grain size contribute to uniform, continuous coatings on pattern due to better packing between the particles. The applied coatings produce stable compounds of titanium oxide, ferrous oxide or aluminum oxide, which depends on the type of sand used.

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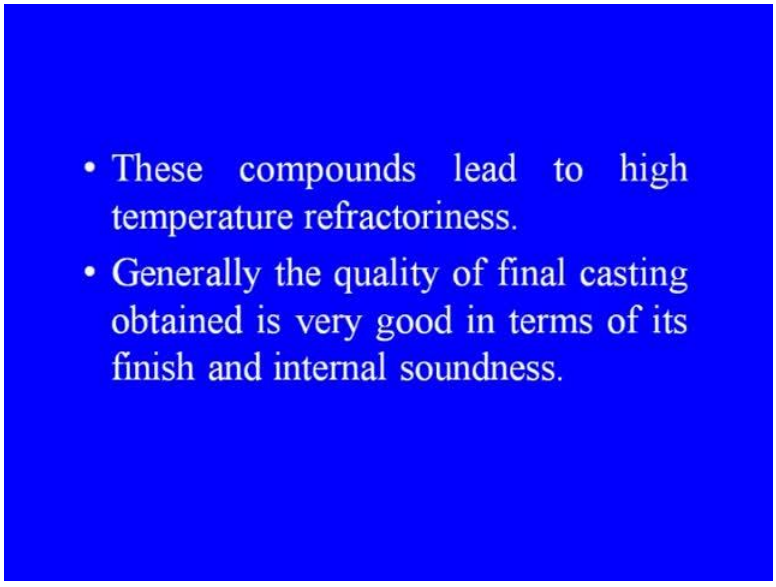

These compounds lead to high temperature refractoriness. Generally the quality of final casting obtained is very good in terms of its finish and internal soundness. Now, let us summarize what we have discussed in this session. In the present session, we have discussed about the basic evaporative pattern, casting process, the steps involved in making it, then the advantages of the process, disadvantages of the process and the setup details of this process. This setup basically we have discussed, which is developed in the IIT Roorkee itself. We have discussed some testing matters and effect of refractory coating on evaporative pattern casting process. We hope the session was informative.

Thank you.