Advanced Manufacturing Processes
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Module - 2
Advanced Metal Casting Processes
Lecture - 5
Set-Up of VEPC and Investment Casting Processes

Welcome to this session on vacuum sealed molding process, and investment casting process under the course on advanced manufacturing processes. Dear students, in this session we will study about further details on vacuum sealed molding process which we have already covered in our previous lecture, and some details on investment casting process. Let us see some details about the vacuum sealed molding process set up.

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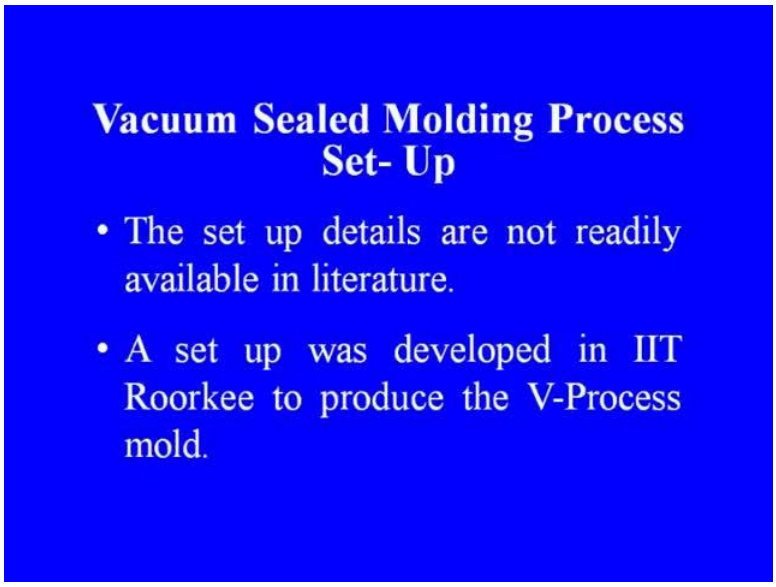

The setup details as such are not readily available in books or other published literature. However, a setup was developed in IIT, Roorkee to produce the V process mold. A photograph of this setup is shown in the figure one and the schematic of of the same V process setup is shown in the figure two.

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Here is the setup in your screen. So, here this is the vacuum pump which creates vacuum and this is connected to, this is the mold system where the vacuum connections are there and the table is given vibration through this motor arrangement.

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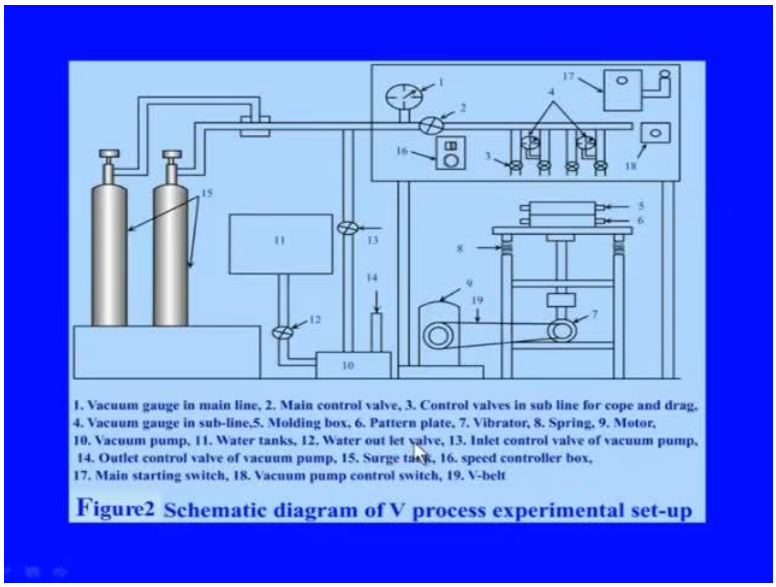

This can be further seen in this setup, schematic diagram, this is what the vacuum pump I was talking about in the previous photograph and then this is the vibratory system which shakes the table which is mounted on this spring mounted table. And this is the mold mold box, these are the connections for the vacuum which is connected through this and

these are some of the vacuum measuring devices. Let us see the molding system. The molding system in this process comprises of the equipment needed to prepare the mold. This includes the pattern box, molding box and the pattern.

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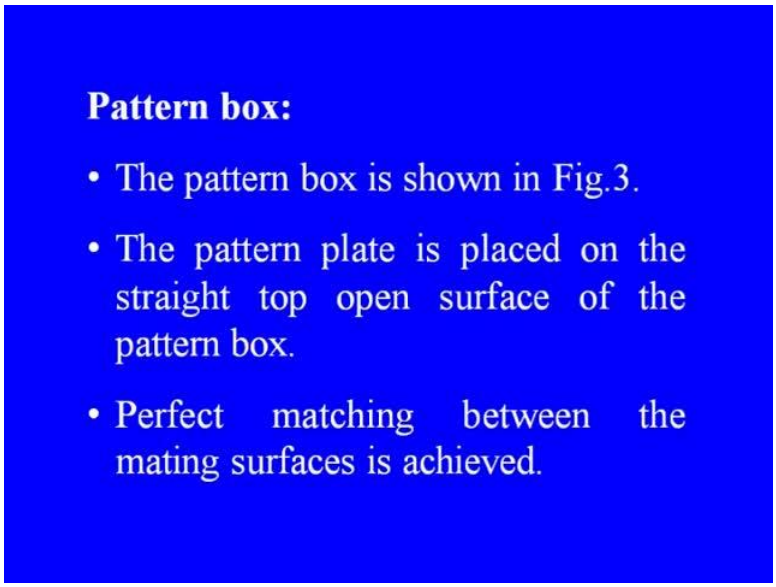

The pattern box is shown in the figure three. The pattern plate is placed on the straight top open surface of the pattern box. Perfect matching between the mating surfaces is achieved.

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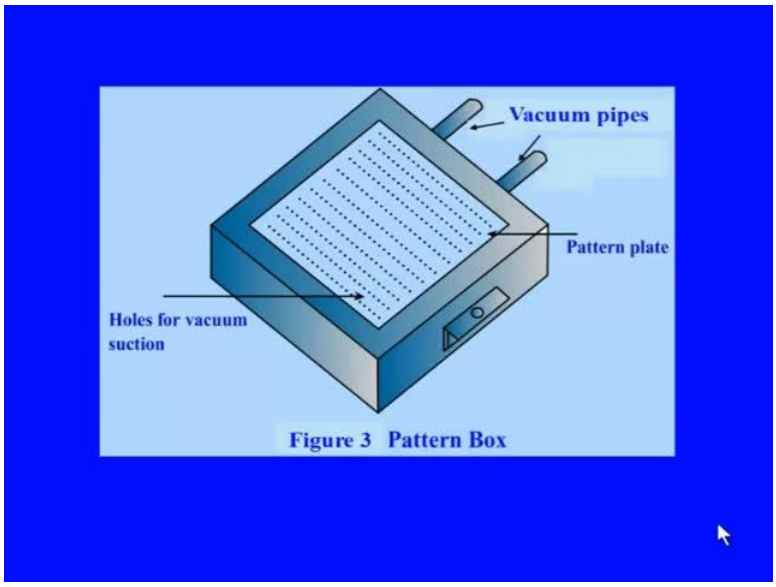

This is the pattern box, was talking about and these are the connections to the vacuum. One is for creating the vacuum and the other one is for releasing the vacuum. This is the pattern plate and these are tiny holes for vacuum suction. In order to ascertain the perfect matching the pattern plate having equidistant holes is provided with four support blocks at the four corners of the pattern box. Additional support at the centre has been provided to prevent vaping of the pattern plate when subjected to vacuum pressure. The pattern box is fixed to the vibrating table.

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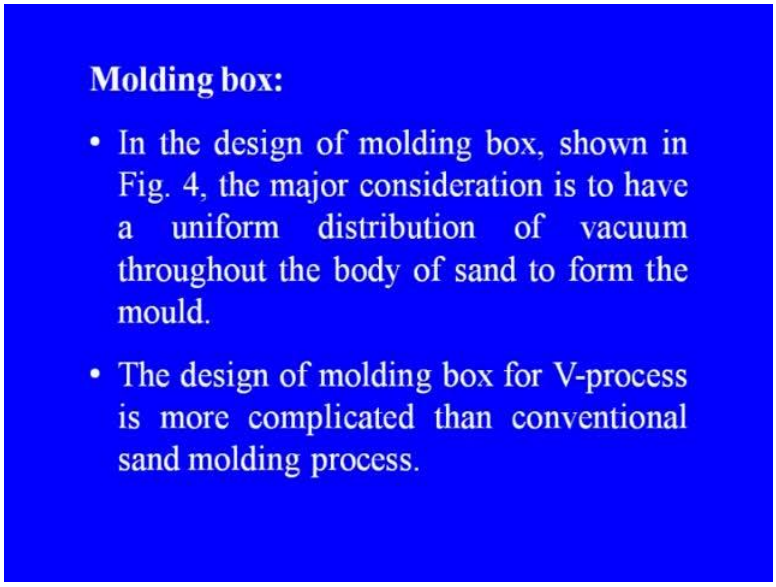

The molding box, in the design of molding box as shown in the figure 4, the major consideration is to have a uniform distribution of vacuum throughout the body of the sand to form the mould. The design of molding box for V process is more complicated than conventional sand molding process.

The box has to be made with annular wall on all the four sides. Inside walls are provided with windows, these windows are covered with very fine mesh and backed by a thin metallic strip having small holes for supporting the fine mesh. This mesh prevents very fine sand particles from being sucked up from the sand voids in the box into the vacuum pump.

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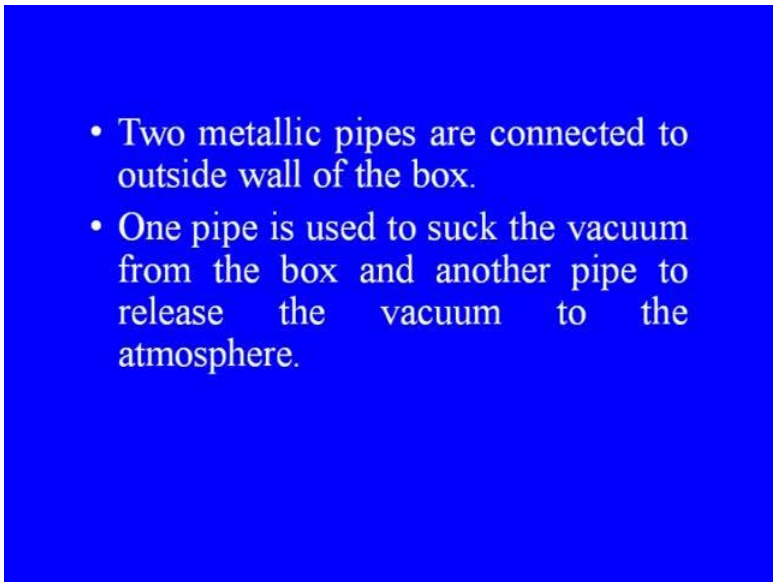

Two metallic pipes are connected to outside wall of the box. As I said one pipe is used to suck the vacuum from the box and the other pipe is used to release the vacuum to the atmosphere.

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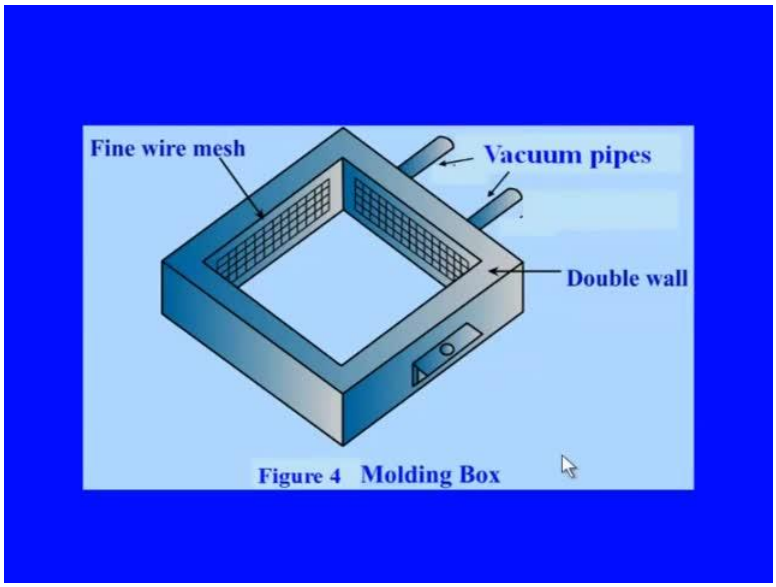

This is the molding box. A typical figure used in this process. This is the double wall box and this is the fine wire mesh system. The pattern, the patterns used in vacuum process are similar to the pattern used in other conventional sand casting processes. Numerous small holes are created on the vertical edges of the pattern used in the V process. Hence,

the plastic film correctly adheres to the vertical surface of the pattern thus creating the right cavity in the mould.

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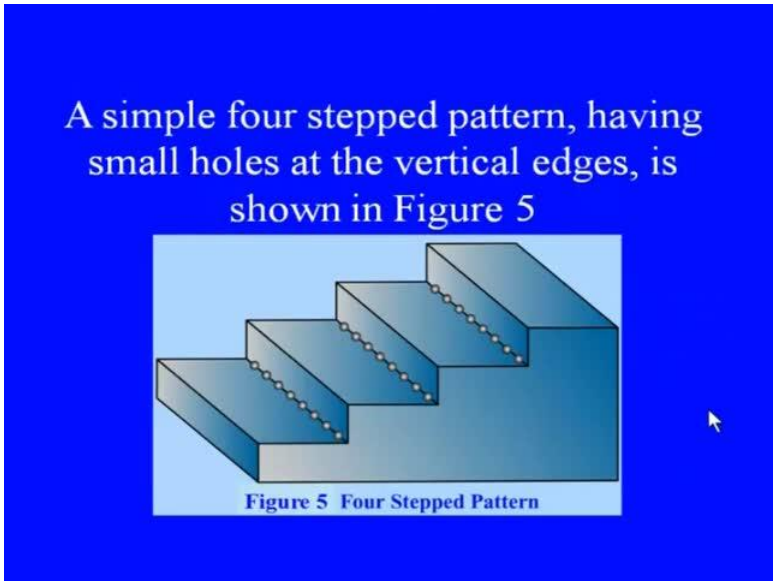

A simple four stepped pattern having small holes at the vertical edges is shown in this figure. These are the small holes and this is the four stepped pattern, the vacuum system. Vacuum is applied to the molding box containing sand to (( )) the mould as well as to withdraw the decomposed gases. It remains constant and active during pouring of molten metal till solidification.

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The vibrating system, the vibrating system is used to compact the sand. The vibration system must have a provision for varying vibration amplitude and frequency. The vibration system consists of a vibrating table; vibrator and digital drive motor, plastic film holding and the heating system. In order to prepare a mold to plastic polythene ethylene venyl alcohol films are used. The purpose of using two plastic films one on top and the other for bottom of the molding box is to seal the box.

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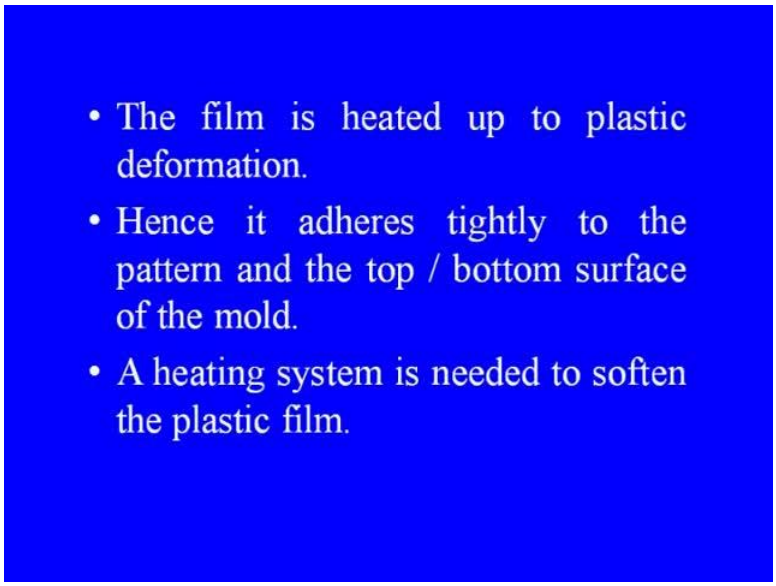

The film is heated up to plastic deformation. Hence, it adheres tightly to the pattern and the top or the bottom surface of the mold. The heating system is needed to soften the plastic film.

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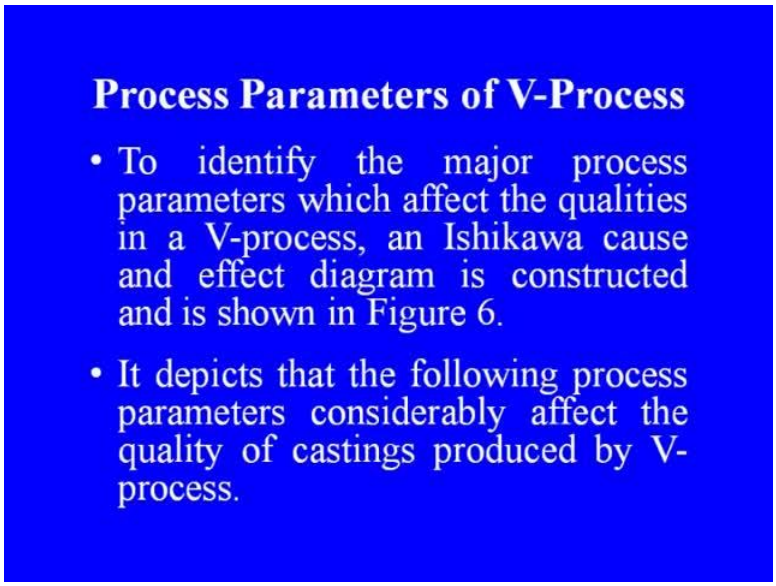

Now, let us see the process parameters of the vacuum process. In order to identify the major process parameters which affect the qualities in a V process, an Ishikawa cause and effect diagram is constructed and is shown in figure six. It depicts that the following process parameters considerably affect the quality of castings produced by this process.

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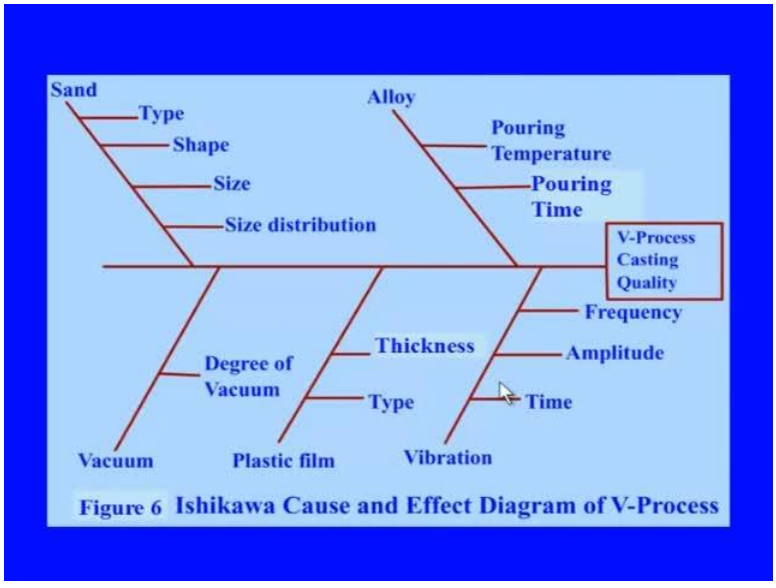

Here is the Ishikawa cause and effect diagram. These are the major parameters like sand. In sand the type of sand, shape of the sand, size of the sand and size distribution of the sand causes or can cause some quality best product parameters in this process. Then the

other parameter is the alloy based parameters. Here the pouring temperature and the pouring time are the main parameters that can affect the quality of the product.

The other group of parameters are vacuum based parameters in which the degree of vacuum is the main concern, then the plastic film in which type of the film and the thickness of the film are the two parameters that matters most. And then the vibration based parameters in which time of vibration, amplitude of vibration and then frequency of vibration affects the quality of the V casting process. Let us recollect the parameters once again.

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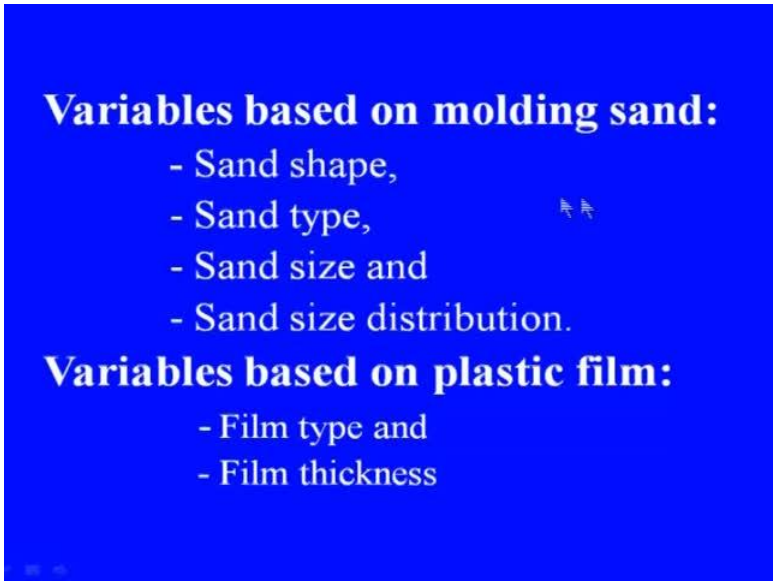

The variables based on molding sand, sand type, sand shape, sand size and sand size distribution. Then another group is variables based on plastic film in which film type and film thicknesses are of major concern. Next group is variables based on vibration in which amplitude and frequency of vibration apart from the time of vibration are of major concern.

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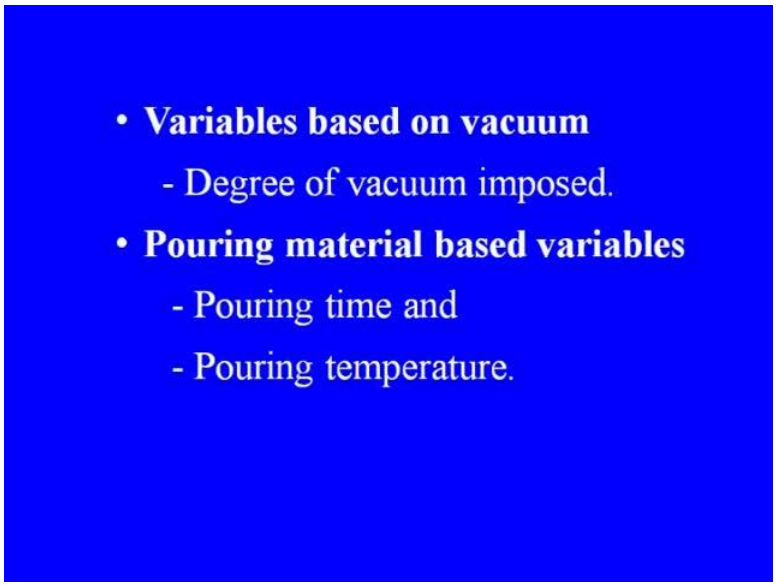

Then the variables based on the vacuum in which degree of vacuum imposed is the most important parameter. Then pouring material based variables, these are pouring time and pouring temperature. Now, let us move onto another important casting process that is investment casting process. In this investment casting process which is commonly referred to as the last wax method originated in and around the fourth millennium BC. It is evidenced through the architectural works found in the form of idols, pictorials and jewellery in remains of the ancient Egypt and Mesopotamia.

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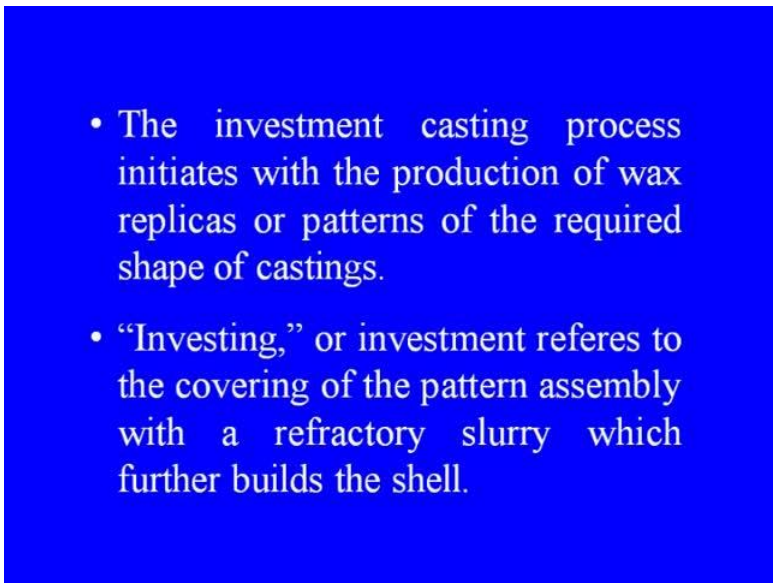

The investment casting process initiates with the production of wax replicas or patterns of the required shape of castings. Investing or investment refers to the covering of the pattern assembly with a refractory slurry which further builds the shell. The required shape is invested in the refractive coating which protects it. Each and every casting requires a new pattern to be produced from the master pattern which is made one time only. Wax or polystyrene is made used in the injecting material. The assembly of large number of patterns are made and attached to a wax sprue centrally.

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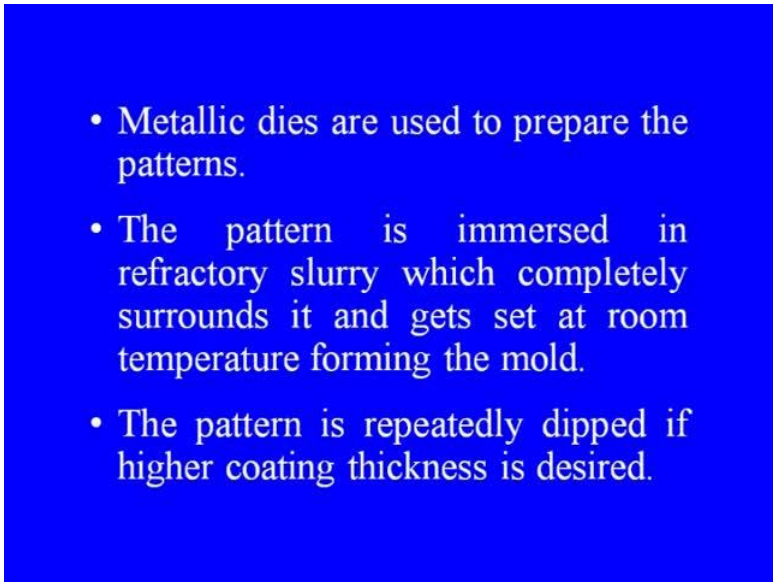

In this process metallic dies are used to prepare the patterns. The pattern is immersed in refractory slurry which completely surrounds it and gets set at room temperature forming the mold. The pattern is repeatedly dipped if higher coating thickness is desired. The mold is further heated so that the pattern melts and flows out leaving the required cavity behind. After heating the mold gets further hardened and molten metal is poured while it is still hot.

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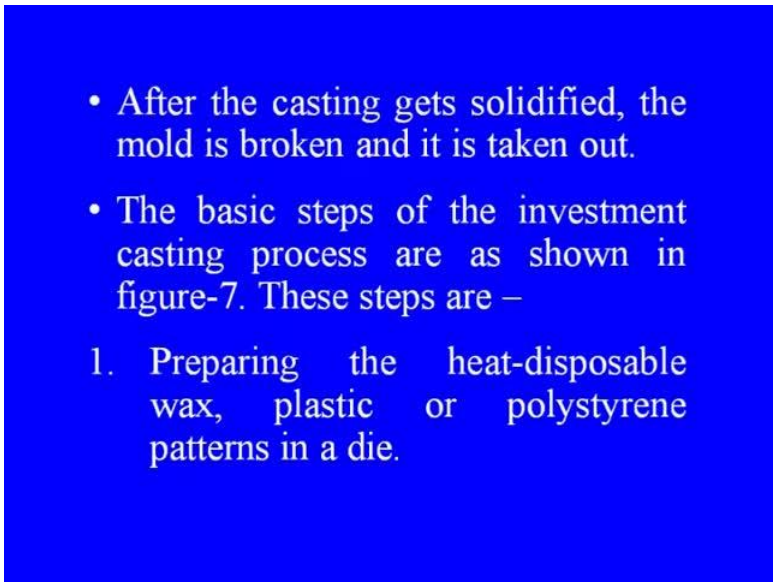

After the casting get solidified the mold is broken and it is taken out. The basic steps of the investment casting process are as shown in the figure seven. These steps are number one preparing the heat disposable wax, plastic or polystyrene patterns in a die.

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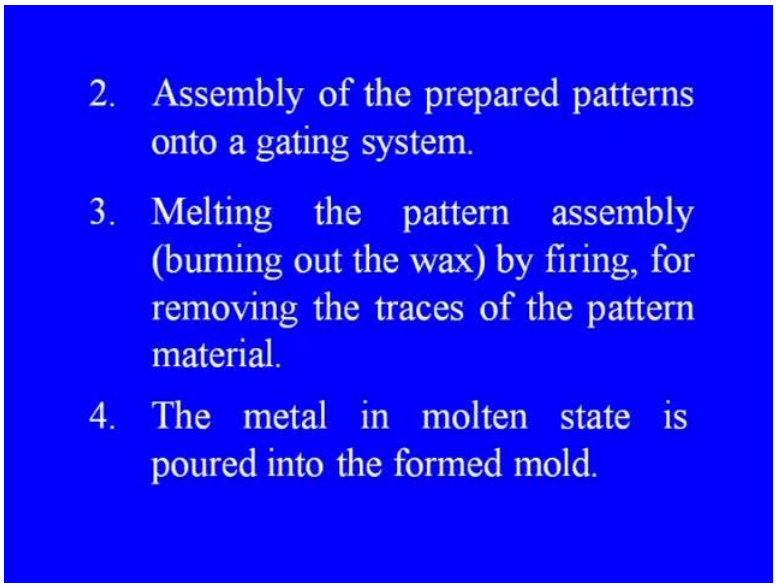

Number two, assembly of the prepared patterns onto a gating system. In step number three melting is done, melting of the pattern of the assembly also known as burning out the wax by firing, for removing the traces of the pattern material. In the next step the

metal in the molten state is poured onto the formed mold. Once, the metal solidifies the shell is removed or knocked out.

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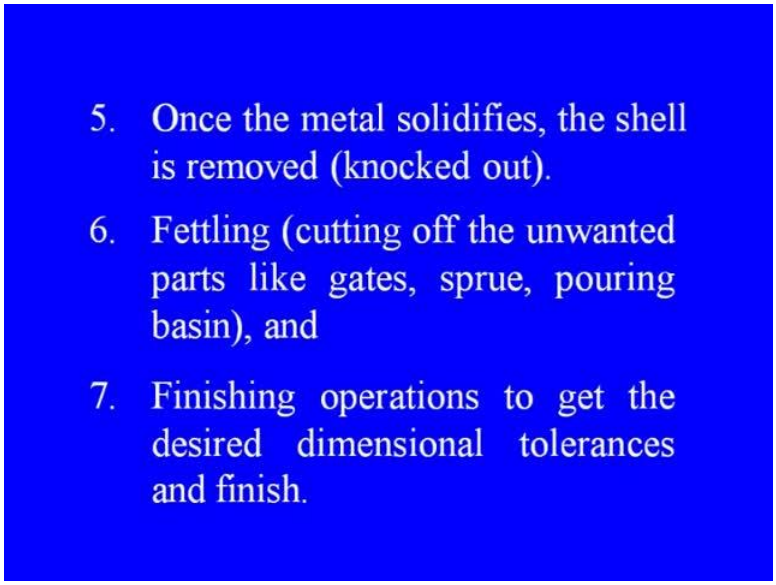

In the next step fettling which is nothing but cutting off the unwanted parts like gates, sprue, pouring basin etcetera is done which is followed by finishing operations to get the desired dimensional tolerances and surface finish.

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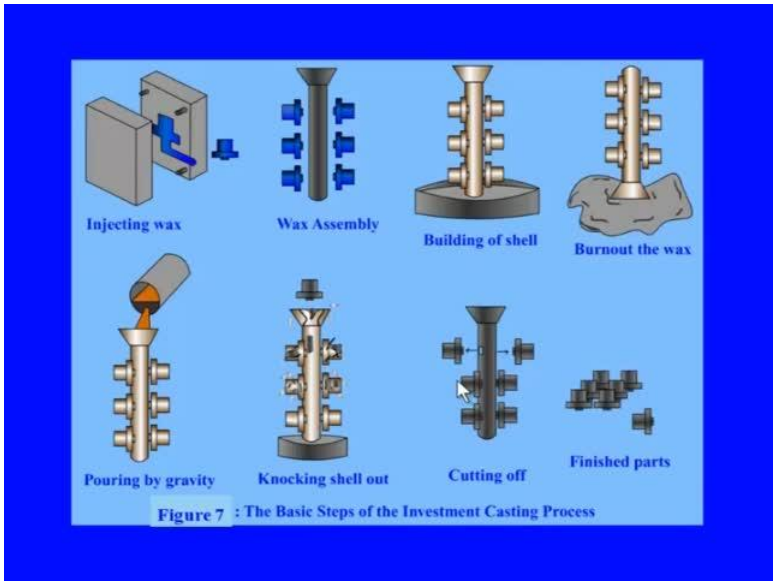

This is the pictorial representation of the sequence of the process. This is schematically shown how the injecting wax is being done. This is the wax assembly, these are the parts

are to be made, then these are, this is the, this type building of the shell and here the wax is burnt out, removed. Now, the mold is ready for pouring and the molten material is poured onto it. Next step, in the next step the shell is knocked out and followed by cutting off operation in which the finished parts are separated and finally, we obtained the parts like this.

So, from the mold of the parts we get the parts axel parts while coming through various steps like this in which we lose the wax we used in between. Now, let us see briefly the advantages of the lost wax method. In this process closed dimensional tolerances are possible, intricate geometries are easily obtained, alloys with higher melting points can also be easily cast. In this process the wax can be recovered and formed again into a new shape. This makes it advantageous. Wax is easy to save and work with and saves considerable time once the master pattern is ready.

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A single process gives excellent surface finish. Therefore, in most of the cases secondary surface finishing processes are not required. Hence, the material wastage is less as finish tolerances can be reduced. Now, let us also see the limitations of this process.

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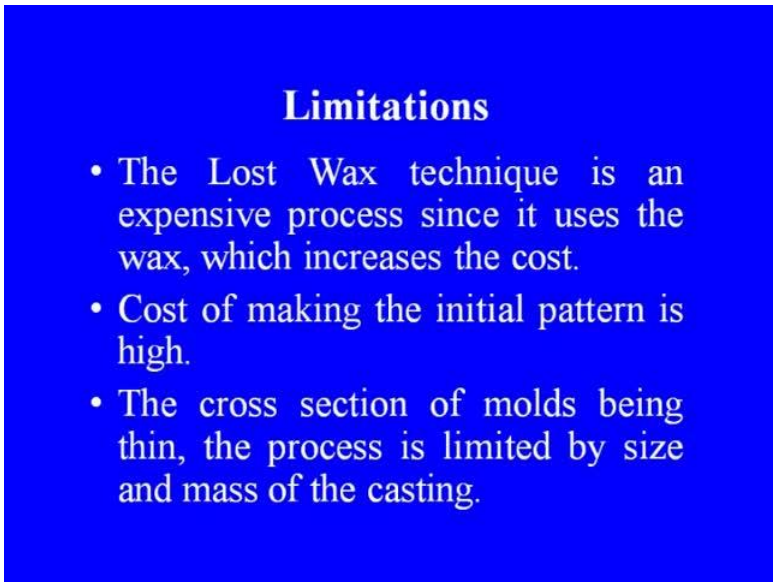

The lost wax technique is an expensive process since it uses the wax which increases the cost. Cost of making the initial pattern is very high. The cross section of molds being thin the pattern is limited by size and mass of the casting. The wax patterns require careful handling as their strength is not high and they are not strong as well in large lengths thin and fragile cross sections, the forces being too high to withstand during mold making. The quality of the pattern determines the quality of the casting. The removal of the wax from the mold again adds up time and cost.

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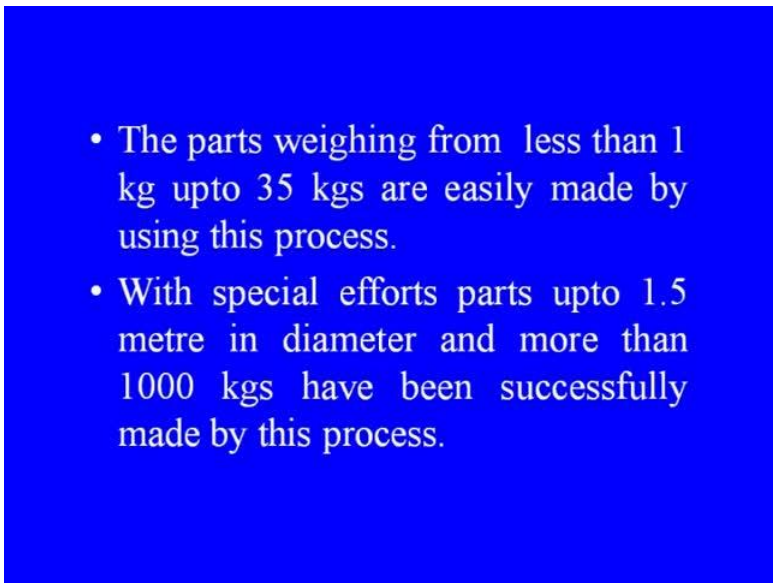

The parts weighing from less than 1 k g up to 35 kilograms can easily be made using this process. With special efforts parts up to 1.5 meters in diameter and more than 1000 kilograms have been successfully made by this process. Now, let us see the capabilities of the process.

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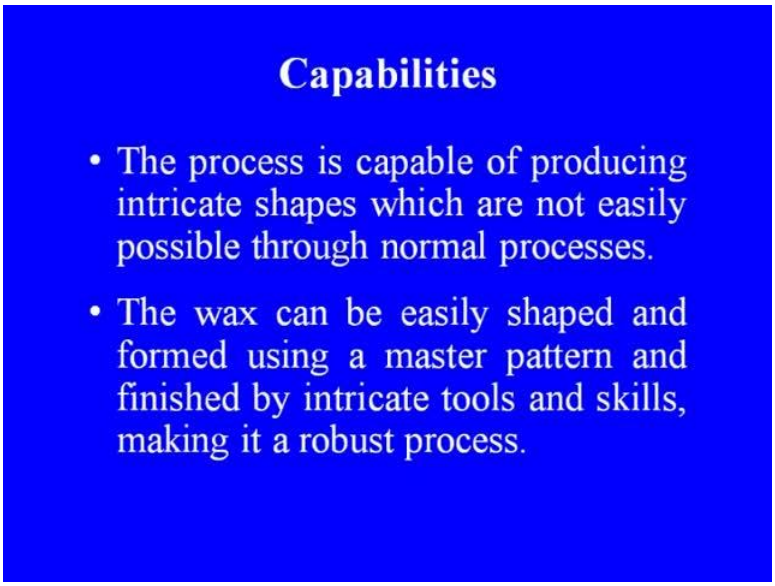

The process is capable of producing intricate shapes which are not easily possible through normal processes. The wax can be easily shaped and formed using a master pattern and finished by intricate tools and skills making it a robust process. Now, let us see the applications of investment casting processes.

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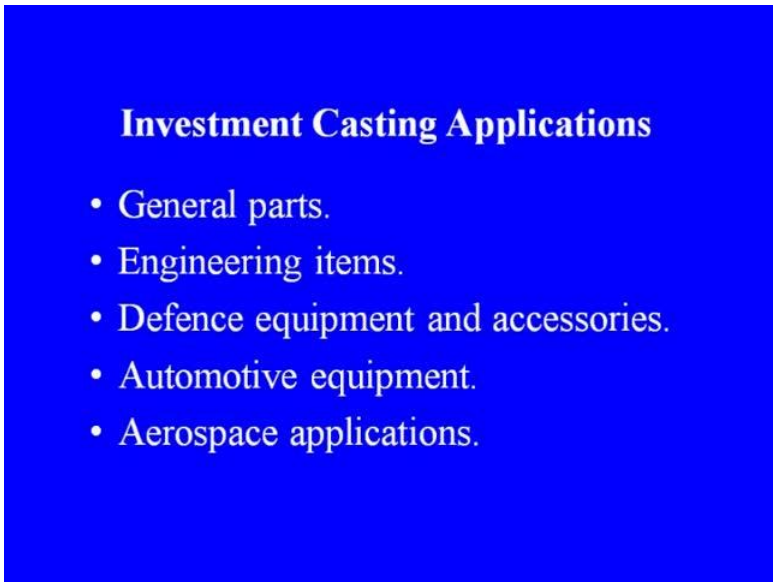

Generally almost all parts can be cast, engineering items, defence equipment and accessories, automotive equipment, aerospace applications, marine engineering applications…

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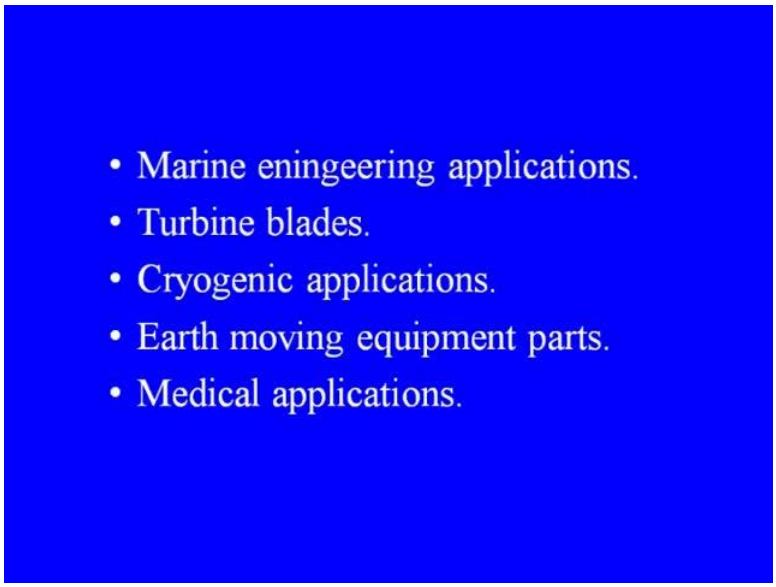

Turbine blades, cryogenic applications, earth moving equipment parts and medical applications.

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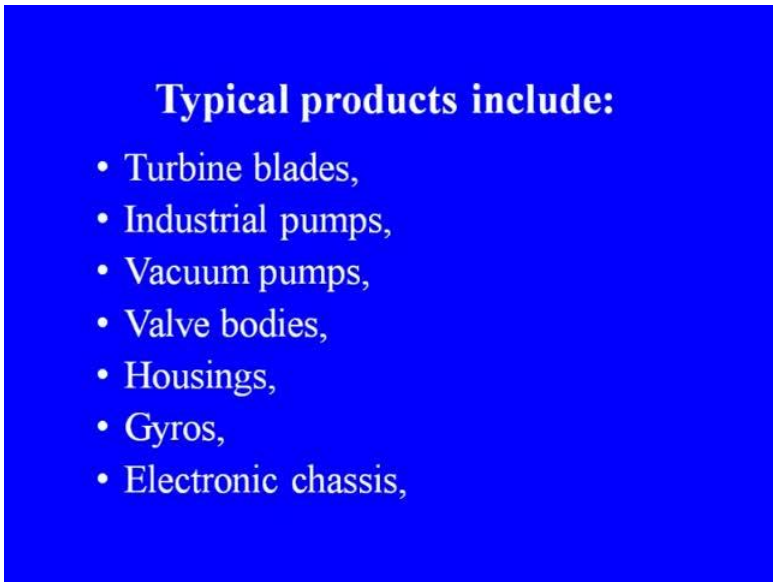

The typical products include turbine blades, industrial pumps, vacuum pumps, valve bodies, housings, gyros, electronic chassis…

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Gimbals, computer components, control panel for aircraft cockpits, structural glass fittings, components for office equipment, medical implants, jewellary and artistic applications etcetera. The process has got special applications in dentistry. Here the exact profile of the tool is extracted using a suitable wax mold. The soft wax material copies the shape of the tooth cavity.

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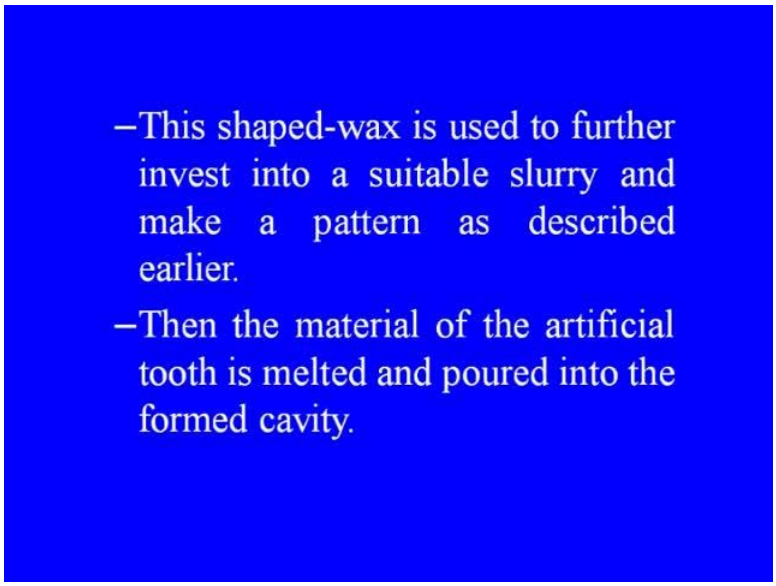

This shaped wax is used to further invest into a suitable slurry and make a pattern as described earlier. Then the material of the artificial tooth is melted and poured into the formed cavity. Upon cooling it gives the required shape of the tooth, it is further ground and shaped to fit into the requirement.

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Some of the products made using this process are shown in this screen. Let us discuss some more issues which are developed or discussed only in the recent times regarding this particular process, investment casting process.

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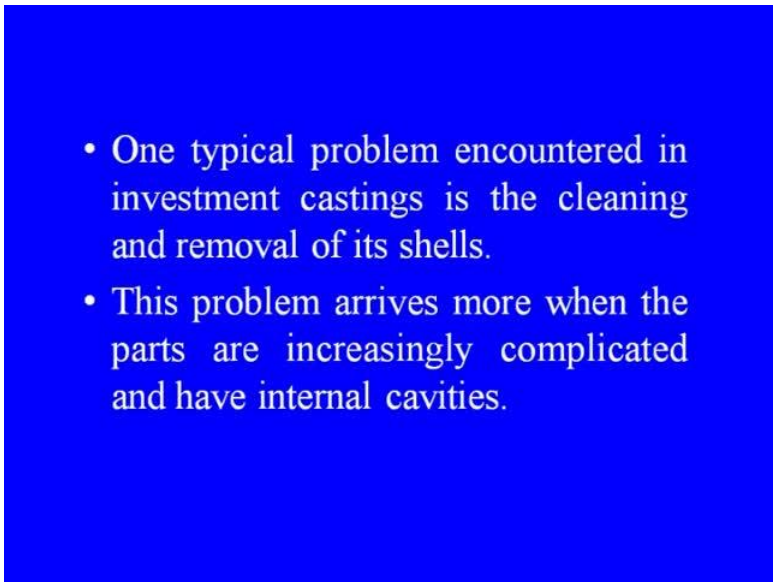

One typical problem encountered in investment casting is the cleaning and removal of its shells. This problem arrives more when the parts are increasingly complicated and have internal cavities. As we know as the parts becomes complicated or the complex cleaning those complex profiles is very, very difficult. First of all vexing those cavities or the profiles or small curves with the cleaning agent itself is a difficult task and therefore the cleaning the entire cast, the mold is a difficult task.

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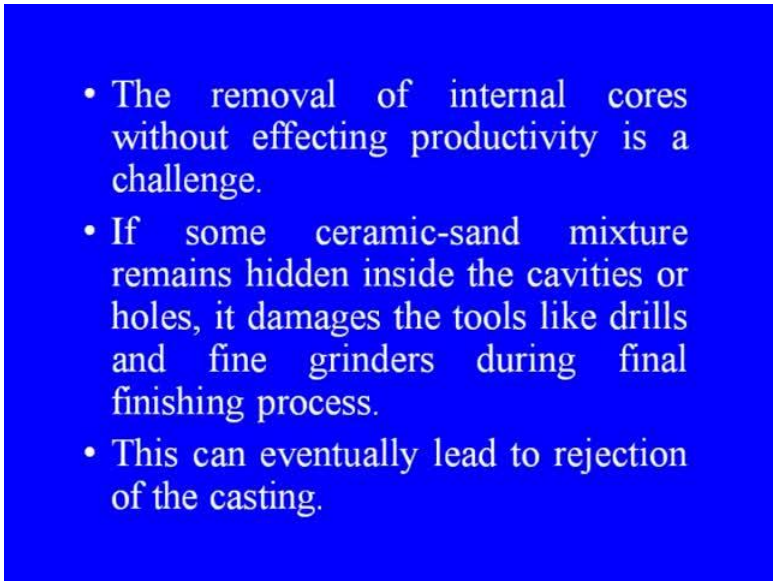

The removal of internal cores without effecting productivity is a challenge. If some ceramic sand mixture remains hidden inside the cavities or holes it damages the tools like drills and fine grinders during final finishing process. This is another important aspect why we should clean it very thoroughly. Some tools, it some tools they themselves may get deformed or broken if they are not cleaned properly. Therefore, the tool cost and on top of it the time for changing the tool increases. Therefore, it is a sensitive issue as per as this process is concerned which can eventually lead to the rejection of the casting itself, which draws very high cost and in any case this should be reduced to a minimum.

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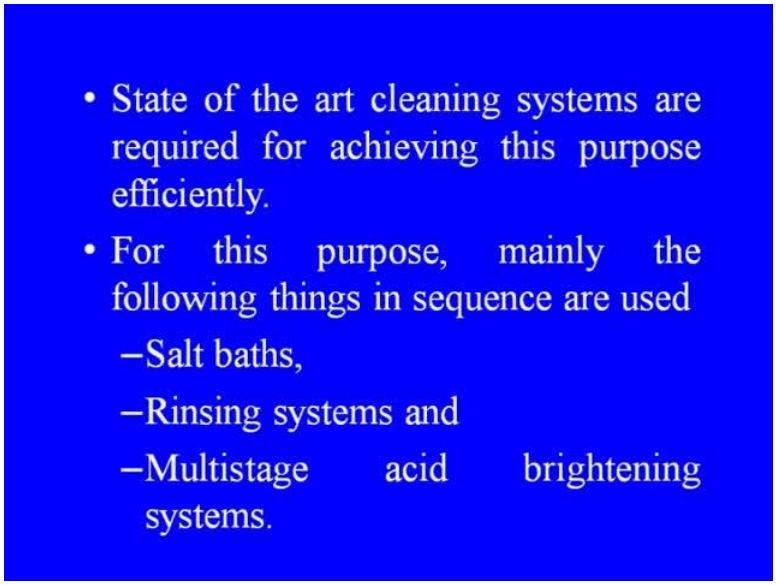

State of the art cleaning systems are required for achieving this purpose efficiently. For this purpose mainly the following things in sequence are used. Number one salt baths which will be able to remove most of the things from the body, then rinsing systems which will further remove those which are still sticking, then multistage acid brightening systems. If there are any further the acid will remove them with their reactive nature.

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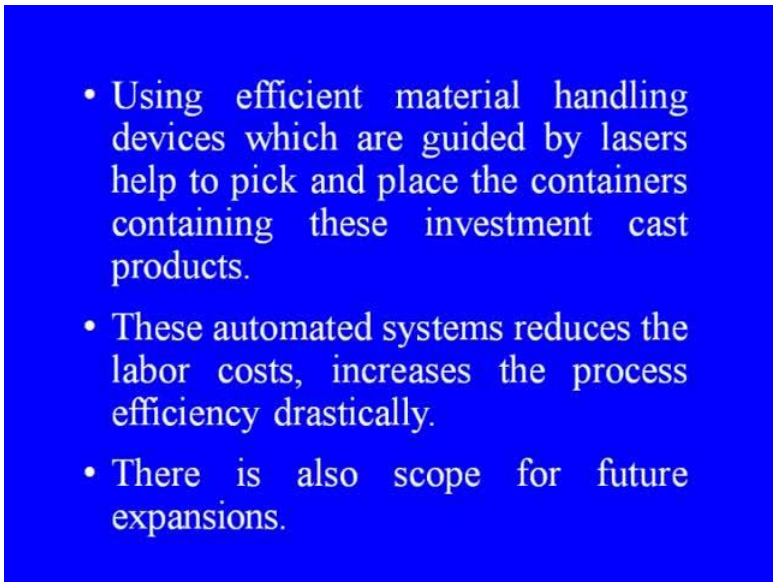

Using efficient material handling devices which are guided by lasers help to pick and place the containers containing these investment cast products. This is another important aspect. Generally laser guided pick and place systems are used. These automated systems reduces the labor cost, increases the process efficiency drastically. In another session earlier also we have indicated, discussed different aspects of the benefits of automation.

In the first place it reduces the (( )) error drastically where human being are prone to errors and in another case it increases the process efficiency and reduces of course, the labor cost as well. Labor cost which is a running cost and with time it increases and at times it is difficult to control labors as well depending on the availability of the skilled labors. In all these cases use of automated systems can help the industry to a great extent in achieving their productivity very well.

There is also scope for future expansions. Now, let us discuss few desired properties of wax used in patterns. As we have already discussed on few occasions wax is one of the material which is highly sought after in the casting industry, foundry industry and let us see what are the different desirable properties one can expect with wax.

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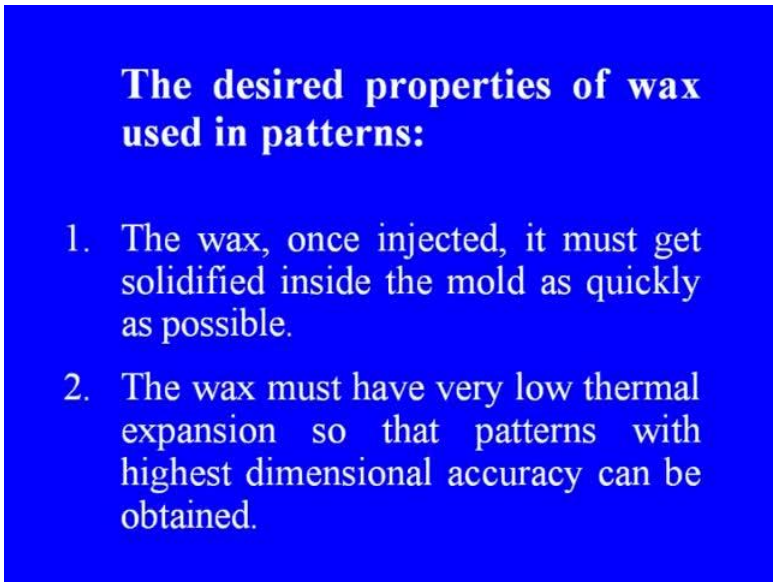

Number one, the wax once injected it must get solidified inside the mold as quickly as possible. So, longer the time to take, get solidified lower will be the productivity.

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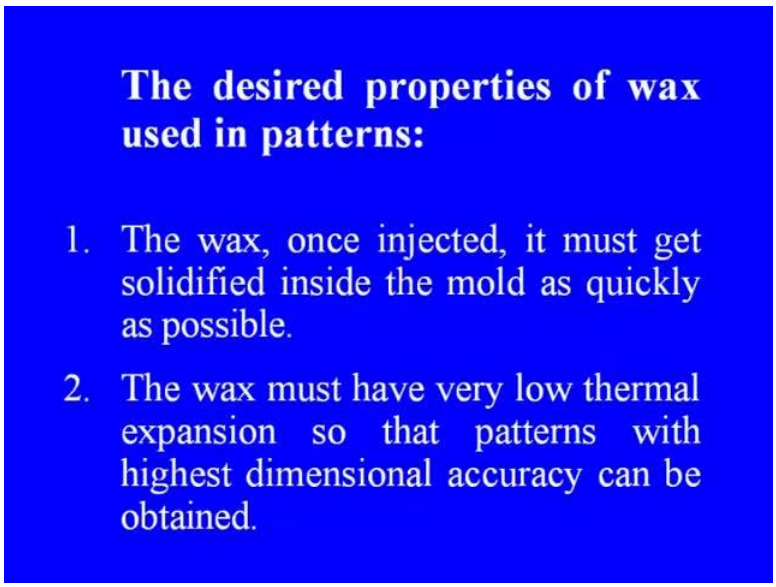

The number two, the wax must have very low thermal expansion so that patterns with highest dimensional accuracy can be obtained. This is another very important aspect as far as the accuracy of the product are concerned. The product accuracy will depend to a large extent to the accuracy of the pattern and pattern on the other hand will depend, the accuracy of the pattern will depend on the material of the pattern. Therefore, the wax we

are using if we are using as pattern material they should have low thermal expansion, so that the pattern with highest dimensional accuracy can be expected.

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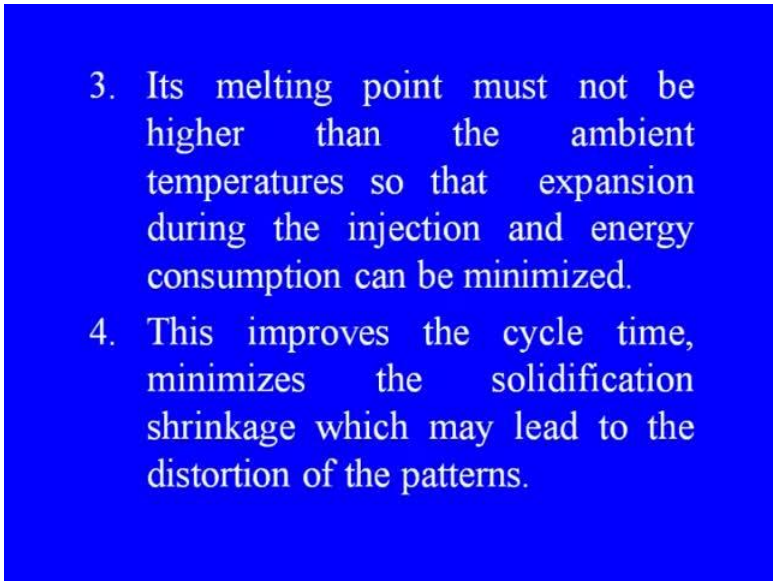

The melting point of the wax also must not be higher than the ambient temperatures so that expansion during the injection and energy consumption can be minimized. This improves the cycle time, minimizes the solidification shrinkage which may lead to the distortion of the patterns. This solidification shrinkage aspect we have already discussed and it is also very common thing as far as the foundry technology concerned that higher the solidification shrinkage worse will be the pattern produced. Therefore, shrinkage in the pattern material should be minimum as it gets solidified. That will ultimately effect the accuracy or the quality of the part being produced using this pattern.

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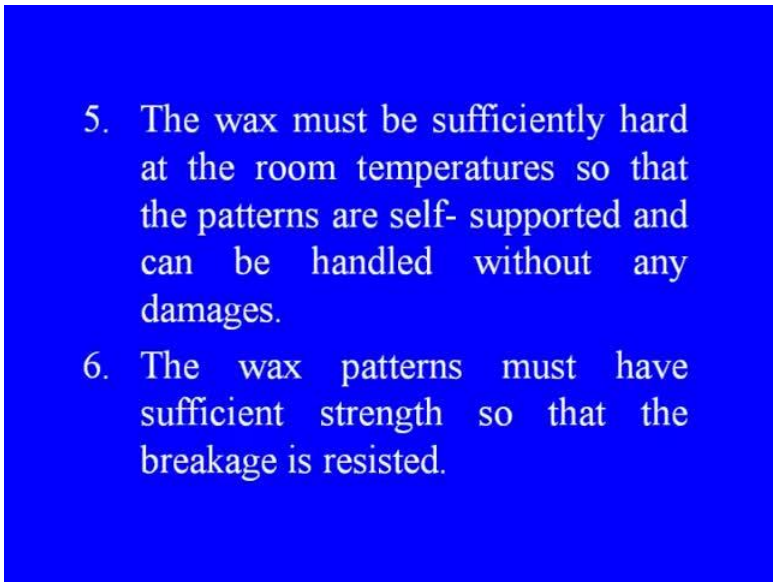

Number five the wax must be sufficiently hard at the room temperature so that the patterns are self supported and can be handled without any damages. This is another important aspect. Handling also should be easier otherwise the cost incurred in handling will be much more.

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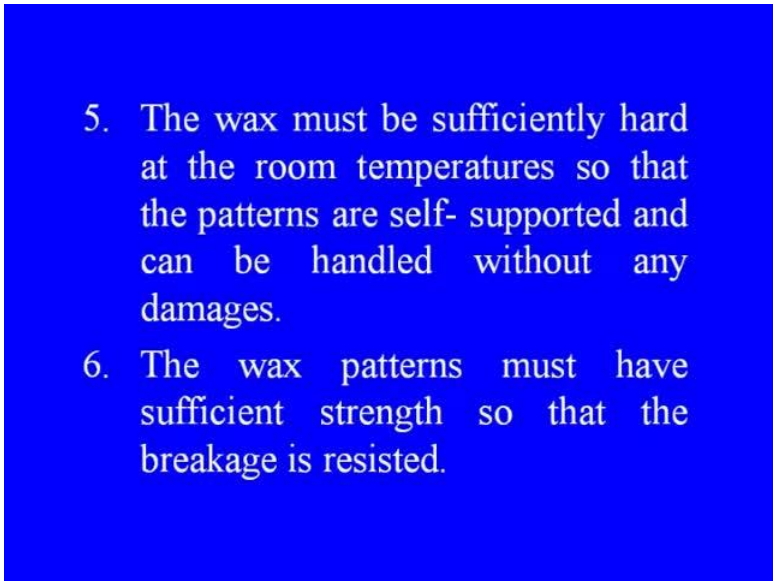

Number six, the wax patterns must have sufficient strength, so that the breakage is resisted. This is another mechanical consideration as far as the pattern is concerned.

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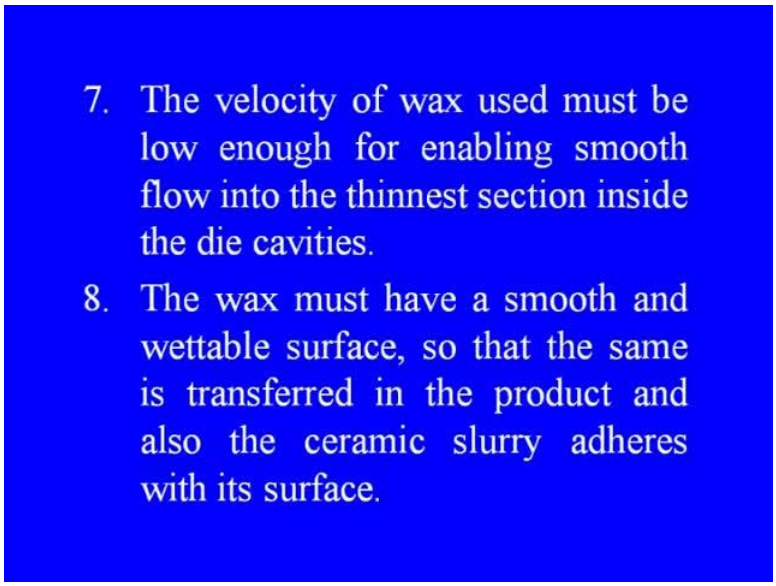

Number seven, the velocity of wax used must be low enough for enabling smooth flow into the thinnest section inside the die cavities. If the velocity is high there will be a risk of turbulent as well as erosion of the mold walls and thereby we may be losing or there will be a risk involved in losing the part information or the pattern information. Therefore, it should be possible to use at low velocity so that there is distortion can be kept at minimum.

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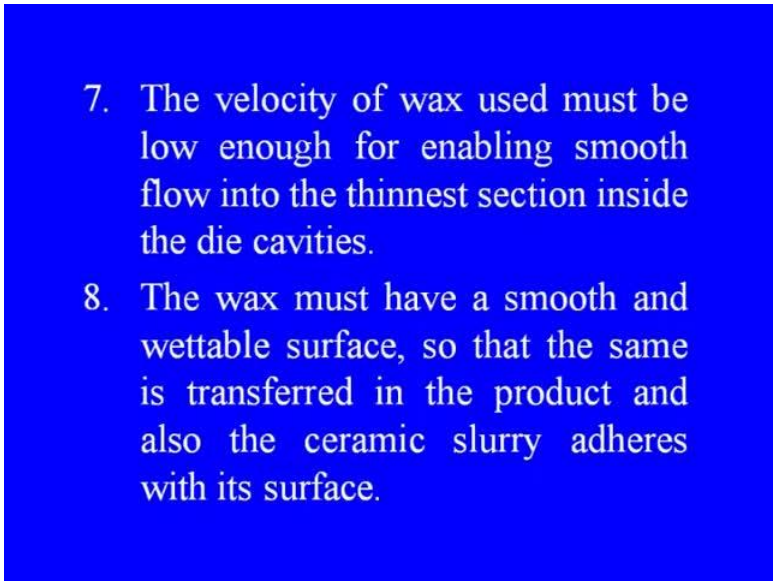

Number eight, the wax must have a smooth and wettable surface so that the same is transferred in the product and also the ceramic slurry adheres with its surface, another important point. So, better the smoothness of the surface of the pattern better will be the surface of the part or the cast being produced and generally, wax will offer a better surface finish as far as the patterns are concerned.

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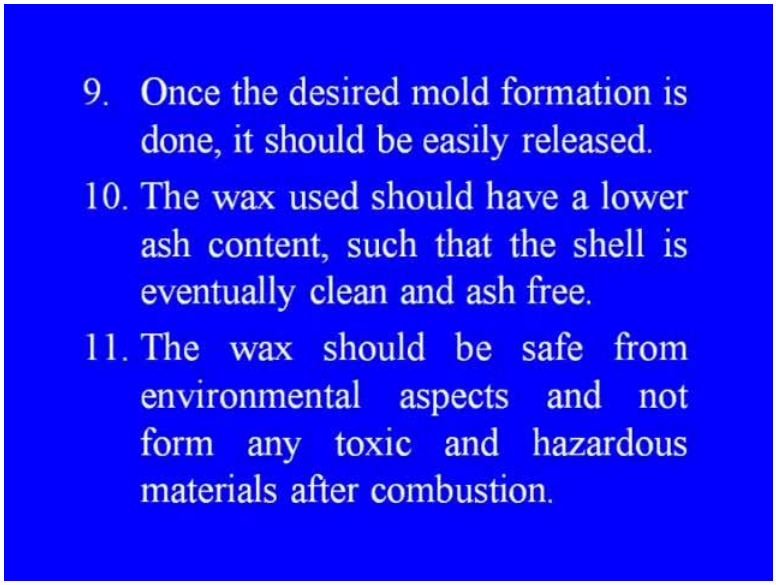

Number nine, once the desired mold information is done it should be easily released, another important point. Number ten, the wax used should have a lower ash content such that the shell is eventually clean and ash free. As we know investment casting the pattern is invested or lost. Therefore, if during the process ash is produced then it might add to the impurity in the product, cast product itself. Therefore, it is desired that the wax should not leave behind some ash as the remaining product or the remaining material.

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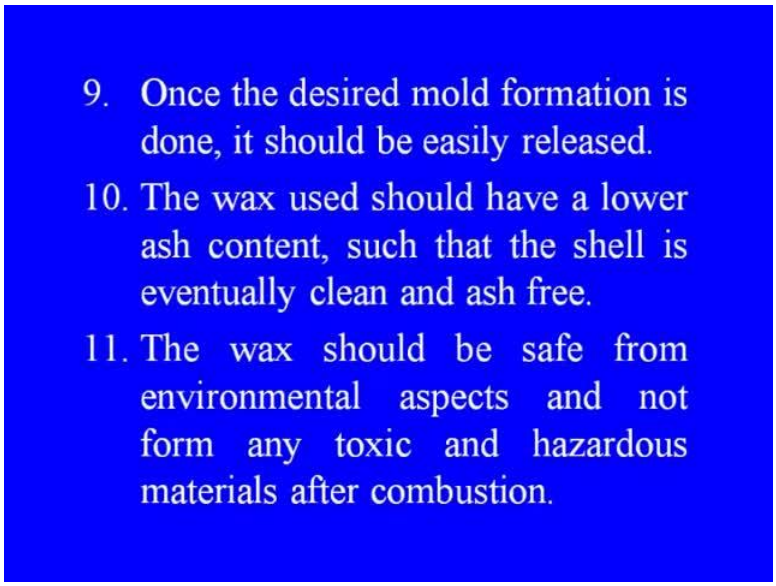

The number eleven, the wax should also be safe from environmental aspects and not form any toxic or hazardous materials after combustion. It is evident that this wax will be subjected to a high temperature that is the melting temperature of the molten material or the molten alloy system which will be used for casting. Therefore, at that temperature while coming in contact with that molten material this wax should not produce any toxic fumes or any other toxic gases which could be detrimental for the entire unit or for the concern personnel who are working in that.

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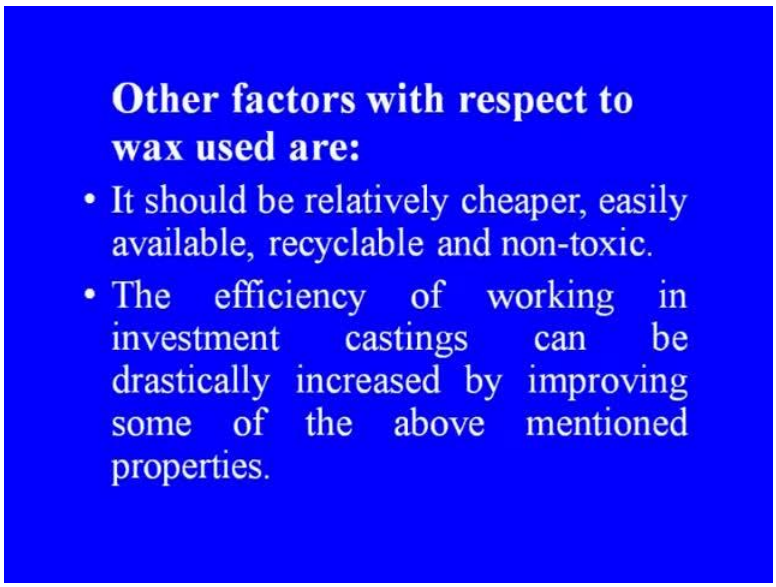

Let us note few other factors with respect to wax. It should be relatively cheaper, easily available, recyclable and non toxic as we have already indicated; availability is also a major concern particularly when we will be going for number of parts. So, huge amount of raw materials for this pattern will be required. Then the efficiency of working in investment castings can be drastically increased by improving some of the above mentioned properties.

Now, let us summarize what we have studied in this session in this session we have studied the setup details of vacuum sealed molding process and investment casting process. Also we have seen some important considerations regarding wax which is a vital component in this entire system. We hope the session was informative and interesting.

Thank you.