**Processing of Non-Metals**
**Prof. Dr. Inderdeep Singh**
**Department of Mechanical and Industrial Engineering**
**Indian Institute of Technology, Roorkee**

**Lecture - 6**
**Compression Molding**
**Module - 5**
**Polymer Matrix Composites: Processing**

Good morning to all of you, today we are going to discuss the basic principle, advantages, limitations and applications of the process compression molding. Before we start our discussion on compression molding, we are going to discuss what we have covered till now in this particular module. As you know in this particular module, our focus has been on the processing of polymer matrix composites or we can say polymeric matrix composites.

We have seen that what is the challenge of selection, why new and new materials are required? We have seen the basic concept of the polymer matrix composites, we have seen the comparison of polymer matrix composites with other conventional engineering materials. We have also seen that how the concept of polymer matrix composites is important in today's engineering scenario. Then we have seen that how to blend the two macro constituents together or how to make a composite material, the basic concept of a composite?

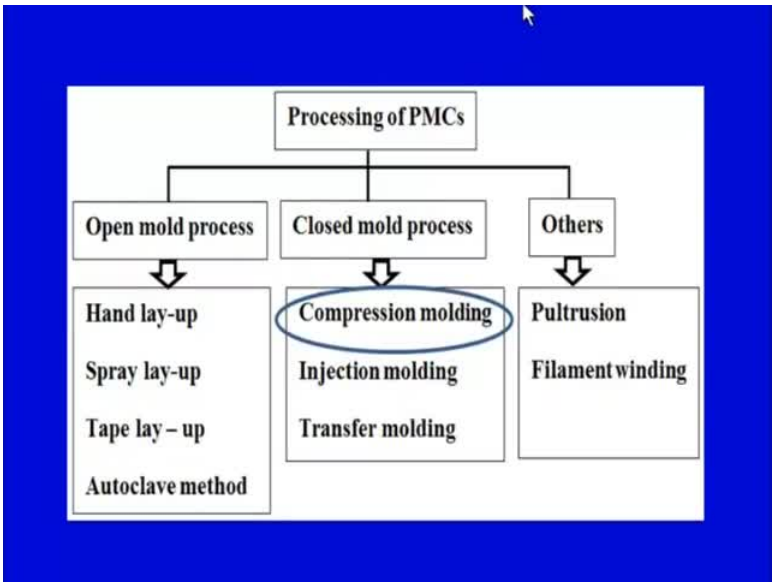
We have seen three processes till now, we have seen the basic principle, advantages, limitations and applications of the hand layer process, the spray layer process and the pultrusion process. We have also seen that how the various processes for processing of polymer matrix composite can be classified broadly. So, today we will start our discussion with a broad classification of the processes which are used to fabricant products of polymer matrix composites. And then we will see where does compression molding fit in to that particular diagram.

After seeing the role of compression molding in the fabrication of polymer matrix composites or processing of polymer matrix composites, we will see that what is the process? What is the procedure or what is the step followed in the process? What are the steps followed in the process? Then we will see that what are the advantages what are the

limitations and what are the applications of the products or the applications of this particular process?

Also during our discussion we will focus on the control variables, the various processing parameters that we have to consider when we are making a product, when we are fabricating a product, when we are processing a product using the compression molding process. So, all these things we are going to study today in this particular lecture on compression molding. This is under the module 5 in which we are discussing the processing techniques for polymer matrix composites. So, let us start our discussion on compression molding. Now, this diagram you have already seen in some of the previous lectures

(Refer Slide Time: 03:18)



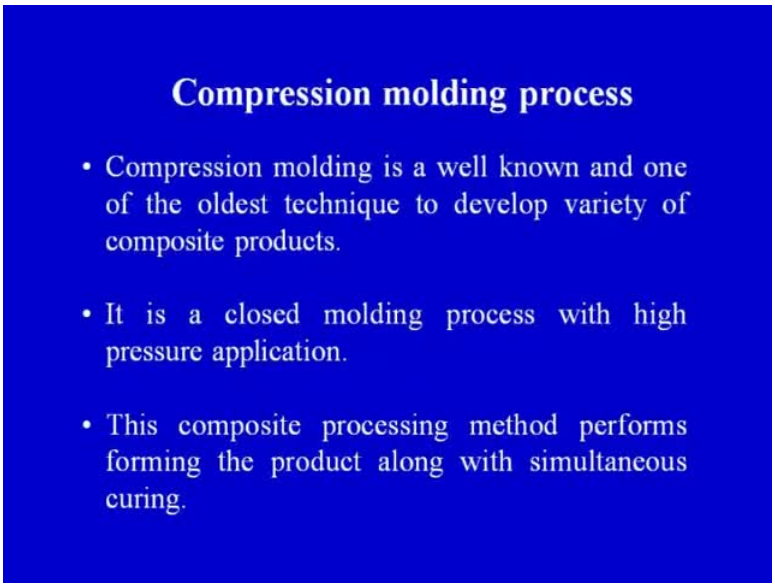

This gives the classification of the various process for processing of polymer matrix composites. So, on your screen you can see the processing of polymer matrix composites can broadly classified into three; open mold process, closed mold process and others. Here you can see in open mold process you have hand layup, spray layup, tape layup, autoclave method. In closed mold process you have compression molding, injection molding, transfer molding and in others you have pultrusion and filament winding.

So, we are covering one process at a time in open mold process, we have seen hand layup process and spray layup process in the previous lectures. In the other type of process we have seen the pultrusion process. So, today we are going to see what do we

need by the compression molding process? In case of hand layup also, we are applying the pressure but, the pressure is not applied up to that extend. It is a hand layup and whole process is manual.

In case of compression molding we have a compression molding set up, in which we have a closed form of mold, in which the raw material is kept and it is pressed between the two die halves or two mold halves that we will try to understand with the help of a diagram. So, there is a difference between the hand layup process and that compression molding process although principally that two may be set to be having the same principle. So, let us start now the basic details about the compression molding process.

(Refer Slide Time: 03:18)




Compression molding is a well known and one of the oldest technique to develop variety of composite products. So, if we go into the details of this particular statement, it gives us that it is a very versatile process, it is a very old process because it can develop variety of composite products. So, it is a old process and it is a versatile process because of its ability to develop or process of variety of composite products. It is a closed mold process with high pressure application.

As I have already told in a hand layer process it is a completely manual process in which pressure is applied is not very high, but in compression molding as you see on your screen in point number two, it is a closed molding process and it applies high pressure application. So, it is a high pressure application the pressure is applied on the raw

material, which has to be made into the final product. This composite processing method performs forming, forming the product along with simultaneous curing. So, here the curing also takes place simultaneously.

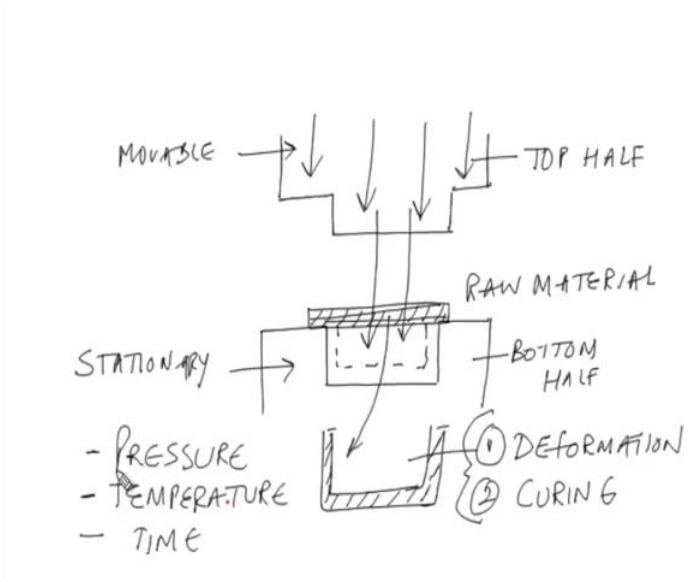
So, one of the difference between one of the process is which we have already seen that is the pultrusion and the compression molding is, in case of pultrusion the continuous products come products comes out of the final die. As we as seen in the case of pultrusion process the fibers are coming there impregnated in the raisin bar, they enter the performer from performer they are given a shape and finally, they enter into the die. The die is in the heated condition and out of the die we get a cured product, final product and it is on a continuous basics. So, pultrusion is a continuous process whereas the compression molding process is a discrete process.

Here the products will be made in discrete shape we will have one product at a time. Although the process may be continues in which after one cycle we will go for another cycle. Suppose we undertake 100 cycles, in 100 cycles we will get 100 products. But one particular discrete product would be made in case of a compression molding process. So, the last point emphasizes this point that is composite processing method performs forming the product along with the simultaneous curing. So, it performs the action of forming as well as simultaneous curing.

So, it will deform the raw material into the final product as well as the curing process will also take place. So, what do we mean by curing? Curing is a process of conversion of the raw material into the final solid product. It can also sometimes is used the name again is used as polymerization sometimes. So, basically this is a process in which the deformation and the curing conversion from a semi solid state to a fully solid state takes place simultaneously. So, we have a particular die end a mold halve we have sorry, upper die and a lower die or we have two mold halves in which the raw materials is kept.

Then the pressure is applied that time temperature is maintained and after that we get a final product, after the curing is completed. So, we have to set the curing time that after this much amount of time or after time t the mold halves would open and the final product would be taken out. So, the process is fairly simple process. As you can see, I am drawing a very simple diagram.

(Refer Slide Time: 08:24)




So, on your screen you can see a diagram in which I have shown that top half of the mold. This is the top half and on the contrary we have on the opposite side a bottom half, a bottom half. This is the bottom half of the mold. Now, pressure is applied from the top and the bottom halve is stationary. The raw material is kept on the bottom halve of the mold. This is the raw material and when a pressure is applied the opening between the top half and the bottom half. This particular raw material would be deformed into that particular shape.

So, here we can make this type of a product using this type of a top and the bottom half. So, we can see this particular raw material will get deformed like this, when the top half of the mold come down. So, this is the, suppose the final product that we are going to get out of the compression molding process. So, here we can see we have a top half of the mold we have a bottom half of the mold and we have a raw material. And this raw material is a composite material. The bottom half is stationary and the top half is movable.

The top halve would be brought down and it will compress the raw materials in between the cavity generated between the top and the bottom half of the mold. Finally, we will get the raw material converted into the final product. So, basically during the process of conversion, two things have taken place as we have seen on the slide. One is the deformation which has taken place. A flat raw materials has en converted into the desired

shape and the process of curing also has taken place. The process of curing and deformation has taken place simultaneously and the raw material has been converted into the final product.

So, this is the basic principle of the conversion molding process. But there are few which have to be kept in mind, that what should be the thickness of the raw material, that will depend upon the final thickness of the final product that we are going to generate. What should be the pressure which should be applied? So, pressure is one of the important parameters which have to be controlled. Then there is another parameter that is temperature because the curing time will depend upon the temperature that we are maintaining. Then there is another point that is the time for which, the two halves of the mold will remained closed.

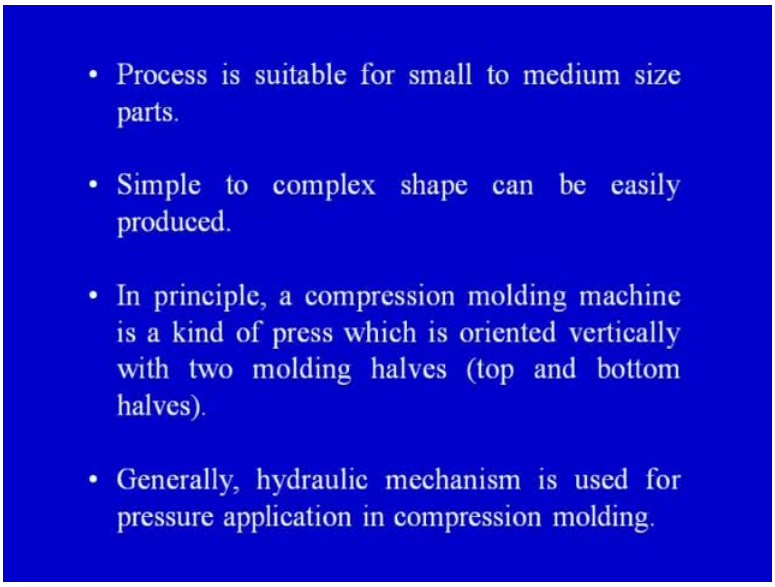
So, these are few integrates points that have to be taken care of depending upon the type of raw material, depending upon the pressure that we are applying, depending upon the temperature that we are maintaining, we will be able to find out that for how much time the mold halves should remain closed? So, these are the important process parameters, or operating parameters or we can say critical parameters that have to be kept in mind when we are using the compression molding process for a particular application. So, in today's lecture this is a very basic principle of compression molding.

We will try to understand these with a help of a diagram and we will see that what are the important parameters which have to be kept in mind? Also we will see what are the advantages of compression molding process? We will see that what are the limitations of this process? Finally, we will come to the point where we will emphasize the use of compression molding process in some of the important engineering applications. Now, let us take forward for our discussion on the basic procedure of the compression molding process.

So, we have seen the basic idea or the basic principle of the compression molding that the mold is made into halves top halves and the bottom halve. The cavity which is generated between the top and the bottom halve is the place where the deformation or the formation and like curing of the raw material would take place. Then there are few important parameters, which have to be kept in mind when we are using the compression

molding process for deformation and curing of the raw material, in order to convert the raw material into the final product.

(Refer Slide Time: 13:50)



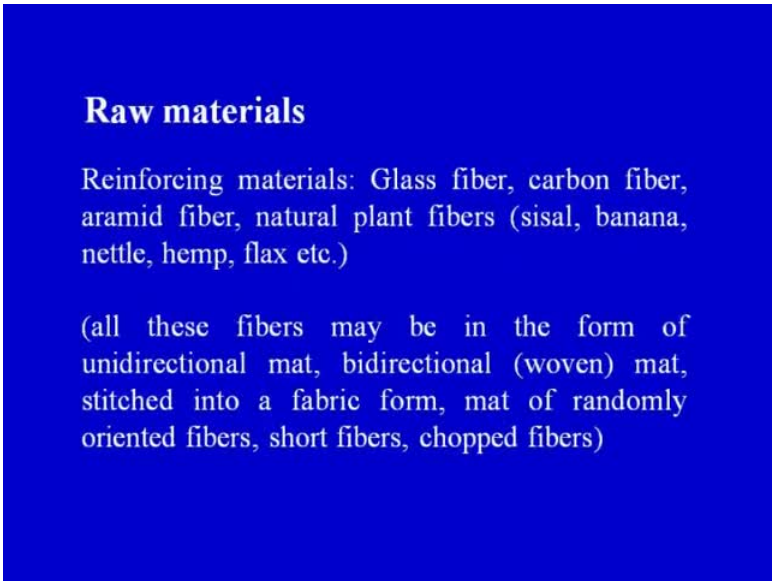

So, this process is suitable for small to medium size parts. As we have seen that the top half and the bottom half of the mold, would generate at cavity among in between themselves. So, the one of the limitations we can say of this compression molding process is the size of the final products that we are going to get. So, process is suitable for small to medium size parts, but if you remember in case of hand layup and spray layup we have emphasize that hand layup and spray layup processes are very suitable or are more suitable for very large composite parts.

So, side by side we are trying to highlight the importance of this process in comparison to the other process, which are used for the processing of polymer matrix composite products. So, hand layup and spray layup for large parts and compression molding for discrete small to medium size parts. Simple to complex shape can be easily produced that is one of the advantages we can say. In principle, a compression molding machine is a kind of press, which is oriented vertically with two molding halves top and the bottom halves, which I have already shown or explained with help of a diagram.

We have already seen that they top half of the mold bottom half of the mold, top half is movable bottom half is stationary. Top half comes it deforms the raw materials which is come, which is placed on the bottom half of the mold and it gives the final shape to the

product. So, the mold or the die in case of compression molding machine is made into two parts, that is the top half and the bottom half. Generally hydraulic mechanism is used for pressure applications in compression molding. There can be other mechanisms also like, pneumatic or mechanically the load may be applied with the help of gears. But in case of most of the compression molding setups we make use of the hydraulic mechanism for applying the pressure in case of compression molding.

(Refer Slide Time: 15:48)




Now, coming on to the raw materials, which are used in case of in case compression molding. Now, what are the raw materials used? Reinforcing materials that are used or the reinforcement materials are can be glass fiber, carbon fiber, aramid fiber, natural plant fibers like sisal, banana, nettle, hemp and they we have seen in one of our previous lectures or introductory lecture of processing of polymer matrix composites. We have seen that there is a wide variety of natural fibers which are available and which are been used today in a lot many applications, why?

Because natural fibers sometimes or may be can be bio degradable. When this bio degradable natural fibers are combined with the bio polymers with the composite that will available with the composite which is bio degradable or sometimes may be partially bio degradable. But still it is better than the synthetic composites in which the matrix and the reinforcement are non bio degradable. So, the reinforcement fibers that trend today is

towards use of natural fibers, but still we are using some of the synthetic fibers like glass fiber, carbon fiber and aramid fiber in most of our engineering applications.

So, the raw material in case of polymer matrix composites, the reinforcement would be different types of fibers. That is glass fiber, carbon fiber, aramid fiber or any type of a natural plant fiber. Now, this comes to the material of the reinforcement. Now, the shape of the reinforcement or the layup of the reinforcement would also change, depending upon the requirement of the final product that we are going to make out of the compression molding machine. Now, depending upon the requirement, we can have all the fibers in form of unidirectional mat or unidirectional tape, in which all the fibers or oriented in one direction.

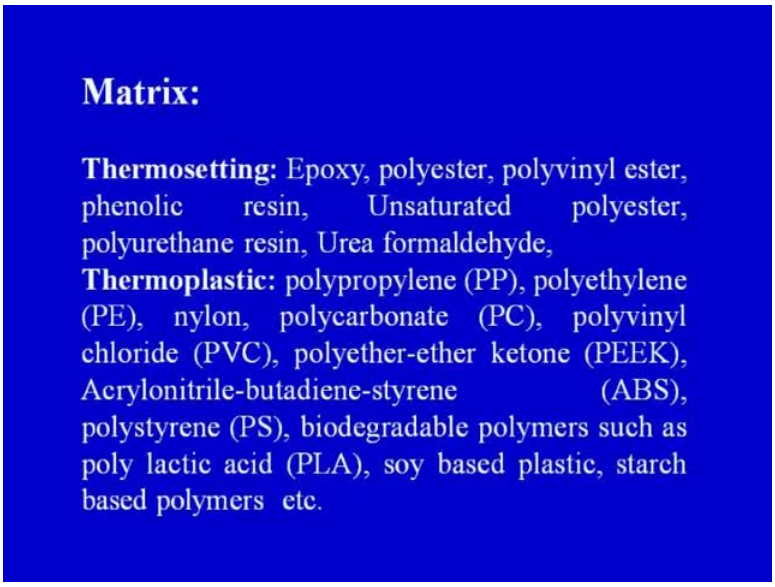
We can have bidirectional woven mat in which the fibers are there in oriented and the way or both in the longitudinal and the transverse direction we have the fibers woven. Then we can have the fibers stitched into a fabric form, we can have mat of randomly oriented fibers also sometimes that may be used and short fibers and chopped fibers are also be used in the compression molding set up. Now, depending upon the shape or the type of the fibers that we are using we have to modify the setup slightly in order to requirements of a particular type of a raw material.

So, one type of set up may not be suitable for all types of raw materials that we are using. So, this is something related to the reinforcement type. As you remember the composite is made up of two important ingredients or two important constituents, that is the reinforcement and matrix. The reinforcement and the matrix combined together to make a composite. So, on the raw material aspect taking the reinforcement point of view, we have seen the what are the what are the materials that can be taken and what are the shapes of the fibers that can be…

Shapes means the form in which they are been used. The shape otherwise can be spherical, cylindrical spherical cylindrical different shapes are there, but we are not talking about the shape of the individual fiber, we are talking about the form in which fiber is used. The form can be mat form, it can be stitched form, it can be unidirectional form or it can be short fiber form. So, we are talking about the form of the fiber as they are placed in the bottom half of the mold. So, we have different types of fibers which can

be used. On the other side what is the other thing as we have already discussed is the matrix, which will go as a raw material. So, the matrix can be of different types.

(Refer Slide Time: 19:34)




On your screen you can see thermosetting and thermoplastic matrices can be used or polymers can be used as the matrix materials. Now, what are the different types of matrices that can be used? That is epoxy, polyester, polyvinyl ester. Then there are other examples on your screen which are some of the types of the thermosetting polymers which can be used as the matrix material, in case of compression molding machine or compression molding setup.

Similarly, we can use some kind of thermoplastic polymers also as a raw materials for processing of composite parts by compression molding process. In thermoplastic we can use polypropylene, polyethylene, polycarbonate, polyvinyl chloride, polyether ether ketone, ABS acrylonitrile butadiene styrene, polystyrene. So, we have different types of matrices which can be used or different types of polymers, which can be used as the matrix material in order to make a composite product out of a compression molding process.

We can see towards the end in the thermoplastic the biodegradable polymers. Such as poly lactic acid, soy based plastic, starch based polymers etcetera. So, these are some of the biodegradable polymers which when combined with the natural fibers will result in a composite which may be partially or fully biodegradable. So, the focus today again I

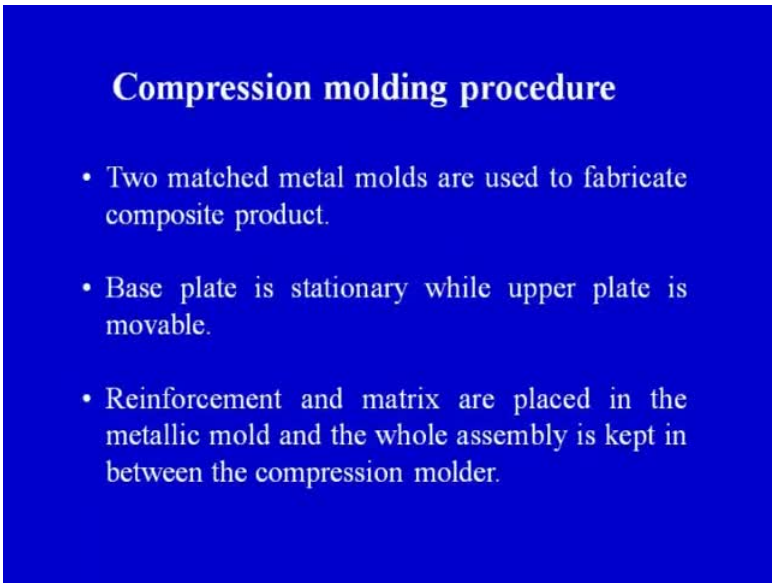
have emphasizing towards the helping composite which are biodegradable in nature because of the environment consciousness that has taken over most of the engineers and the scientist.

So, I am not saying that synthetic fibers are not being used or should not be used, but trend today is towards natural fibers and bio polymers. But the most of the application are still for the synthetic fibers such as the glass fiber, the carbon fiber, the aramid fiber. Most of the engineering applications of polymeric matrix composite is used the glass fiber, the carbon fiber and the aramid fiber as the reinforcement materials in different types of thermosetting and thermoplastic polymers, which attached the matrix material. So, raw material you can see as we have already discussed in one of the previous slides, that this is a very versatile process.

So, the versatility comes from the types of the raw materials that we are using. So, the raw materials that we can used are different types of reinforcement and different types of matrices. So, when the different types of materials can be processed, the process becomes versatile in nature because it can then make different types of composite product using one type of reinforcement with another type of a matrix.

So, different types of fibers different types of matrices combined together in the form of a composite product using that compression molding process. So, the process becomes a very, very versatile process. So, we have seen the basic principle and we have seen what type of raw materials can be used. In raw materials the maximum applications in of the compression molding process are for glass fiber, carbon fiber and aramid fiber composites.

(Refer Slide Time: 22:42)




Now, compression molding procedure; the basics of the compression molding procedure we have already seen. In this particular case of compression molding process we have two matched metal molds are used to fabricate the composite product. So, we have two matched metals molds. So, the mold is made up of a metallic material, any type of metallic material can be used. The main properties are that it should be wear resistance, it should not be dimensionally unstable, it should be dimensionally stable.

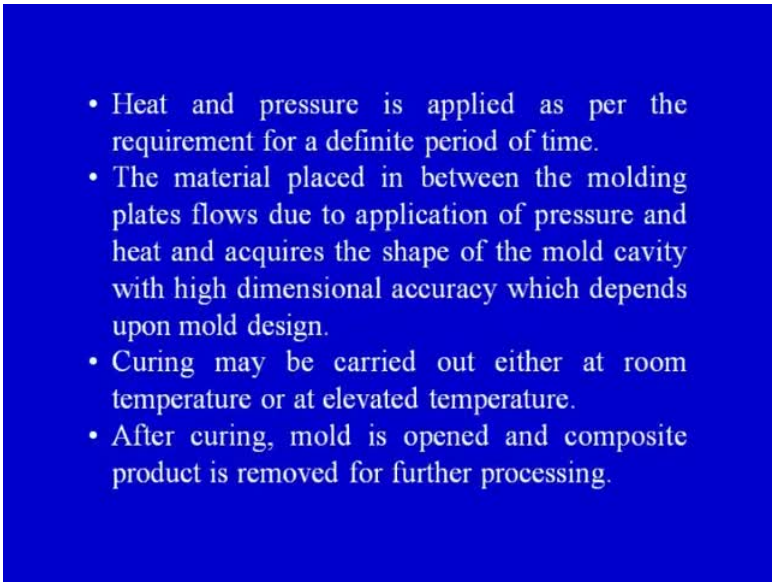
There can be other properties; it should have tough, it should have toughness, it should be hard, it should have good strength. So, there are few mechanical properties it should be there in the material which we are going to use for making the mold half, but it can any good metal can be used. Good metal in the sense, which have good mechanical properties as I have already discussed, that type of metal can be use for making the mold halves. So, two matched metal mold are used to fabricate the composite product.

So, in this particular sentence two matched, so matched has got importance because that final product will be made in the cavity is generated between the top half and the bottom half of the mold. We will try to understand this with the help of a diagram also. So, it is match means the top half of the mold should match with the bottom half of the mold and in between the cavity should be generated, which is the exact shape of the final product that we want to generate. I will explain this with the help of a diagram in the subsequent slide.

So, here two mold halves should be matching, the base plate is stationary as I have already emphasize in the basic principle, while upper plate is movable or the upper mold half is movable. Reinforcement and matrix are placed in the metallic mold and the whole assembly is kept in between the compression molder. So, the raw material is kept, the raw material is in the form of the reinforcement and the matrix. So, the two parts or the two constituents of the final product, that is he raw materials are placed on the, placed in the metallic mold. This whole particular thing is kept in the compression molding machine.

Sometimes the mold is also a part of compression molding set, the mold is fixed with the compression molding setup. Sometimes we want give machine mode versatile nature, we can have a replaceable mold in which we can change the shape of the mold, the application or pressure and temperature and be maintain, but the shape of the mold can be change depending upon the final requirement. So, basically there are three things; the shape of the mold, the pressure that we are applying and the temperature that we are maintaining. So, two things are constants, the temperature and the pressure, but the mold shape of the mold or the cavity in the mold can be changed or the molds can be replaced in order to make different shapes. So, that is again giving a degree of versatility to the whole process of compression molding.

(Refer Slide Time: 25:52)



Heat and pressure is applied as per the requirement for a define period of time, which we have already seen, that we are going to maintain that temperature and the pressure as specified for that particular raw material. Finally, for a specific period of time we will allow the curing process to take place. Finally, the two mold halves would open and the final product would be taken out. The material placed in between the molding plates flows due to the application of pressure and heat and acquires the shape of the mold cavity with high dimensional accuracy, which depends upon the mold design.

So, everything will depend upon the surface finish of the mold, everything will depend upon the mold design, because the mold is we can say is the heart of the whole process. Mold is a place where the actual action is taking place, mold is the place where the deformation of the raw material into the final product and the curing of the raw material into the final product is taking place simultaneously. So, with the mold design is very, very important in case of the compression molding process. So, I will again read this particular sentence.

The material placed in between the molding plates, so the raw material is placed in between the two mold halves flows due to the application of pressure. So, the material flows it tries to take the shape in between, that is been generated in between the top and the bottom half of the mold cavity, top and bottom halve of the molding plates or the molding halves or the olds. So, when the top and the bottom halves would combine together there would has been generated cavity which would be generated inside the two mold halves and the raw material would try to fill up that gap and take the shape of the gap that have been generated between the two mold halves.

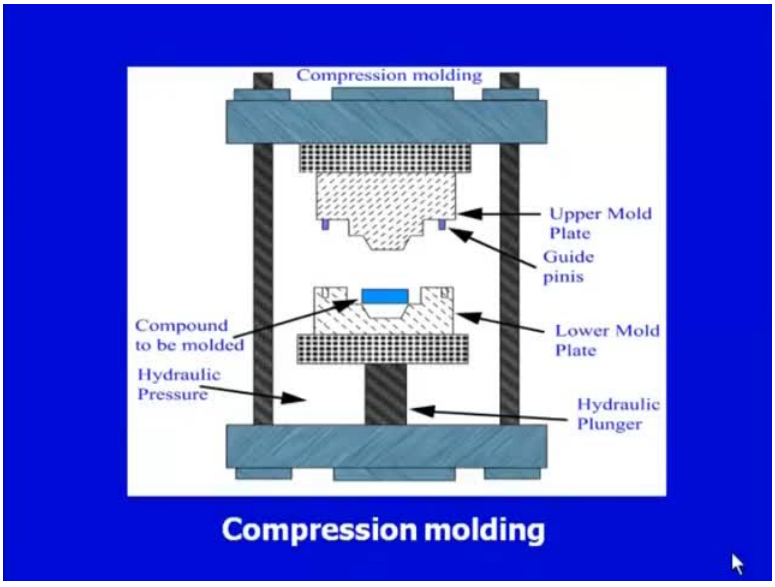
The temperature and the pressure facilitates this process of flow of the raw material into that cavity, which has been generated between the two mold halves. And finally, the curing process takes place the temperatures also hates the curing process. It helps the curing process, it accelerates the curing process. So, the temperature will help to accelerate the curing process and we will be able to make more number of parts per minutes or more number of parts per hour. So, curing is done at a elevated temperature, curing may be carried out either at room temperature or at elevated temperature.

So, if we have time we can give adequate room temperature curing, but if we want to make a large number of parts in smaller amount of time or quickly we would go for

elevated temperature curing. But certainly the important point is that curing may be carried out either at the room temperature or at an elevated temperature. After curing the mold is opened and composite product is removed for further processing. So, finally, the mold halves would open and the final product would be taken out and final processing would be done. Final processing in terms of some flesh made developer, fins made developer or party line may develop, which have to be trimmed of are finished before the final product is given for the final usage.

So, in these two slides we have seen how the compression molding actually takes place. The raw material is kept on the bottom mold half, the top mold half is movable, the bottom mold half is stationary, the top mold half comes and it deforms the raw material into the shape, which is generated between the bottom and the top half of the mold. The temperature and the pressure facilitates the movement or the deformation of the raw material between the two die halves. For a particular movement of time or for a particular time interval the top and the bottom halves remains closed. After the curing process has been completed, the two mold halves are open and the final product is taken out for final processing or for further processing.

(Refer Slide Time: 30:02)




Now, you have a diagram a very simple diagram on your screen. You can see in the diagram you have a upper half mold and you have a lower mold half, this is the lower mold half and this is the upper mold half. You can see, when this mold halve of would

come down and take the takes its place here, this particular raw material, this is the raw material compound to be molded. This is the raw material and this is the hydraulic pressure and this is maintained in order to apply the pressure.

This whole assembly would be coming down and compressing this particular raw material. These are the two guide ways, these two vertical columns. These are the guide ways, this total top assembly would move on these two guide ways the total assembly would come down and the upper mold half would compressed or would deform this raw materials. This raw material would take the shape of the cavity which is generated between the two mold halves.

So, we have two mold halves and a cavity would be generated or we can say the shape would be generated between the top half and the bottom half and this particular raw material would be deformed into that particular shape, which is generated between the top half or the upper half and the lower half of the mold. So, this is the hydraulic plunger which would apply the pressure between the two halves of the mold. So, we have a lower mold plate and we have a upper mold plate. Now, what is the role of this guide pinis?

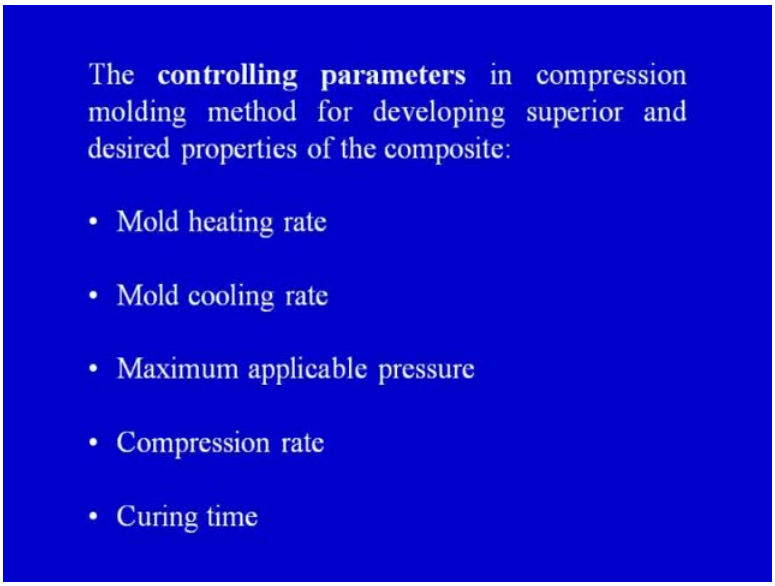
These guide pinis would aligned with the bottom halve of the mold this guide pinis would come down and get fixed at its particular location here. This guide pin would come these two simultaneously would come down when the top half of the assembly would come down to compress this material and guide pinis would at for the exact location of the top mold halves on top of the bottom mold halves. So, this is the basic process in which the deformation would take place. Now, what are the important parameters which we have to look in this particular process. We have to see that how much hydraulic pressure is applied or how much hydraulic pressure is required? We have to see that what is the raw material that is used?

Depending upon the raw material we have to choose the pressure, that how much pressure is required? Also there would be heating elements around this mold, these molds would be heated mold. So, we have to see what should be the temperature that should be maintained? Finally, when the two mold halves would closed in one particular cycle or for making one particular product, what should be the duration or what should be the period of time for which the two mold halves should remained closed? That is another critical parameter which has to be kept in mind.

So, there three important parameters which have to be kept in mind; the pressure which have to be applied, that temperature which have to be maintain and that time or the duration for which the two halves, two mold halves would remain closed and the deformation and curing plates would take place between the two mold halves. The duration for which we will allow the curing to take place.

So, these are three important parameters again I am emphasizing the pressure temperature and the time of curing for which the two mold halves would remain closed. Once the curing has been completed, the two mold halves would open and the final deformed and cured product would be taken out for the processing. So, this is the most simplistic and a very easy representation of the compression molding process.

(Refer Slide Time: 34:03)



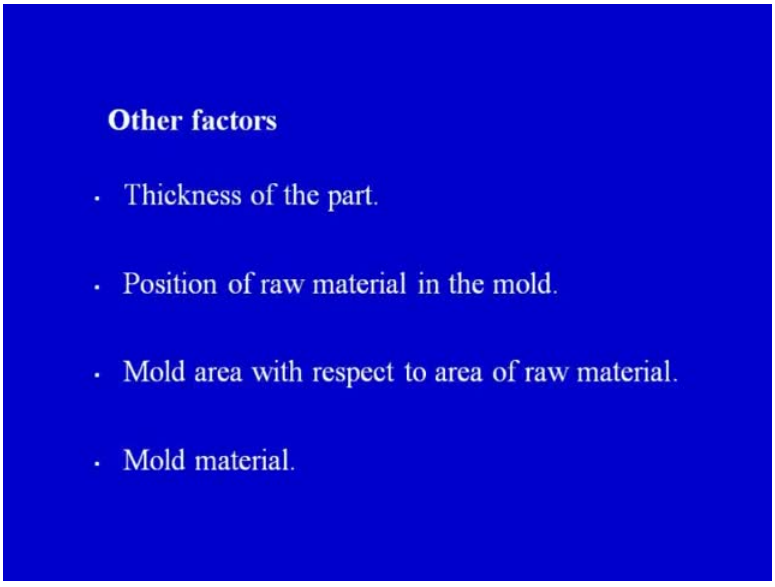

Now, as I have explained along with the diagram the controlling parameters in compression molding method for developing superior and desired properties of the composite are, now we want to make a good quality product, it should be have good surface finish, there should not be any defect in the final product and in order to make a superior good quality high precision product, we need to control certain parameters. Now, what are these controlled parameters in case of a compression molding process.

So, these controlling parameters are; the mold heating rate, how the mold should be heated? At what rate it should be heated? For what duration it should be heated? The mold cooling rate, before the next cycle the mold would have a cooling process. So, how

it should be cooled? We can have some waters circulation or we can have some air air cooling can be used. So, we have to see what is the heating rate? What is the cooling rate? What is the maximum applicable pressure that can be applied for a particular raw material? What is the compression rate or the rate at which the compression will take place?

We can have a sudden compression and we can have a slow compression. So, what is the rate of compression, that we are we are using. Then the curing time; we can have room temperature curing, we can have curing at an elevated temperature. So, these are some of the controlled parameters which have to be kept in mind, when we are using the compression molding process. Again I am reading the points that are there on the slide. First is the mold heating rate, the mold cooling rate, the maximum applicable pressure that can be applied for with the help of a compression molding setup, the compression rate and the curing time. So, these are some of the points which have to be taken care or the most technically oriented points which have to be taken care. Then there are few other points which we have to take into a count, when we are using the compression molding process.

(Refer Slide Time: 36:02)




Now, what are these factors? These factors are the thickness of the part that we are going to process, that I have already explained when I was drawing a diagram and I told that thickness of the part is very, very important which will dictate the application of pressure

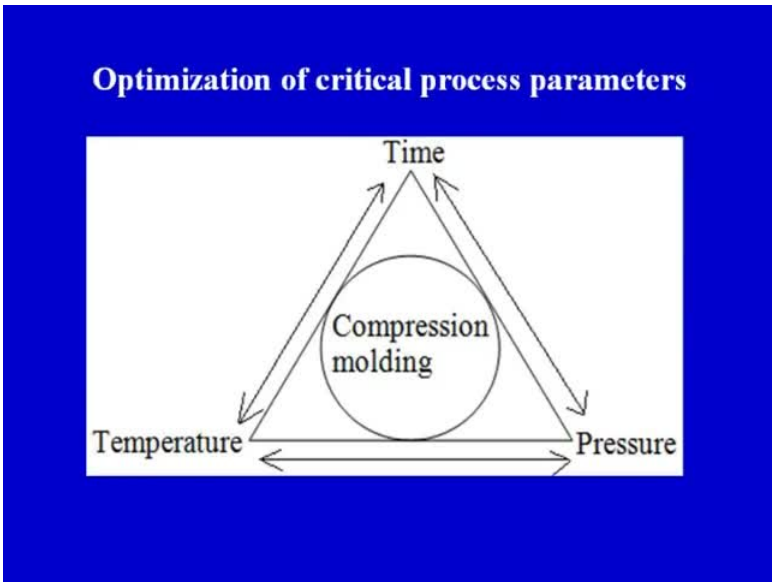
and the maintaining of temperature and curing time. So, thickness of the part is also very, very important when we are using the compression molding setup or the compression molding process.

Then the position of the raw material in the mold is also very important. That how and where to place the raw material in the mold, so that the mold cavity or the cavity which is generated between the top and the bottom half of the mold is fully filed in the shortest possible time and the product that we get is a very high quality accurate and presides product. Mold area with respect to the area of the raw material, which also as to be taken into a account. That there is the area of the mold because if we have large volume of the raw material then there would be some internal stresses, some internal problems that may take place.

Sometimes it may come out of the parting line where the two mold halves are meet each other, that excess materials may flow out of that particular area and we may not be able to get the desired thing uniformity of the thickness in the final product. So, there may be some problems associated if the volume of the raw material is higher as compared to the volume of the cavity, which is generated between the top and the bottom half of the mold. Then I have already emphasize using the metallic are use for making the molds, but the mold material is also very, very important.

Some of the properties which I have already highlighted for the mold material are; that it should be wear resistance and it should have high strength hardness, toughness because the load is coming on the material. It is a pressure application technique in which the pressure is applied on the two halves of the mold. So, the mold material should be able to sustain that kind of loads that are coming. So, it should have high strength, hardness, toughness and it should be wear resistant. So, the mold, the material that we are using or where the material choosing for making a mold should have all these desirable characteristics.

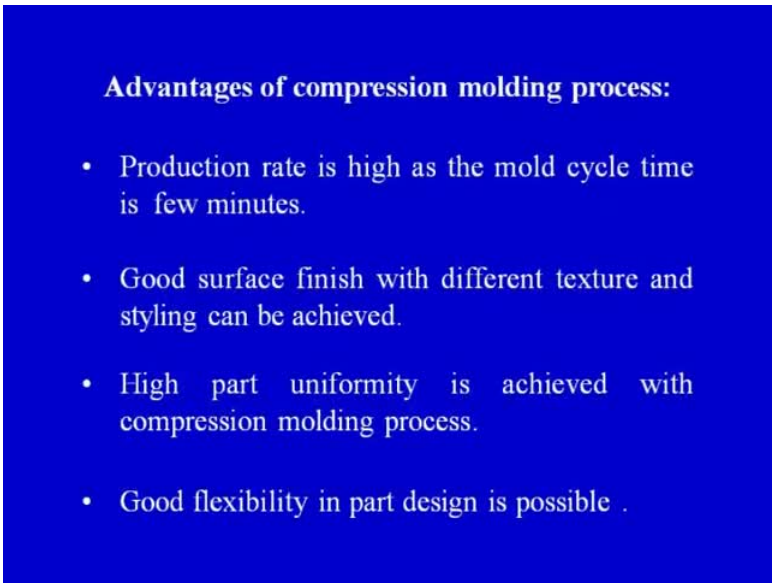
(Refer Slide Time: 38:22)




Now, optimization of the critical process parameter. So, we have seen so many parameters or so many factors that have to be kept in mind, when we are using the compression molding process. But broadly these can be classified into three important parameters which have to taken into a account. On your your screen you can see a very simplistic diagram of the compression molding in which there are three critical parameters; that time of curing or in a easy language or in a very understandable language we can say that time for which the two halves of the mold would remain closed.

So, the time of curing that is one important critical parameter, that maintenance of the temperature around the mold and the pressure that we are applying. So, these are the three important parameters or three important critical parameters, which would dictate the quality of the product, which we are making using the compression molding process. So, quality is very very important. So, for making good quality product our focus should be on time of curing the temperature and the pressure application.

(Refer Slide Time: 39:29)




Now, what are the advantages of the compression molding process? The production rate is high as the mold cycle time is few minutes only. In case of hand layup when we are doing the room temperature curing, it may take may be 24 hour for the curing process to take place. But in case of compression molding the production rate is high, as the mold cycle time is a few minutes only. So, within a particular hour or may be within a 4 hour shift, we can make a large number of products using the compression molding process.

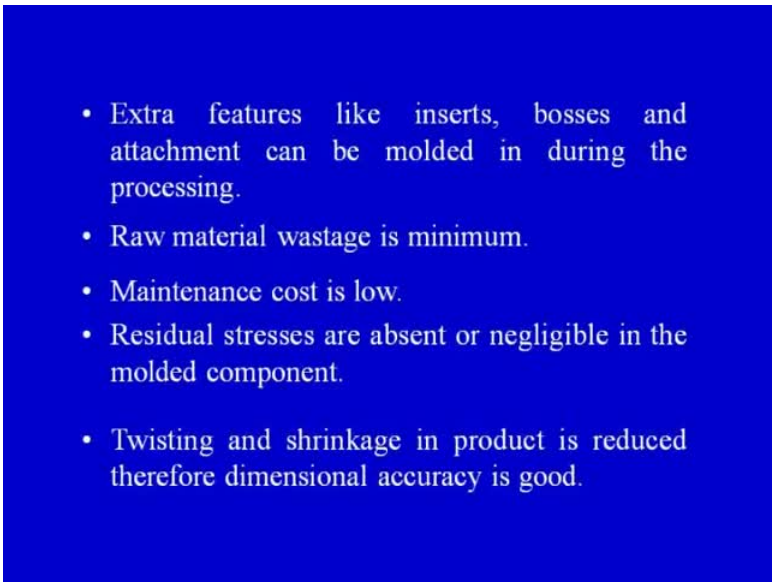
So, this is one of the advantages because large number of products can be made production rate is higher with the compression molding process. Good surface finish with different texture and styling can be achieved. So, the surface finish would depend upon the mold material and the mold we are using metallic mold in case of the compression molding setup. So, good surface finish, surface texture can be controlled and the good surface finish can be got or good surface finish can be achieved using the compression molding process.

High part uniformity is achieved with the compression molding process. So, we have good production rate, good surface finish and high paretic uniformity, so the part will have uniformed dimensions all around. So, if you remember in case of spray molding we have seen, that the thickness uniformity is some time difficult to manage or difficult to controlled. In case of spray molding, spray spray layup process if you remember, we

have seen in the spray layup we are using a chopped gun or a gun which is used for delivering the raw material on to the mold surface.

So, thickness is difficult to control in the spray layup process, but in this particular process that is compression molding the part uniformity is achieved. So, we can have uniformity in thickness along the total profile of the product. Good flexibility in part design is possible, so we can have different types of designs. As I have already told we can change the mold plates, we can have a different shape of mold plates and we can use different types of designs for making the composite products. So, it is the flexible process, it is the versatile process different types part signs can be made using the compression molding setup.

(Refer Slide Time: 41:52)



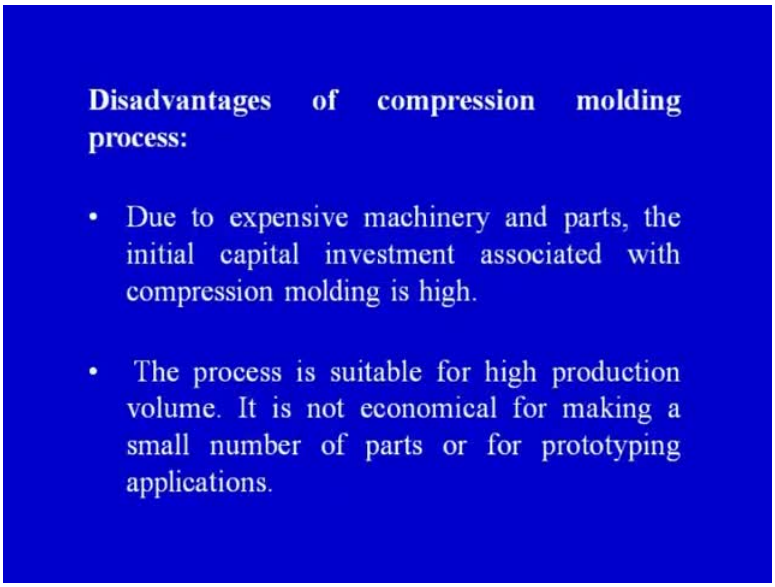

Extra features like inserts bosses and attachment can be molded in during the process. Sometimes in a particular part design we require inserts or sometimes we requires bosses. So, these type of extra features can also be incorporated into the product that we are going to make using the compression molding process. Raw material wastage is also minimum because in case of hand layup and spray layup process, if you remember the extra raise in is squeezed out of the final product, but in this particular case we are going to put the metered amount of raw material in between the two mold halves.

The wastage of the raw material would also be minimum in case of the compression molding setup. Maintenance cost is low residual stresses are absent or negligible in the

molded component. So, there are no residual stresses that are developed using the compression molding process. Twisting and shrinkage in product is reduced, therefore dimensional accuracy is also good. So, the material in this case would flow in between the cavity or the mold cavity generated between the two mold halves.

So, the dimensional accuracy that we are going to achieve in this particular process would be a extremely higher or extremely high. So, twisting and shrinkage in the product is also minimum. So, these are few advantages of compression molding product, process and we can make a good quality, dimensionally accurate, highly presides products using compression molding process.

(Refer Slide Time: 43:27)



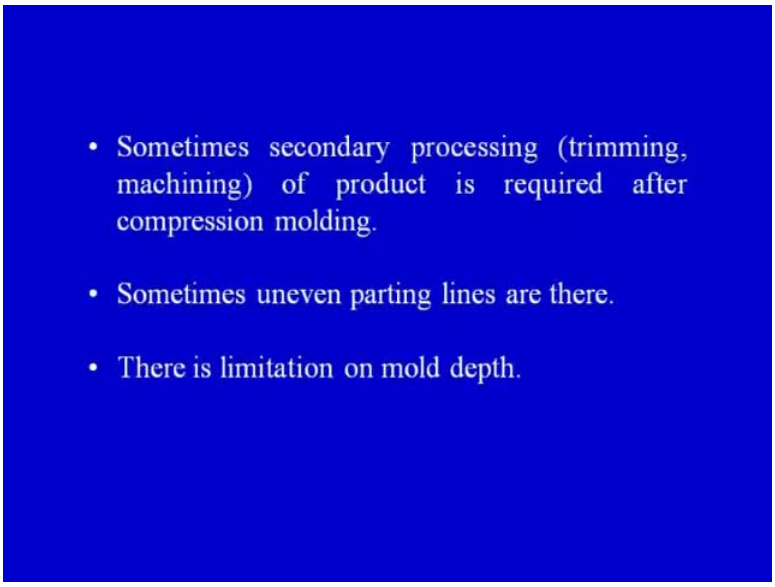

Now, what are the dis advantages of compression molding process? The dis advantages are, due to expansive machinery and parts the initial capital investment associated with the compression molding is high. So, the we have to procure the machine, the high initial investment in case compression molding process is one of the dis advantage which is not there in case of the spray layup process or the hand layup process because those are manual process.

Here we require a separate, we require a machine, so the initial investment in case of compression molding process is high. The process is suitable for high production volume all it is not economical for making a small number of parts or for prototyping application because if we are spending some amount of money for procuring a compression molding

machine we should, we should use it for a large number of product or for a high production volume. We should not procure a compression molding machine for only making 4 to 5 or to 10 or 15 prototypes.

So, which is very, very which is a general common sense that we should not buy a sophisticated or we should not buy a very expensive product or very expensive machine for making very few parts. So, few parts of prototypes have to made they can be easily made by the hand layup process or the spray layup process. But if the production volumes are comparatively higher or we have our large production volume or high production volume, suppose we want to make 2,00,000 components per year or we want to make 5,00,000 components in 2 year. So, for those type of large production volumes we can go for the compression molding setup, but for small volume production the use of the compression molding is not advisable.

(Refer Slide Time: 45:14)




Sometimes secondary process, processing in terms of trimming of product is required after the compression molding. So, that is also one of the disadvantage, because the final product that we are getting may have some fins or flushes. So, which have to be trimmed of this fins or fleshes are developed at the, developed at the parting line, where the two mold halves are meeting each other. So, in that case, these have to be trimmed off. So, final secondary processing is in terms of trimming is required before the product is put

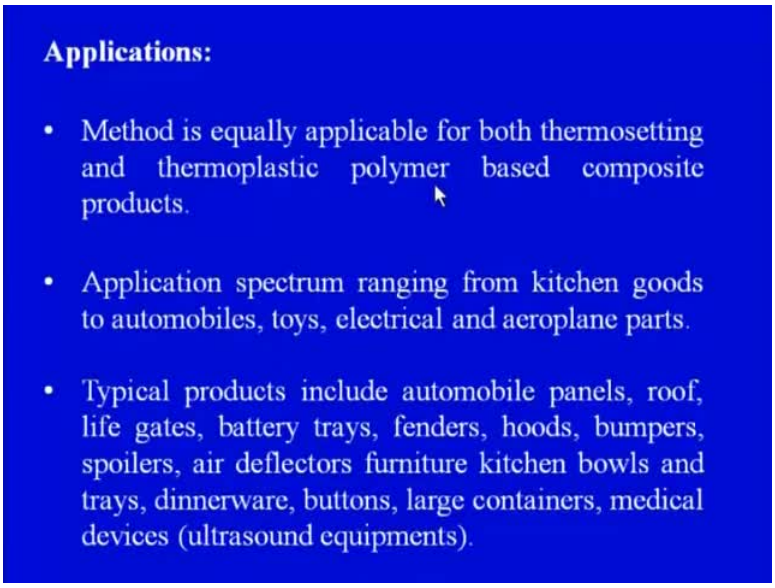
into the market for sales or before use of the product by the customer, so secondary processing is required.

Sometimes uneven parting lines are there, which is also one of the disadvantages. This may takes, uneven parting lines may take place because of many reasons, one of the reasons can be the shift in the two, because we have not use the location pins as we have seen in the diagram. So, those pinis are absent location means are not there, there may be slide shift in the two halve of the mold were the two molds are matching. There may be slide shift because of this shift we may have uneven parting lines, there is also limitation on the mold depth. So, that is the mold design, one of the limitation is on the depth we can use a specific depth or the critical depth only for making the products by the compression molding process.

So, depth of the design mold design or the depth of the product is one of the limitations in case of the compression molding process. So, limitations are in terms of production volumes limitations are in terms of mold design. So, these are some of the limitations are the final products final quality of the product we may have some fins or fleshes, which have to be trimmed off. So, this two or three important areas which have to be looked into, when we are proposing the use of a compression molding process for developing the composite product out of a raw materials of a specific category.

So, these are few things which we should keep in mind, that what should be the quality that we are going to get? What is the production volume that we are targeting? So, these things keep in mind at earlier stages all this limitations can be done away with. Now, what are the applications? The applications of the compression molding process are numerous. There this particular process is used in for making large number of or large different types of composite products for different applications.

(Refer Slide Time: 47:44)




On your screen you can see, this method is equally applicable for both thermosetting and thermoplastic polymer based composite products. Applications spectrum ranges from kitchen goods to automobiles toys electrical and aero plane parts. So, different types of pats or components which can be used in kitchen, which can be used in automobiles, which can be used in toys, aero planes etcetera can be made. Typical products, what are the specification or applications that are the automobile panel, roof, life gates, battery trays, fenders, hoods, bumpers, spoilers, air deflectors, furniture, kitchen bowls and trays, dinnerware, buttons, large containers, medical devices ultrasound.

Now, some of these particular products can only be made up of a polymer. In some cases we can have the fibers impregnated with the polymer; so compression molding can also be used for simple polymer products also. Here we can see different types of applications are there for the compression molding process. So, in today's lecture, we have seen that what is the compression molding process, we have seen the different aspects of the compression molding process, in terms of the process details. The procedure of the process with the help of the diagram you have try to understand that how the process actually takes place?

What are the critical parameters, which should be controlled in order to make a good quality composite product, out of a compression molding process? Then we have seen that what are the various advantages of using the compression molding process? What

are the various limitations of the compression molding process? Finally, we have come to the point where we have seen that where the compression molding process is finding the applications?

We have seen there are large number of products, which can be made by the compression molding process. In our further subsequent discussion in this particular module on processing of polymer matrix composite our focus would beyond some other process such as filament winding and we would focus on filament winding, try to understand the process details the critical parameters as well as the advantages limitations and the applications of the filament winding process.

Thank you.