Processing of Polymers and Polymer Composites

Dr. Inderdeep Singh
Department of Mechanical and Industrial Engineering
Indian Institute of Technology, Roorkee

Lecture - 19
Compression Molding

[FL] friends welcome to lesson number 19 or session number 19 in our course on Processing of Polymers and Polymer Composites, just to have a brief review of what we have discussed currently we are focusing on processing techniques that are used for processing of polymer based composites, till our discussion in session 13 our focus was primarily on polymers. And in polymers if you remember we have seen that there are 3 important steps or stages for every process for polymers we have seen there are different techniques. For example, thermoforming, compression molding, injection molding, rotational molding, transfer molding, and there were 3 common steps followed there what was the 3 common steps.

Heating or melting of the polymer, then deforming the polymer as per the required shape and finally, cooling of the polymer. Similarly now for polymer composites also we are seeing at least we have seen 2 different processes that are used for making composite parts we have try to understand these processes with freely available YouTube videos. We have seen the hand layup process which is the most primitive most simplistic type of process used for making of parts or composite parts and then we have seen the spray layup process. So, hand layup process and spray layup process already we have covered for polymer composites, now I want to emphasize that what is happening in case of polymer composites.

Both the processes that we have covered are majorly used for thermosetting type of plastic materials that is the polymer is available in the gel or a zell or the whiskers form. So, what will do we prepare a mixture of a polymer we add hardener into the base polymer and then we steer it we try to remove all the bubbles etcetera and then we apply it on fibers, so that heating, melting, deforming, cooling all these steps are not common in polymer based composites in composites we are seeing that we layup and then we apply the polymer. The polymer is available in the whiskers form and that is there why because we were using a thermo setting type of polymer, also we have thermoplastics which are available in the pallet form or the granule form or the powdered form.

We will see today that in compression molding we can make uses of the thermoplastics also where the things remain common what we have to do, we have to heat, we have to melt and then we have to deform and finally, we have to cool. In case of thermo plastics majorly we will see that we have to follow the same steps as we have followed in case of polymers, in polymers we have seen during the extrusion process when I am taking one example of extrusion what we do, we put the polymer or the pallet us in the hopper and from hopper they come into the barrel through the screw they are heated as well as through the heating arrangement around the barrel.

The heat is supplied through the screw they are pushed forward the screw has different zones and when the it has it is in the molten state it is pushed with the application of the force by the screw into the mold cavity or in case of injection molding into the mold cavity I have taken an example of a extrusion process through a die and the shape of the die will directly we duplicated on the composite part and one of the examples that we have covered what is the gardeners pipe the gardeners usually use for watering the plants. So, that is a made by the extrusion process, what is happening raw material is fed heating, melting and then deforming as per the shape as die and finally, cooling, after the product has come out from the die.

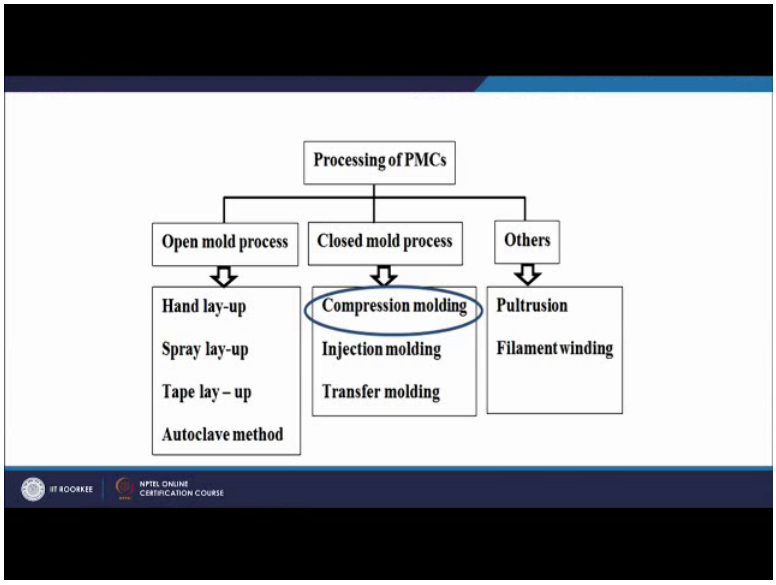
Those things will remain common in case of composites also only addition will be that we have to now incorporate fibers in the polymer and therefore, you called them as the polymer composites. The basic principle that we have understood till today of processing of polymers will be applied similarly in polymer composites also with little modification that how are the fibers will be incorporated into the polymer that is the only addition that we have to understand here and compression molding why I have taken this discussion in the beginning of today's session first because whatever processes we have covered till today the last 2 processes handle layup process and the spray layup processes both processes are mostly applied for thermosetting based polymers , but compression molding has the ability to be use for both the thermosetting type of the polymers as well as for the thermoplastics also and for the steps almost are same that is heating, melting, deforming, and finally, cooling.

We will see the process with the help of a diagram also, but this discussion was important because there may be a doubt or there may be a question that how the processing techniques or technology is different for polymer composites as compared to

the nascent or the neat polymer. So, the differences in polymer composites we have to think we have to use our mental faculties to find out that how best we can incorporate our fibers into the polymers.

That is the only challenge that we have to answer or that we have to address, otherwise the basic molding of the plastic or molding of the thermoplastic will remain the steps will remain almost same. Let us now quickly go through the process of compression molding it is an advanced version we can say of the hand layup process, but is this case we have better dimensional control why because this is a closed mold process.

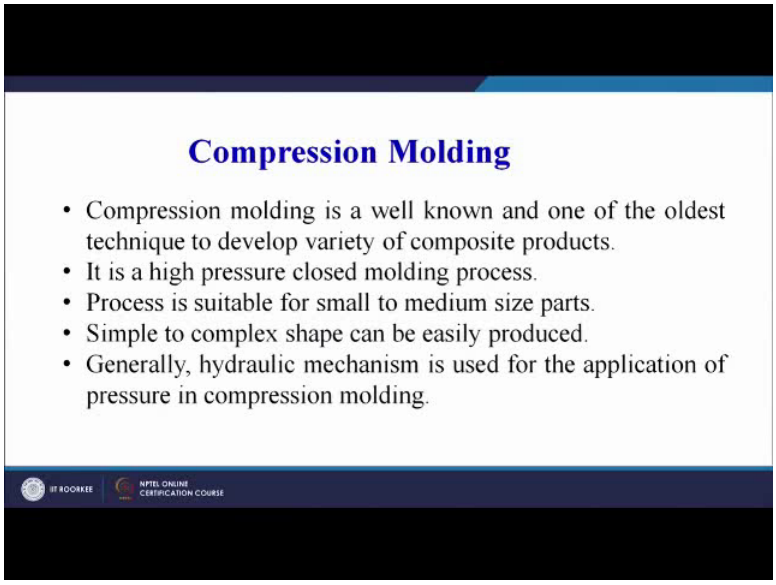
(Refer Slide Time: 06:46)



On your screen you can see compression molding is a closed mold process we have seen till today 2 processes that is the hand layup process, as well as we have seen the spray layup process both are open mold processes, but compression molding gives us better dimensional control over the composite part and it is following under the closed mold process.

Let us quickly try to understand the basic fundamentals or the fundamentals of compression molding process.

(Refer Slide Time: 07:21)



Compression molding is a well known and one of the oldest technique do develop the variety of composite products. It is also well established commercially available machines are there which are used for compression molding process. So, compassion molding is a well known and one of the oldest technique it is a high pressure closed molding process, here we can control the pressure also.

If you remember in case of hand layup how the pressure was being applied the pressure was being applied by closing the 2 halves of the mold and in our case the example that we have taken 2 flat plate molds were there and by nut and bolt fastening mechanism we were applying the pressure. The pressure is not automatic pressure is applied manually and sometimes also after doing a flat plate molding, we apply a dead weight on the top half of the mold in order to apply the pressure, but here we can control the pressure all around the mold and we can see how much pressure is acting on our laminate or the composite part being manufactured.

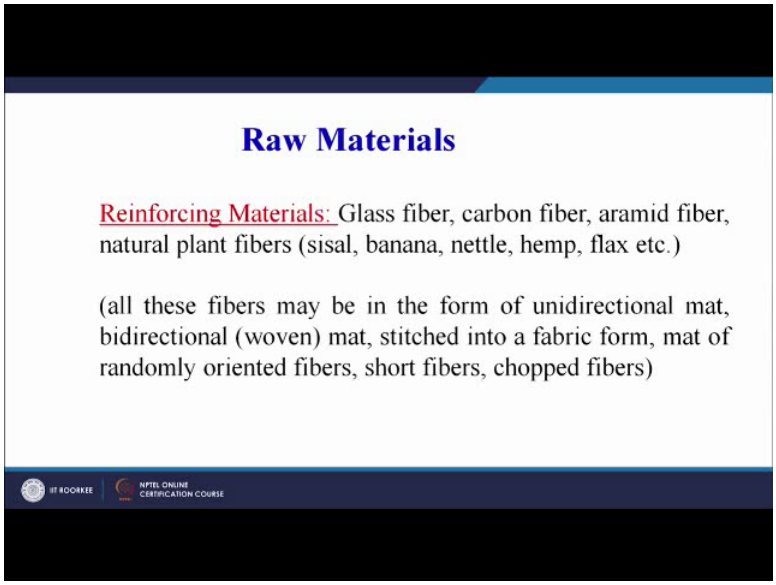
It is the high pressure process, we have to apply lot of pressure the consolidation is quite strong in this case process is suitable for small to medium sized parts as we have seen in hand layup and spray layup process size is not a limitation, if you remember in spray layup process we have seen a big boat marine boat can be made by spray layup , but in this case as we are using a compression molding machine, the machine will always have it is limitation there will definitely be a X,Y and Z coordinate according to which we can decide the maximum size of the product that we can make. X,Y and Z coordinate will be the coordinates of the mold or the maximum coordinates of the mold that can be used to

fabricate a composite part in that compression molding machine. The major part in case of compression molding machine will be the mold and in mold we have dimensions that is there are limitations that what can be the maximum size of the mold that can be used for that particular process or that particular machine.

Small to medium size parts can be made simple to complex shapes can be produced easily, now why complex shapes because it is a high pressure molding technique, when high pressure is there we can always make a complex geometry. So, that is one thing which is advantageous in case of compression molding machine, generally hydraulic mechanism is used for the application of pressure in compression molding now we have seen that is a high pressure process, how we will apply the pressure, the pressure will be applied with the help of a hydraulic mechanism.

We will try to understand this with the help of a figure also, what can be the raw materials that can be used, basically 2 types of raw materials or 2 types of constituents are there.

(Refer Slide Time: 10:19)



The first one is a reinforcing material that is glass fiber, carbon fiber, aramid fiber, natural plant fibers can be there like sisal, banana, nettle, hemp, flax etcetera, all these fibers may be in the form of unidirectional mat, bidirectional, stitched into a fabric form, mat of a randomly oriented fiber, short fibers, chopped fibers. If you remember in the last 2 processes we have seen in case of hand layup process majorly we will use even mat

type of reinforcement, that is mat type in which fibers are there in X direction also as well as in the transfers as well as longitudinal warp and weft in the longitudinal and the transfers direction. Now, basically both the directions like this, fibers are running in this destruction also fibers are running in this direction also, fibers are in both the direction.

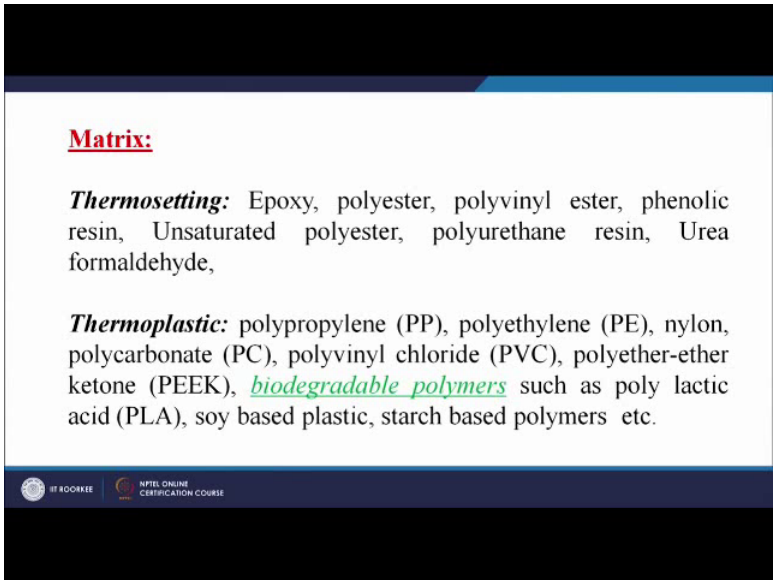
In spray layup we have seen the fiber is coming from the rowing and if the spray gun it is being chopped into small fibers, hand layup for majorly for continuous fibers, spray layup majorly for small fibers, but compression molding both type of fibers can be used we can have continuous fibers also, we can have small fibers also. So, you can see again I am ready we can use synthetic fibers also we can use natural fibers also that is one classification then all these fibers can be in the form of unidirectional mat.

All fibers running in one direction only unidirectional mat by directional or woven mat stitched in the fabric form as I have already explained or mat of oriented fibers, short fibers or chopped fibers. So, that chopped short fibers also must be available in the form of a mat because we have to put it in the mold and then we have to apply our reinforce, we apply our matrix which will which can be either a thermosetting matrix, if it is thermosetting as we have seen in the video for hand layup process we have to apply it by hand and we have to it will be a whiskers fluid or it will be a liquid form of reinforcement in case of thermosetting polymer, but in case of a thermoplastic it will be in the form of pallet us.

We can sprinkle those pallet us and then apply the pressure or we can convert those pallet us into a thin film and we can place that thin film over this mat of fibers and then we can put neither mat of fibers and then we can place another film of polymer and then this laminate or this laid up thing we can apply the pressure the polymer will melt specially in case thermoplastic composite and will impregnate the fibers and we will get our composite part which we will have fibers also which we will have polymer also we will try to understand this with the help of a diagram.

But first before going to the process let us try to understand the constituents, the first constituent was the reinforcement, second constituents is the matrix, the matrix can both with the thermosetting as well as thermoplastic you know all the examples.

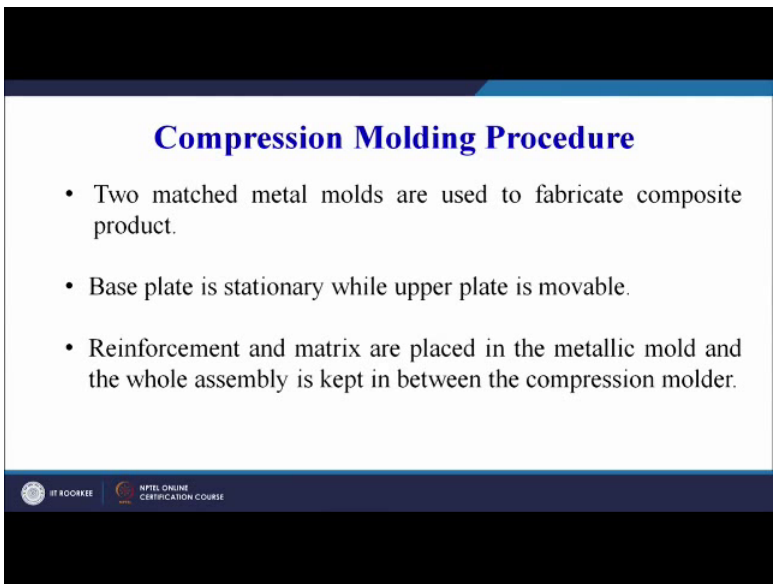
(Refer Slide Time: 13:23)



Thermosetting can be a epoxy, polyester, polyvinyl ester, similar to what we have already seen in hand layup process and spray layup process. Similarly in thermoplastic we can use polypropylene, polyethylene and sometimes we can also go for biodegradable polymers such as poly lactic acid, soy based plastic or starch based polymers. So, we can use both we can use thermosetting type of polymers also we can use thermoplastic type of polymers also.

Let us see the step by step procedure that how the process will evolve first we have to as I have already told the main part or main constituent or component of the compression molding machine is the mold or the die cavity.

(Refer Slide Time: 14:10)



So, two matched metal molds are used to fabricate the composite product, the major point here to address is the shape of the mold, size we have already seen small to medium, the mold will not be a very large size, mold will be of small to medium size, but the shape is important the shape of the mold should confirm to should be the exact replica or the duplicate of the final product that we want to make.

Suppose we want to make a flat plate or sheet the mold should be flat plate mold, if we want to make a 3 D geometry the mold should be the exact replica of that geometry. So, that our final product that comes out conforms to the final shape of the composite product that we are planning to design and develop. Now first thing is the mold will be 2 part 2 half mold, one half will be the base another half will be the movable half, at that we will try to see with the help of a figure, 2 matched metal molds are used to fabricate the composite product, the total mold will be split type of mold in 2 halves base plate is stationary while the upper plate is movable. There are 2 halves, one half will be stationary, other half will move up and down with the help of a hydraulic plunger reinforcement and matrix.

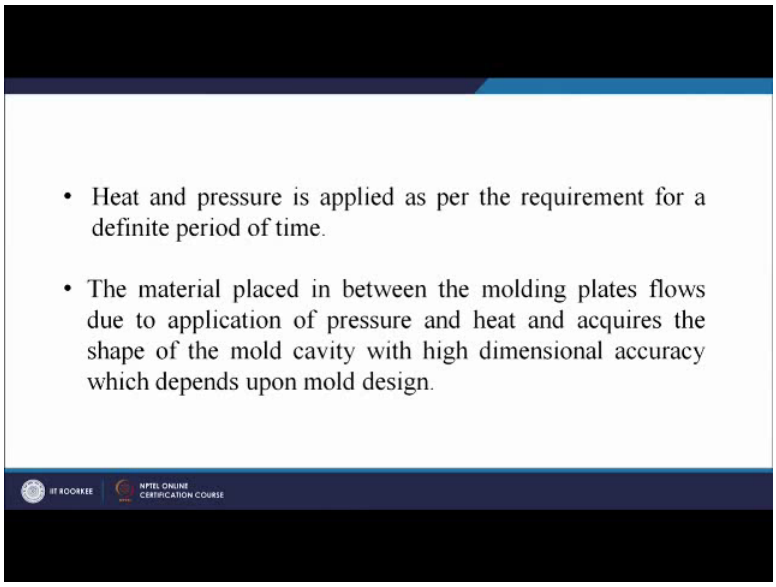
In our case we are focusing on polymer composites as all of you know, our case reinforcement will be fibrous reinforcement or in the form of fibers it can be continuous fibers in the form of woven mat or the it can be short fibers in the form of a mat, but the there has to be some bonding between the short fibers also. So, that we are able to place them as a in the mat form inside the mold cavity, a reinforcement will be fibrous and the matrix will be polymeric or polymer. We can have thermosetting as well as thermoplastic if it is a thermo setting it will be available in whiskers form we have to apply it with the help of a brush.

If it is a thermoplastic it will be available either in the pallet form or in a film form, depending upon the availability we will take our thermoplastic polymer and we will apply it on the fiber or the layer of the fiber. Then we will stack up the different layers depending upon the final product that we want to make, it can be maybe 0.5 centimetre thick or may be 5 millimetre thick, it can be 8 millimetre thick, it can be 1 centimetre thick or 10 millimetre thick, that decision we have to make based on the design requirement, based on that we will lay different layers one by one and accordingly we will get the desired thickness.

The reinforcement is fibers matrix is polymer both are placed in the metallic mold and the whole assembly is kept in between the compression molder, now the compression molder from here the meaning is the plungers that apply pressure on the laminate that we are trying to make in the mold cavity. The reinforcement and matrix, what is desirable, whatever raw material we want to make we will put it in the mold cavity in one half of the mold cavity the top half will come and will apply pressure this mold cavity will have the heat from all the direction, it will be a heated mold, we can apply heat from bottom top and even from the sideways also.

There will be heat that is supplied to the mold there is a pressure that is acting on the mold and finally, by the application of heat and pressure we will be able to produce our composite part, it is kept in between the compression mold.

(Refer Slide Time: 17:58)



Heat and pressure is applied as I have already highlighted as per the requirement for a defined period of time, third thing that I have missed was the period of time, there has to be a time domain also. So, we have 2 important things here one is the pressure, another one is the heat and the third part is the time holding time usually we call it that for how long the material is there inside the mold cavity.

The material placed in between the molding plate placed due to the application of pressure and the heat and acquires the shape of the mold cavity with high dimensional accuracy which depends upon the mold design as I have highlighted the product that we

will get will be having high dimensional accuracy, high dimensional stability as compared to the product made by the hand layup process.

This is an extension of the hand layup process and the material will flow why it will flow because of the application of heat, if it is a thermoplastic material as I have already told there are 3 steps only first is heating, melting and then cooling 3 steps only. So, when you are using a thermoplastic inside the compression molding machine if you supply the heat the polymer will melt and it will spread all around the fibers impregnate the fibers and finally, we will get a composite product if it is a thermo set.

It is available in the gen form we will apply the gel keep it under temperature and pressure and it will solidify, why it will solidify, just give that give a thought over it. In case of thermoplastic we have seen how the product is made injection molding, compression molding, transfer molding, transfer molding is majorly used for thermosetting polymers, but injection molding extrusion are used for no plastics. So, how it solidifies we take the polymer pallet, we put it into the barrel, it is heated through the screw, we feed it through the die the product comes out and it is cooled and it has already solidified whereas, in case of thermo sets how it will solidify it is in the gel form, I think the answer must have come to your minds that why a thermo set will solidify how thermo sets usually cure.

If you remember in other spray gun in our chopper gun in case of spray layup process what was the 3 ingredients that were entering into the gun if you just give a thought over it you will get the answer there was one constituents theta are fiber rowing a fiber is entering and in between it is getting chopped into small fibers the other was the resin or the polymer or the thermosetting resin that is entering on top of the gun there was a catalyst there was a hardener. So, this hardener or the catalyst reacts with the polymer and the polymerization or curing takes place which solidifies the polymer and it takes a solid or a rigid shape.

That is the important point to be taken care of in compassion molding also, when we apply heat, when we applied pressure, the hardener and the resin will react and they will become solid or they will become rigid and we will get our composite product. So, that is an important difference between the solidification of a thermosetting resin and solidification of a thermoplastic resin. So, thermosetting we will solidify because of the

reaction between the catalyst and the polymer and thermoplastic will solidify because we have melted the polymer we have deformed it and finally, when we cool it solidifies to take a solid shape. So, that is the Laymans definition of how solidification takes place otherwise we can go to the material science aspects the chemistry of the thermosetting polymers and the chemistry of the thermoplastic polymers and try to see that how the change behave under different conditions and how the solidification takes place.

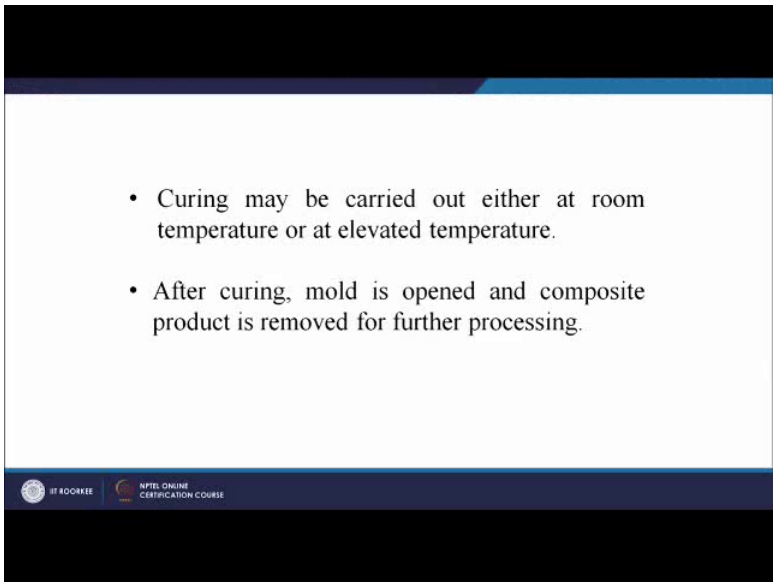
But currently our focus is on the processing techniques for this polymer therefore, we are restricting our discussion to on the macro scale only and we are trying to understand that how a thermosetting polymer cures and how a thermoplastic molds or thermoplastic the curing time is mostly use for thermosetting resin. In this case we will say how the thermoplastic can be molded and it can be solidified, there is a difference in compression molding why I am giving emphasis on this thing again and again because we can use both we can use the thermosetting polymer also we can use the thermoplastic also.

If it is a thermosetting type of polymer we will first do the layup we can do it outside the machine also we can do the layup on the table work table or workbench we can have different we can take a mold, we can layup as we do in hand layup process, we can put one layup of fiber, then we can apply the resin or the polymer another layer apply the resin another layer apply the resin and before doing this layup we will prepare our polymer we will add the requisite amount of hardeners steer it properly to release any kind of air entrapment or bubbles and then this mixture of hardener and polymer or resin or we can say epoxy and hardener we will bring we will apply it on the polymer.

Then this laid up laid up laminate we will take and we can put it inside the compression molding machine and then we can apply the pressure and we can give heat from all the directions and finally, the curing process will take place for the thermo setting type of polymer. In case of thermoplastics we can do the layup inside the mold only we can apply the pressure and the heat and because of the heat the thin film or the pallet us of the polymer or thermoplastic polymer will melt and they will impregnate the fibers and finally, they will solidify we have to cool the mold and when the cooling has cycle has been completed we can take out the composite part from the compression molding machines.

That we need to understand the difference in the procedure when we were using a thermosetting polymer and while we are using a thermo plastic polymer the material placed between the molding plate 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, the final surface finish of the product will depend upon the surface finish of the mold cavity.

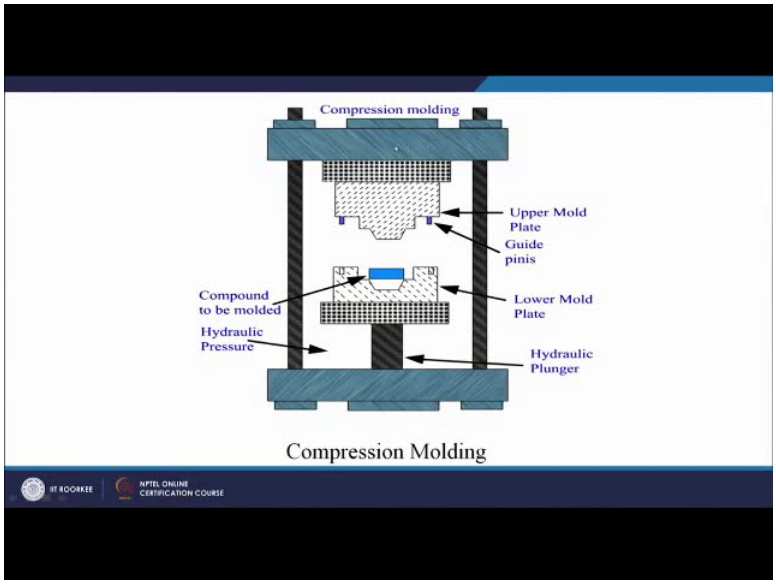
(Refer Slide Time: 24:53)



Curing maybe carried out either at room temperature or at an elevated temperature specially for thermosetting type of polymers, after curing the mold is opened and composite product is removed for further processing. Further processing may involve trimming up of the edges if there is a formation of flesh sometimes we may go for heat treatment of the product that we have made. Sometimes we may be required to cut a particular section inside the product that we have made, that will come under all these steps will come under the further processing.

Now your screen you can see there is a most simple type of diagram that we can see or that we can make for a compression molding machine there is a movable part.

(Refer Slide Time: 25:36)



This is the upper mold plate this part and you can see this shape that I am emphasizing is the exact duplicate of this shape. We can see what type of product we will get this is the compound to be molded it as I have told you specifically in case of thermosetting type of polymer.

We can do the layup on a workbench and then bring that layup and put it inside the mold cavity. So, that is the raw material this blue portion flat plate can be called as the raw material now what we have to do we have to control 3 important parameters, parameter number 1 is the pressure that we want to apply, parameter number 2 is the heat that we want to apply and the parameter number 3 is the duration for which we will keep our 2 plate or 2 mold halves closed position in the closed position, you can see this is movable upper plate move these are the guide pins the guide pins will help us in the exact engagement of the 2 halves of the mold.

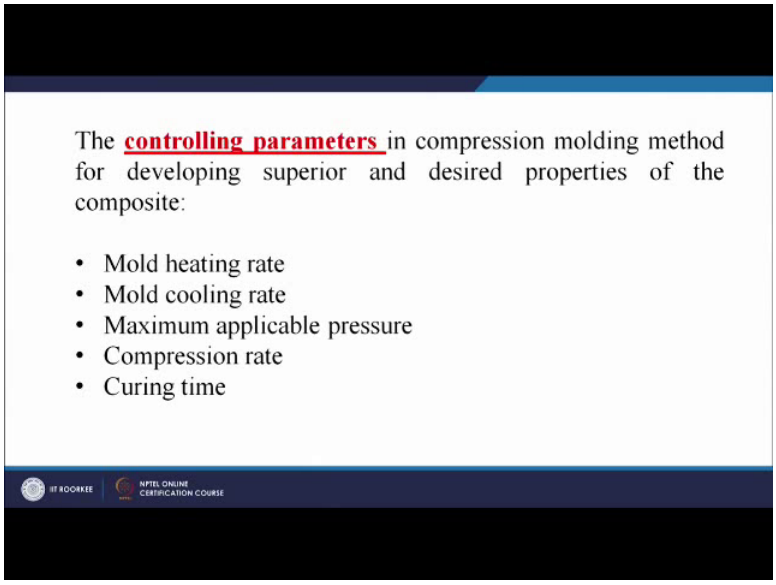
The top half of the mold to the bottom half of the mold and we can just bring this down and this is the hydraulic plunger this will move down and we will close the mold and this particular plate or the raw material will take the shape of the mold and finally, we will get our product. Some of you may be wondering that why this hydraulic plunger has been put at the bottom mold half, there is always a tendency of the composite product sticking to the mold cavity and if you remember in both the previous processes that is the hand layup process as well as the spray layup process we have introduced a concept of release gel or as release gel spray on the mold cavity, before doing the layup we have to spray the release gel on the mold.

So, that our product do not stick to the mold cavity, but still if the product sticks to the mold cavity we have a hydraulic plunger arrangement which will give a little tap to the product and it will be popped out of the mold cavity and similar type of concept if you remember we have seen in the injection molding shut up also that we have covered for polymers. We have seen during injection molding also there are 2 ejector pins which give a slight tap to the composite part or to the plastic part that has been made and it pops out of the mold cavity. Similarly here a hydraulic plunger can help us to remove our product or the final product from the mold even if it sticks to the mold cavity. So, I think the process is very very clear to all of you the mold is divided into 2 halves there is bottom half and there is top half bottom half usually is stationery top half is movable top half will apply that pressure.

This will be operated hydraulically we will put our raw material suppose this is the raw material we will put our raw material in the bottom half of the mold the top half of the mold will come down and it will close the mold and apply the pressure as per the cavity generated between the bottom and the top half of the mold the product will take the shape. Once the product this once the cooling cycle is over the top half of the mold will move up the product may stick to the bottom half of the mold, there will be a plunger which will be just give a slight tap to the material just a slight tap and it will be popping out of the bottom half of the mold, this is the most simplistic explanation for a compression molding process 3 things we can control here.

First thing is the pressure that we apply, the second thing is the heating arrangement in the mold and the third thing is the time for which, the 2 halves of the mold will remain closed. If we judiciously select these 3 parameters we will be very easily able to make a very good composite product, but these are not the only 3 parameters that we need to take into account in compression molding there are so many other parameters that we take need to take into account which we will see in our subsequent slides.

(Refer Slide Time: 30:05)

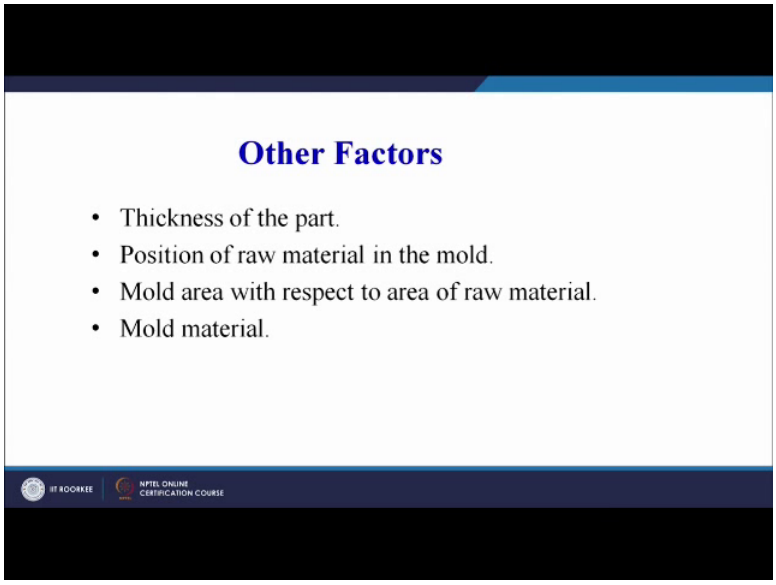


The controlling parameters in compression molding method for developing superior and desired properties of the composite product are, as I have already told you mold heating rate, mold cooling rate, maximum applicable pressure, compression rate, curing time.

Now, compression rate just we can compress it like this also and we can compress it very slowly, both will have it is effect on the properties of the composite or the developed composite, similarly we can increase the temperature at a very sharp gradient or we can slowly increase the temperature that is the heating rate, similarly the cooling rate for metals usually we see there are time temperature transformation ttt curves which affects mattlergy of the product that we have developed, similarly in this case also the heating rate and the cooling rate will definitely affect the properties of the final product that we get.

The parameters that we need to control or the heating rate cooling rate the maximum temperature the maximum pressure that we are applying the cooling time for which the mold is remaining enclosed thickness of the part that we want to produce.

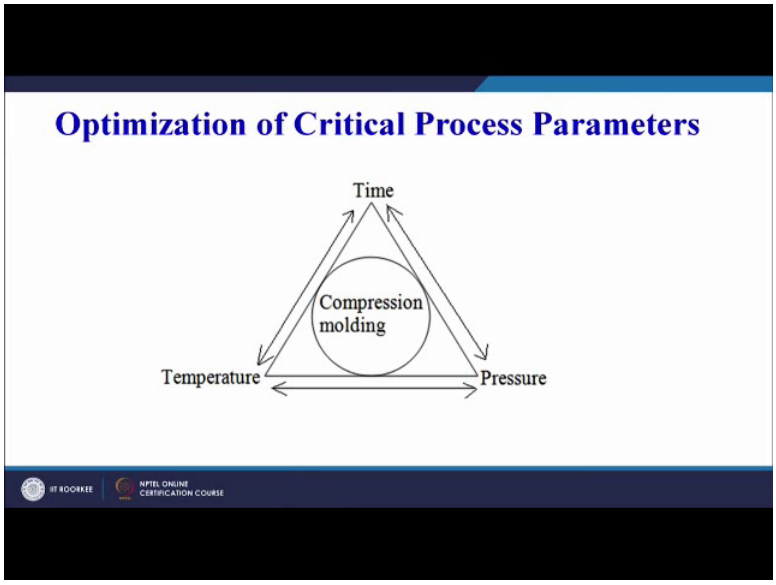
(Refer Slide Time: 31:14)



Position as the raw material in the mold in our in our diagram we can see where we have placed our raw material we could have try to place it at the bottom placed bottom phase of the mold also, but we have placed it slightly on the higher side. So, this may also the positioning of the raw material inside the mold cavity may also affect the properties of the final product, similarly the mold area with respect to the area of the raw material because the raw material has to spread and it has no fill the mold cavity completely.

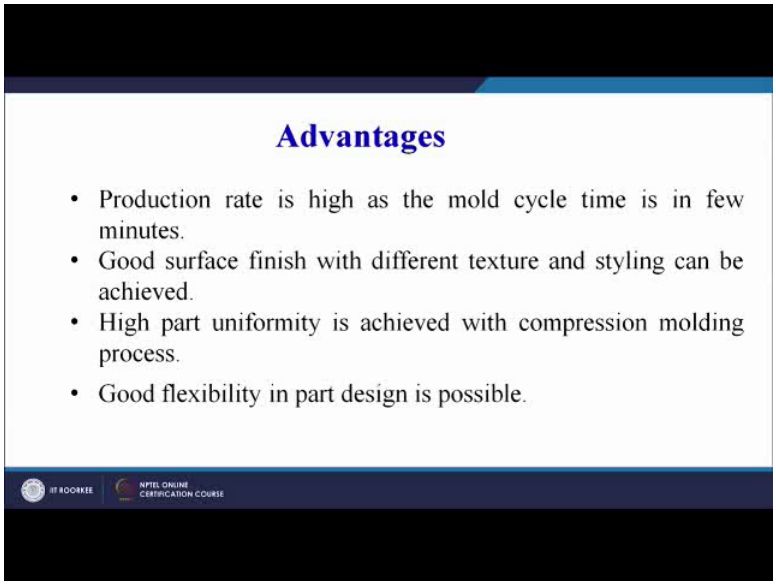
The positioning of the mold the material is important as well as the ratio of the mold area to the area of the raw material is equally important, similarly the mold material is also important because we have to supply heat to our constituents that are there in the mold cavity. So, that the material should have the adequate you can say thermal properties in order to properly heat the constituents inside the mold cavity, the mold material is also very very important.

(Refer Slide Time: 32:23)



But 3 major parameters that are important are the time, the pressure and the temperature, we have to supply heat, therefore, temperature is important we have to cool it, time is important and we have to apply the pressure, we have consolidate our composite product therefore, the pressure is very very important.

(Refer Slide Time: 32:42)



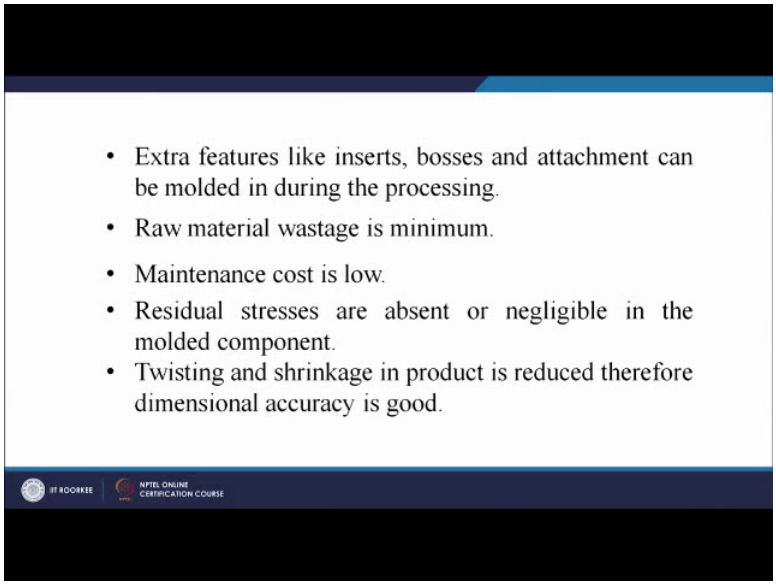
Now, coming onto what are the advantages of this process, advantage as you can see on your screen production rate is high as the mold cycle time is in few minutes, if you remember in hand layup precious we have seen the cycle time is very large it may take may be one day to make a product, but here we see the product can be made in few minutes only. Therefore, the production rate of compression molding is higher as

compared hand layup process good surface finish with different texture and styling can be achieved. So, that is as I have told you in hand layup process also why we do grinding on the 2 inner side mold halves, we do grinding in order to produce good surface finish, in this case also as we have the closed mold where the product is being compressed or application of pressure from all dimension.

If the outer surface of the product will very very good why because surface finish of the mold which is a metallic mold will be duplicated or will be transferred to the surface of the composite product. High part uniformities achieved with compression loading, that we have seen part uniformity is good, dimensional stability is good, surface finish of the product is good, good flexibility in part design is possible. So, flexibility is possible because we can change the mold and make a different product.

Extra features like inserts, bosses and attachments can be molded in during the processing.

(Refer Slide Time: 34:10)

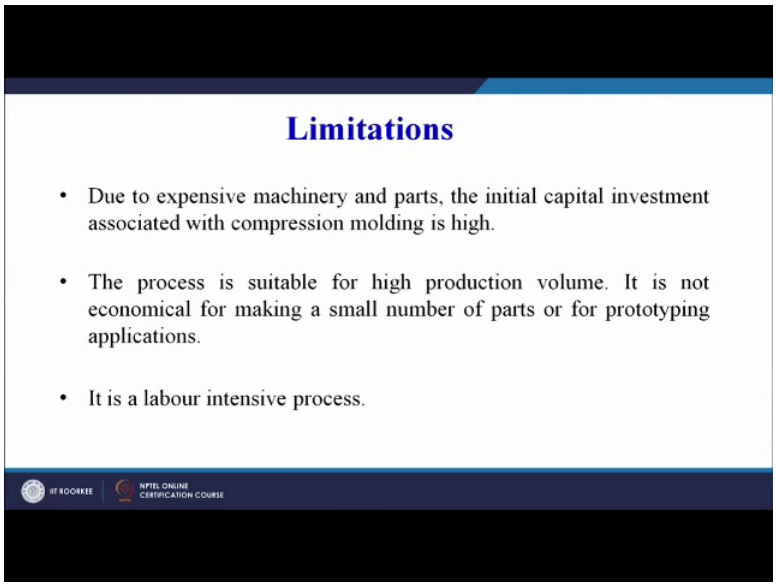


As we have seen that we have to keep our raw material inside the mold cavity use some inserts and other additional components or equipment help to put inside the final product we can place it at it is desired position and then apply the pressure, that extra features like inserts, bosses and fasteners can easily we put inside the final product, raw material wastage is minimum closed mold process, there is no flow of material outside. So, requisite amount of charge or requisite amount of material will only be used as a input in

the mold cavity. Maintenance cost is low, residual stresses are absent or negligible in molded component which is also very very important, twisting and shrinkage in product is reduced therefore, dimensional accuracy is good I have already highlighted this point when we use a closed mold process the dimensional stability achieved is very very good or the dimensional accuracy is good residual stresses are absent.

What are the limitations now limitations as you can see.

(Refer Slide Time: 35:16)

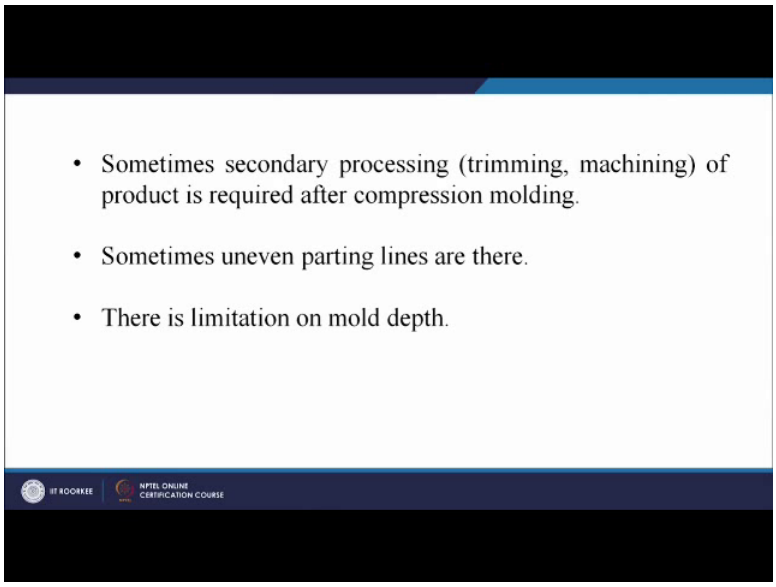


Due to the expensive machinery and parts, the initial capital investment is high as we have seen in case of hand layup process the tooling cost is low, in spray layup process also tooling cost is low, but in compression molding the cost of equipment is high why because we have to apply a temperature, we have to have heating arrangement, we have to control the heating arrangement also because different polymers, will have different melting temperature, they will have different grass transition temperature, we have to control the heat input therefore, the temperature control is require.

Another thing that we control is the pressure, for pressure control we need to have a hydraulic arrangement therefore, the equipment is slightly costly. The process is suitable for high production volume only, it is not economical for making small number of parts or for prototyping application since the initial investment initial capital investment is considerably high. The process is not suitable for small batch sizes it is suitable for large volume production only, it is labour intensive process as I have told you that the layup

for thermosetting type of composite parts can be made on a work bank. So, manually intervention is also there in case of compression molding process and not a fully automatic process.

(Refer Slide Time: 36:35)

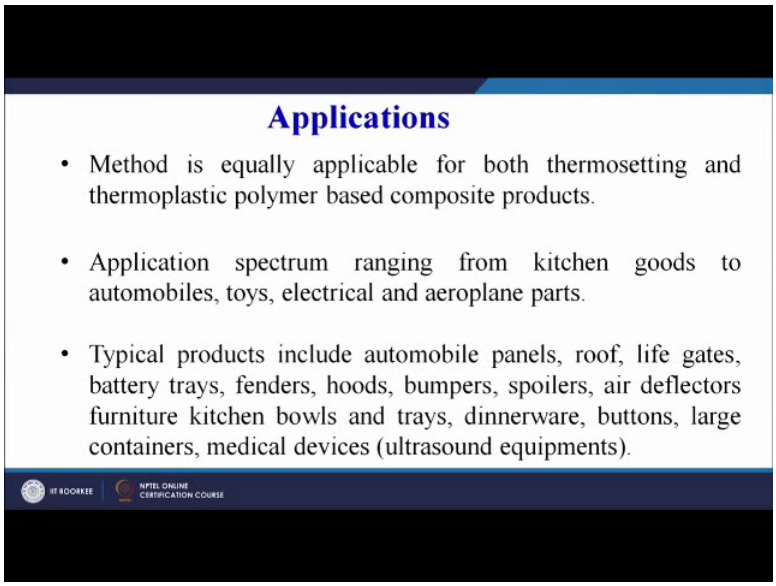


Sometimes secondary processing that is trimming of the product is required after compression molding that I have already highlighted because this is a 2 half 2 mold half process. The product when it is raw material, when it is put inside the 2 halves of the mold and when the 2 halves of the mold closed and we apply lot of pressure, there the raw material sometimes flow out through the parting line between the 2 mold halves and there may be generation of little bit of flash which we can trim of at a later stage. Sometimes uneven parting lines are there, that is a challenging task the uniform application of pressure then becomes a slightly challenging.

There is a limitation on the mold depth in order to have uniform properties, uniform distribution of properties across the thickness of the product we cannot go for a very large depth increases of compression molded parts. Usually you will see the products like trays and flat products are usually made by the compression molding process, the depth is limited.

Applications, as I have already highlighted one application let us see, what are the other applications.

(Refer Slide Time: 37:46)



Method is equally applicable for both thermosetting and thermoplastic polymer based composite products I think I have given lot of emphasis on this aspect today, application spectrum ranging from kitchen goods to automobiles, toys, electrical and aeroplane parts, different parts are made by compression molding process to be very specific in automobile panels, roof, life gates, battery trays, fenders, hoods, bumpers, spoilers, air deflectors, furniture kitchen bowls and trays dinnerware buttons, large containers, medical devices can be made using the compression molding process. If you see most of the application the depth is not that much usually flat products are made, flat geometries are made using the compression molding process, with this we come to the end of our discussion on compression molding process specifically for composite products. In the next session we will address another process which is used for processing of polymer composites.

Thank you.