**Processing of non metals**

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**Module - 5**
**Polymer Matrix Composites: Processing**
**Lecture - 10**
**Resin Transfer Molding and Autoclave Molding**

A warm welcome to all of you, in this last lecture in module 5 on resin transfer molding and autoclave molding. Lets summaries what we are covered in these series of lecture on processing of polymeric metric composites that is the module 5 of our course on processing of non metals.

We have see in the classification of the processing technique for polymeric metric composites, prior to that we have seen what are polymeric metric composites, what are the basic Constance of basic polymeric metric components and we have seen how the polymeric metric composites compare with the convectional material or the convectional engineering materials such as steel and other isotropic materials.

In the discussion on processing techniques, we have seen there are different types of processing techniques which fall under three broad categories, that is the open mold processes close mold process and the other types of process is which do not fall under the open mold and close mold or where the mold may be opened are closed, but they have certain specific shapes or certain specific process details therefore, we discuss them under the different category.

We have seen different process such as, hand layer process, spray layer process, we have seen filament voiding (( )) resin transfer molding we are going to cover today but, we have already covered atleast 6 different processing and we are seen what are the advantages what are the disadvantages and the application areas of these processes.

So, today in our lecture we are going to see what are the process details of, resin transfer molding and the autoclave molding? So, basically before we start our lecture, in the last lecture we have seen what is pre plugging and sheet molding compounds. So, in sheet molding compound and pre plugging, we have pre plugging we have seen that the 2 macro constituents of the composite, that is the fiber and reinforcement are combined together before they are used as the raw material for final composite manufacturing, but

here again in resin transfer molding and autoclave molding the resin and the fiber would be combined during the process itself.

So, we are not rating or pre blending the 2 constituents and later than using them in the process, but we are doing here is that we are combining the resin and the fiber together during the process stage only, that is in resin transfer molding we will have the ingredient in the form of the reinforcement and we will have matrices which would in the form of the polymer. So, we have reinforcement or a fiber and we have the metrics and we are combining them together in resin transfer molding.

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So, what are the process details that we will see in subsequent slides and similarly we will see the process details of the autoclave molding coming on to the resin transfer molding.

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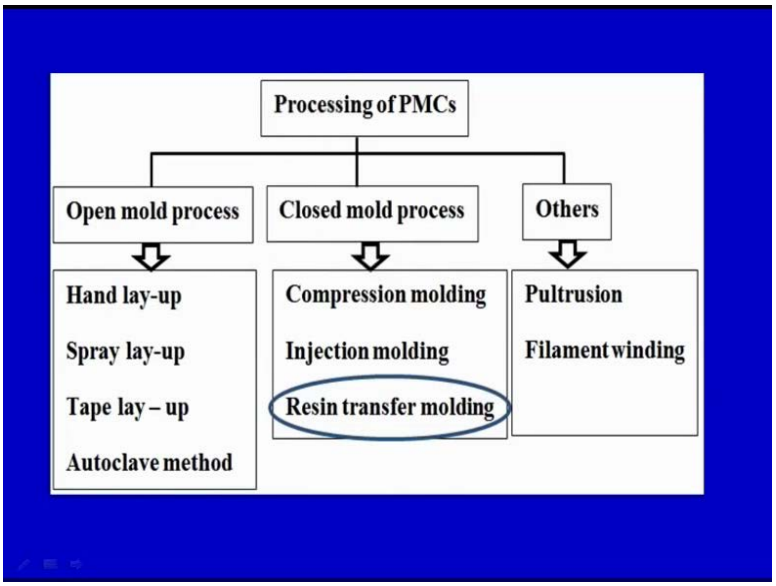


This diagram we have seen in the most of our lectures on processing of polymeric metric composites. On your screen you can see, we have open mold processes, close mold processes and other type of processes for the processing of polymeric metric composites.

So, today we are focusing on resin transfer molding which are the closed mold processes and the auto clave method which is an open mold process. So, again because, we have coming to the end of this particular module that is processing of polymeric metric composites, I want to emphasize once again difference between the open mold process and closed mold process.

So, we have already covered if we summarize what we are already covered we have seen in the hand lay-up process and the spray lay–up process also, we have seen compression molding and injection molding which are the closed mold process and we have studied the basic details and the process details application advantages and limitation of pultrusion as well as those of the filament winding.

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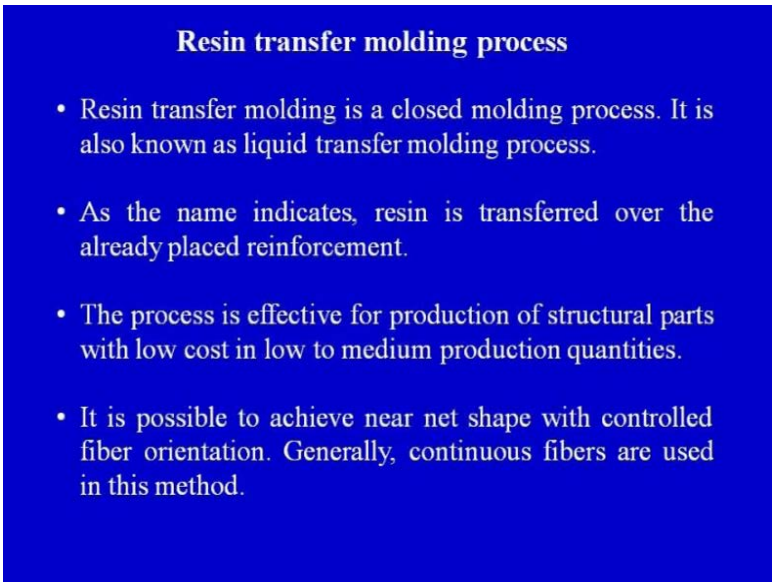


So, we come to the end of this particular module with discussion on resin transfer molding and the auto clave method, resin transfer molding. Resin transfer molding is a closed molding process. It is also known as liquid transfer molding process.

So, liquid transfer molding or resin transfer molding basically the principle is that it we have a metallic mold in that mold we will keep a our reinforcement as in the previous lectures we have see the reinforcement can be in terms of long fiber can be in terms of short fiber the fibers can be in a mat form or they can be inner tape form.

So, we will force our reinforcement in the mold prior to the injection of the resin, then when the reinforcement has been placed, it can be placed in 2 dimensions, it can be placed in to three dimensions also and finely the resin will be prescreened in to the mold along with the catalyst and additives and other filling materials and other filler materials.

So, we have the reinforcement already, in place which is already been placed in the mold and now we are pressurizing the resin in to the mold the resin will flow because, it has viscosity and it will fill the mold cavity and finally, the hole resin and reinforcement will be cured and after curing the molds will open and the final product would be take out.

So, we would be trying to understand the basic principle of resin transfer molding. So, why I have emphasizes without to the help of diagram, just to emphasize or just to clear the name resin transfer molding, in case of hand lay-up process also use to flood plate

mold it is a open mold process and we lay-up the reinforcement and apply the resin with the help of our brush the polymer is a played with the help of brush and we have already mix the hardener and the resin with the in order to cure the poly polymer.

So, basically what we are doing here, we are again doing the same thing we are placing the reinforcement in the mold and pressurizing the resin, in case of hand lay-up process we applied the resin by hand, in case of resin transfer molding we are supplying the resin at a pressurized level pressurizing the resin towards the reinforcement.

So, the basic principle is of combining the fibers and the resin together to make a composite material, but this particular process has got its specific application which would be seen in the subsequent slide.

So, I think by this particular summary the name itself as clarified that what is there in process, the reinforcement is there in the form of fiber can be woven, they can be in unidirectional or they can be in the tape form and even the chopped fiber mat can also be used as reinforcing material. We have reinforcement and we pressurize the resin towards that reinforcement, in the mold cavity and when this assembly of the reinforcement and the resin would cure finally, we will get a composite product.

So, with this summary, let us start discussing point by point. Resin transfer molding is a closed molding process. The mould would be made in to 2 half upper half and lower half of the mold and the mold would close to form a mold cavity. So, it is a closed mold process, it is also known as liquid transfer molding process because, the resin is in the liquid format as got certain viscosity and we are pressurizing the resin into the mold cavity as a name indicate its resin is transferred over.

The already placed reinforcement which I have already explained now, let us revised point by point reinforcement is already in place the resin supplied to the mold cavity we have already placed the reinforcement. The process is effective for production of structural parts with low cost in low to medium production quantities.

So, this particular process is not very suitable for very large production quantity from low to medium quantity but, the cost of production is not very high it is possible to achieve near net shape with controlled fiber orientation, generally continuous fiber are used in this method.

So, most probably or we can say in most of the cases continues fiber reinforcement would be used. So, the fiber mat that we putting inside the mold cavity prior to the injection of the reseno transfer of the resin is in the form of a continuous fiber mat.

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Now, what are the raw materials that are used, the raw materials are the reinforcement material are glass fiber, carbon fiber, armed fiber or some time natural plant fiber can also be used, these fiber can used by the individually or in the combined form we can have hybrid reinforcement also for example, in the war (( )), we may have used different fibers, we can have glass fibers in one direction and carbon fiber in the other direction or there can be combination of carbon and era mat.

So, we have hybrid fibers also fiber mat or it can be made up of the same material may be a glass fiber mat only woven mat can be used. Unidirectional mat can also be used for some time chobstrend mat can also be used. So, the fibers reinforcement that is placed inside the mold cavity can be in different types, it can be woven type and unidirectional type or any type of reinforcement can be put, but it cannot be, we can say randomly distributed fibers because, we cannot put all the fibers in the mold cavity without having proper alignment or without having a proper placing because, when the resin will be injected it will push all the randomly oriented fibers towards one direction. So, that we do not require.

So, what basically required is that the fiber should be placed in the form of mat form. So, that the fiber washed does not take place. So, what is fiber washed, that we would see in the subsequent slides, but just know this particular slide one point is very cleared that different types of fiber can be used for resin transfer molding another point that is clear is that the fiber should be placed properly inside the mold cavity in the woven mat form or in the unidirectional tape form.

Sometimes we may need to add certain additives for example; certain minerals filler may be used, why in order to improve the surface finish or to improve the fire ret ardency, we want to make our composite which is retardant to fire we need to add certain fillers. So, these fillers or mineral fillers can also be added to improve the surface finish. So, whatever ingredients we want to blend together in order to make a composite material these ingredients can be put in the mold cavity sometimes, these fillers or additives can also be additive to the resin prior to being injected or transfer in to the mold cavity.

So, we have to blend (( )) in one of the previous lectures on the introduction to the polymeric material composite, it was emphasizes that these particular material have a tailor ability or tailor made properties, which means that these material can be tailored depending upon the specific design requirement.

If we have a specific requirement, we can tailor the material. So, if we have basically there are 2 macro constituent in the component that is the reinforcement and a matrices, buts Sometime, some addition filler some additional chemical or some additional we can say reinforcement may be added in order to give certain specific property to the composite. So, this particular point mineral fillers are added some times improve the surface finish, some time improve the fire ret ardency and some time they other types of filler may be used to improve the traiabological characteristic of the composite material, there is a work that is going on the effects of fillers on the traiabological properties of the polymeric matrices composite.

So, what type of matrices can be use in resin transfer molding, we can use epoxy methyl methacrylate, polyester, polyvinyl, ester, phenolic resin, different type of matrices material use can be use. As we have seen there are different types of reinforcement material there are can be different types of matrix materials also.

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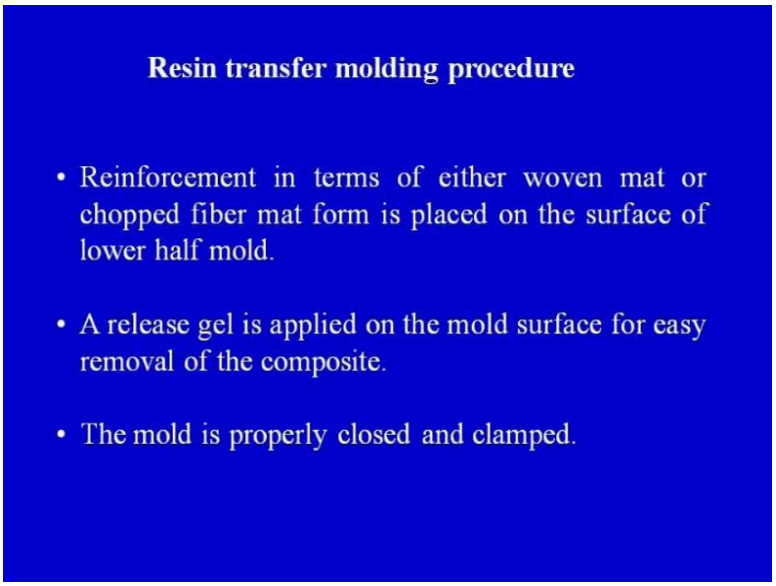


So, on your screen you can see, the procedure of resin transfer molding, So, once again I want to revise that what is the basic step involved in the resin transfer molding procedure. So, in resin transfer molding the reinforcement in term of either woven or in chopped fiber mat is placed in the lower half of the mold.

So, basically here is 2 half of the mold and in the lower half we place the reinforcement a relesial is a plied on the mold surface. So, that the composite when it ready can be taken out easily, the mold is properly closed and clamped. So, in this particular case we have the reinforcement which is already placed on the lower half the mold and the resin is injected inside and the resin and the reinforcement totally cure into the final composite product.

So, as in the hand lay- up process I have already told in hand layup process also we are lying the reinforcement and then we are applying the reinforcement the matrices in the form of resin in the help of a brush, but in case of resin transfer molding the difference lays in the because, it is a closed mold process and different lies in the type of mold and difference pattern in which we are applying the resin in hand lay, we apply with help of hand and a brush. In case of resin transfer molding we apply the pressurizing resin towards the reinforcement, we send the resin in to the mold cavity where the reinforcement is already in place. The resins pumped in to the mold through the ports and the air is displaced through other vents.

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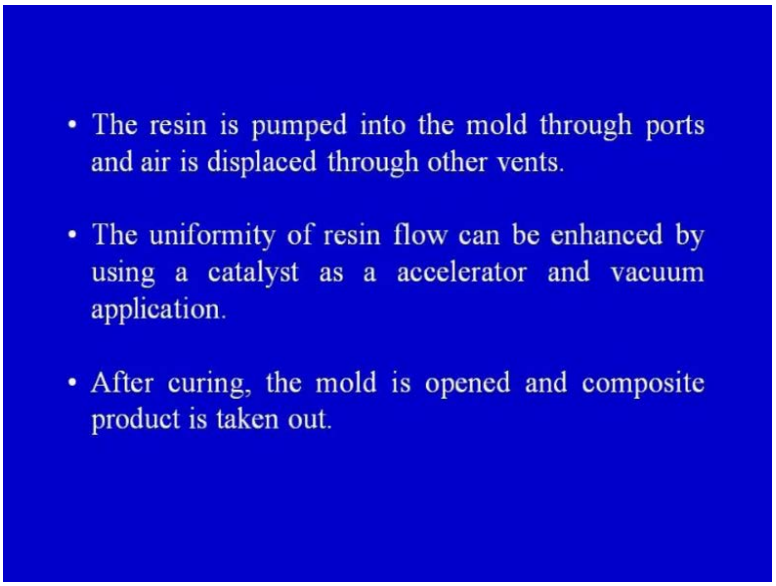


So, we will try to see this with the help of a diagram, again I am emphasize the reinforcement is already in the mold cavity it is closed mold process and we supplied the resin. A pressurized resin which would go and impregnation reinforcement and finally, result in to the fabrication of the composite product or the processing of the composite product. The uniformity of the resin flow can be enhanced by using a catalyst as a accelerator and vacuum application. These are some process we argent in which a catalyst can also be sent with the resin in to the mold cavity to accelerator the process of polymerization or curing after curing, the mold is opened and composite it is taken out.

So, there is basically, three or four very easy step which would lead us to processing of a composite product. So, what are these step we need to have a closed mold a lower half of the mold and upper half of the mold in between, we will form the mold cavity in the mold cavity mostly on the lower side of the mold cavity that is the lower plate of the mold cavity, we would place our reinforcement we would be before lying the reinforcement we would be plying a releases gel. So, that the composite can be taken out, the release gel spread on the mold cavity before doing the total processing steps that is before going for the processing of the composite in the resin transfer molding.

So, we will have a layer of release gel on the bottom plate of the mold as well as the top half of the mold. So, release gel is applied the reinforcement is placed, the mold is closed and resin is injected through the ports the resin goes and displace the layer which is

already present in the mold cavity, the air comes out of the went which are already present in the mode cavity and finally, if we have put a catalyst accelerated rate of curing would take place within the mold cavity and we would be able to find the final composite product.

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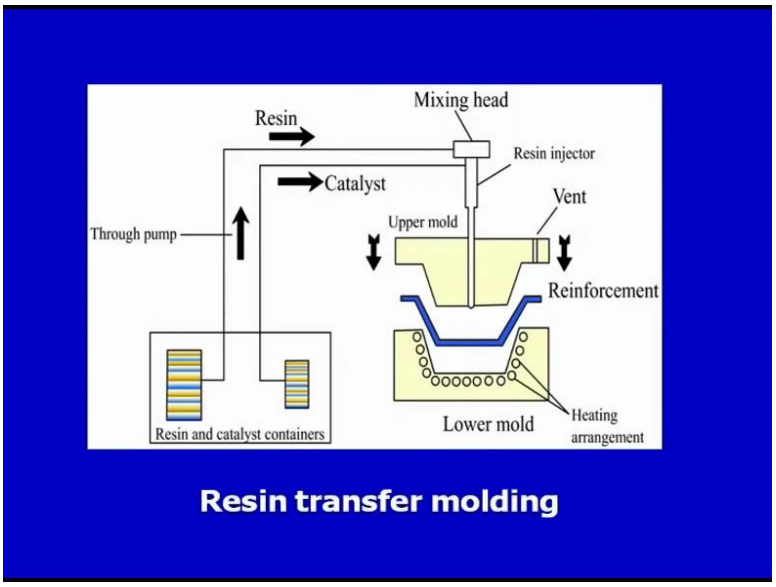


So, whatever procurer we have to discuss now we will try to with the understand with the help of a very simple diagram, on your screen you can see there are 2 ingredients that would going to the processing of composite product, this is the you can say storage for the resin and this is the catalyst container and this is the resin container and the catalyst container. So, resin and catalyst both are through the pump they getting pump into the mode cavity. So, where is the mode cavity? This is the lower mode or lower half of the mode base a lower portion or a screen this is a lower half of the mode and this is upper half of the mode and this is a passage for the where has, where has been would be injected this point this is the mixing head where is the resin and the catalyst would be mixed.

So, there are 2 ingredients in case of resin transfer of molding also 2 macro constitution, that are required to make the composites followed, what are the macro constitution, that is the fiber enforcement and the resin any polymer can be used as resin material which would be acting as matrices in the composite material. So, we have a one ingredient here, another ingredient is placed in the mold in the form of in reinforcement, but, prior to that

we would have prior release gel here, on the mode surface and we will have prior release gel here, at the mode surface.

So, release gel will be a pride and both the mold surface is the mode cavity which is generated between the upper half of the mold and lower half of the mold reinforcement is already placed. The resin is injected through this passage and in the closed mold and the finally, curing of the process, curing of the composite would take place in the process and finally, we will get the composite product.

So, in particular place we see this is the blue portion is the final composite product which has been made by the resin transfer molding, another thing to understand in this particular case, is these points these are the heating arrangement of the heating element. So, why the heating is required? Heating is required to escalate rate of curing.

So, we will have heating elements in the lower half of the mold, sometimes we can even have heating element in the upper half of the mold, also and we can do the accelerated curing of the composite product. So, again to summaries we have already seen the procedure of the resin transfer molding and we have already seen the diagram also it is already it is there on your screen. So, we can again revise the basic process of resin transfer molding before going in to the controlling parameter advantages and limitation in this process.

So, the reinforcement is placed in the bottom half of the mold a reinforcement can be in the form of woven mat of any material like glass fiber or carbon fiber or it can be chopped strand mat in which the fibers are discontinue fibers randomly oriented are available in mat form. So, any form of reinforcement we can take the reinforcement will be place here prior to placing the reinforcement release gel in the mold surface. So that, composite can be taken out easily.

So, reinforcement is placed here, the 2 half of the mould would close down the reinforcement is already there, the resin through pump will be resin and catalyst would be pumped. They will be mixed here and they will be supplied in the closed mold through this passage and once the resin has been supplied heating elements will be on and finally, after the heating curing will be take place and after the curing the 2 half mold will open and composite would be taken out, this is the basic principle of resin transfer

molding there can be other variant of the process also the basic principle would also be remain the same.

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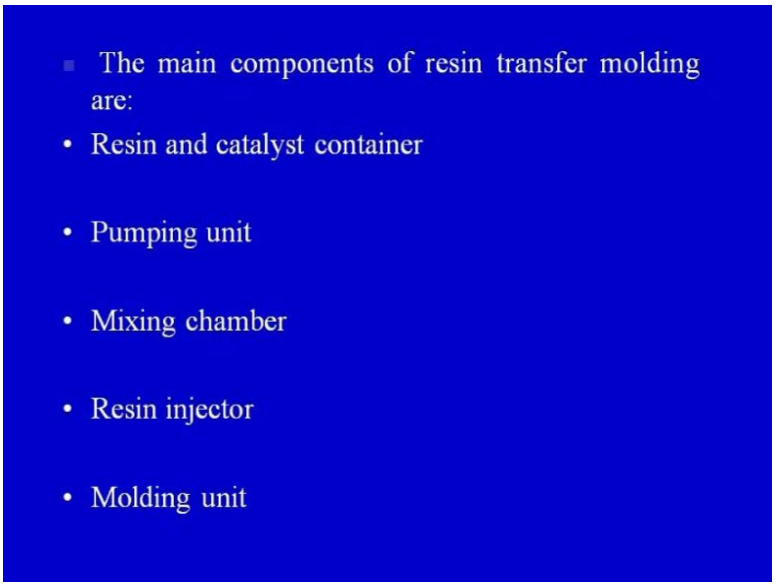


What are the components of resin transfer molding which we already seen in diagram? It is a resin and catalyst container, there is a pumping unit which is used to supply the resin and the catalyst mixture in to the mold cavity, we have a mixing chamber we are resin and the catalyst mixed there is a resin injector, at the point of resin would are the injection system which will help the resin to enter in to the mold cavity and finally, we have a molding unit it has 2 parts a lower half of the mold and the upper half of the mold the 2 half's of the mold would combined to generate a mold cavity.

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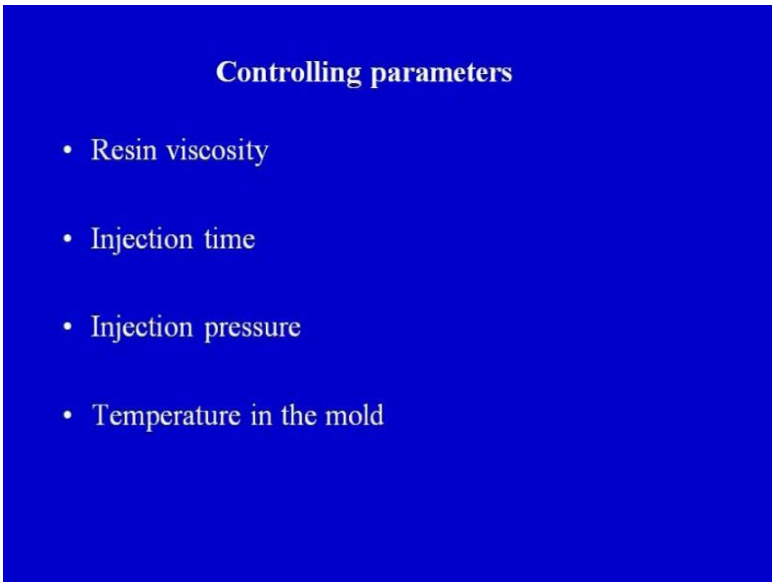


What are the controlling parameters in resin transfer molding? There are few important parameter like resins viscosity, we have discussing this for the other process is also that resin viscosity is very very important in the processing of polymeric matrices composites why because, the resin is one of the important continuant of the final composite if do not have a optimal resin viscosity, we may not get a very good quality composite product. This particular point or a controlling parameter has discussed for other processes also such as resin transfer molding pultrusion and some other closed mold and open mold process.

So, one of the important point is to control the viscosity of the resin system or to have a control over the matrices which would be acting as the one of the constituent for the fabrication of the composite product. Again to revise or summarize the composites are made up of 2 important constituents that is the matrices and reinforcement and in case of reinforcement the strength of the fiber is very very important on the other hand the viscosity of the matrices is also very very important.

So, most of the matrices that we used have to have a very optimal viscosity so that, they can be easily blended with the fibers to get a composites product. Injection time is also very very important if we have a large injection time we may get some problems in the final product, some of that we can say portions would be cured faster compared to the

other portion, we do not get the uniformity of the properties in the whole composite product.

So, the injection time if it is very slow it creates a problem, if it is very fast the resin will flow at a very fast passé, in a short duration of a time we are filling the hole cavity there may be a chance is that the fiber may get washed with the resin. So that, also as to be avoided optimally select the injection time as well as the injection pressure also, if it is less we may face certain problems.

So, that the composite product that we are finally, getting is not of the adequate quality. So, if the pressure is very high still there would be problem. So, we have to find out optimal injection pressure at which the injection in which the resin would be injected in to the mold cavity. Temperature in the mold is also very important as we have seen in the diagram that the 2 molds can be heated molds. So, that the curing process is accelerated. So, it is also very important. In one of the process, we have seen that the temperature control is not exercise the polymer may burned and may get stick to the mold surfaces.

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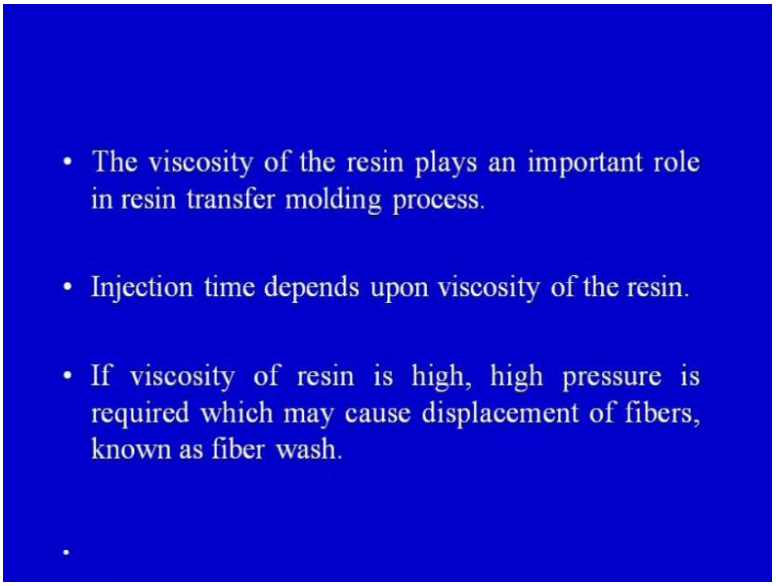


So, optimal control of temperature within the mold cavity is also equally important and is require so that, we get a very good quality composite product. The viscosity of the resin plays an important role in resin transfer molding process which I have already told, injection time depends upon the viscosity of the resin that we already seen, that if it is we can say optimally selected we will get a very good quality product and if the viscosity is

good the injection time will automatically be adjusted, If was viscosity of resin is high, high pressure is required which may cause the displacement of the fibers known as the fiber wash.

So, basically we have to avoid this problem of fiber wash, that if be a very large pressure the fiber may get washed with the resin and we may not get the uniform distribution of the fibers in the final product which is one of our final product is concentrated at a particular point and the reinforcement is concentrated at the another point in the bulk of the composite and when we use this composites there are chance is that it may fail from the resin rich area or from fiber rich area. So, we have to optimally select the pressure at which we are injecting the resin, we have to select the viscosity of resin and which would subsequently dictate the injection time, the time in which the resin would be able to fill the mold cavity.

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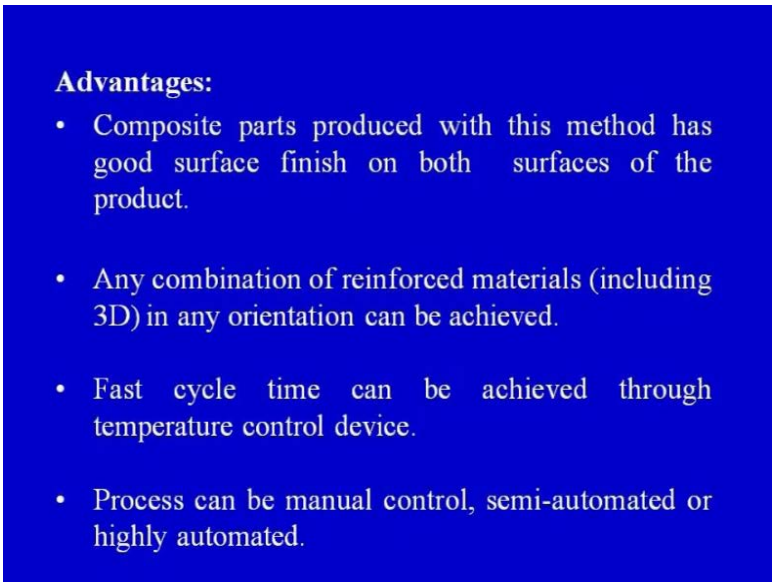


Now, what are the advantages of the resin transfer molding process? To composite I mold and we have lower half of the mold. So, we can get good surface finish on the both the side of the composite of the product. So, the composite that are made by the resin transfer molding have good surface finish on both surface of the product any combination of reinforcement materials any orientation can be achieved because, we are already place reinforcement in the bottom of the mold before the injection of the resin we can very easily manipulate, the orientation of the fibers and even go in the 3 dimensional

direction. So, we can even get the height even get the reinforcement in x and y direction very easily in this case we can have the reinforcement in the z direction also. Fast cycle time can be achieved through temperature control device.

So, we have already see in the diagram that we have a heating element all around the mold, so if a we have heating arrangement the cycle time would be short, may be shot cycle time are achieved why because, the curing process would be faster in case when it as heated by the temperature. So, temperature control will help us to make large no of parts in a small duration of time using the resin transfer molding process. Process can be manual control semi automatic or highly automatic depending up on the no of parts we are making depending up on surface finish that we require and depending up on the demand in the market, we can have a manual or semi automatic or fully automatic resin transfer molding process. Composite part thickness is uniform which is determined by the mold cavity.

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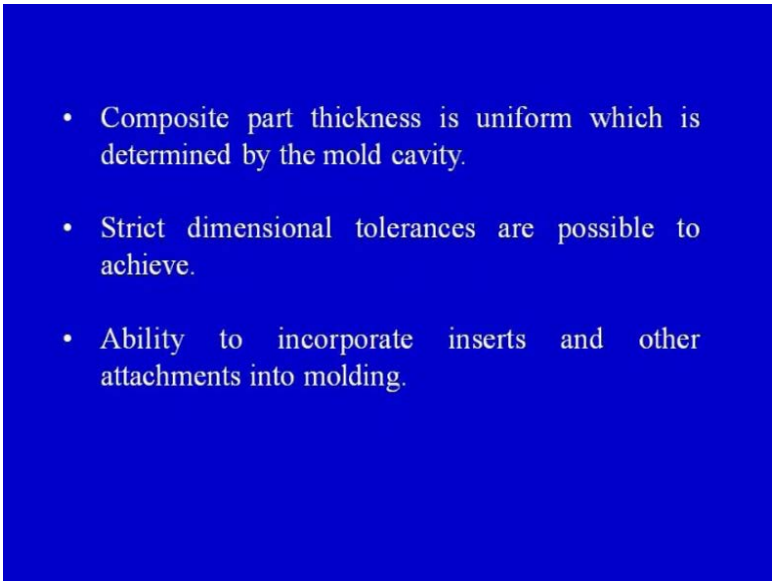


So, as per the design of mold cavity we will get a uniform thickness of the composite product, when we use the resin transfer molding process strict dimensional tolerances are possible to achieve because, it is a closed mold process. We will get strict dimensional tolerance or dimensional stability of the final product would be good it has ability to incorporate inserts and other attachments into the molding.

So, we are already may placing our fibers very judiciary in the lower half of the mold now suppose we want to put certain inserts at certain places in the final product those can be easily done in the lower half of the mold prior to the injection of the resin.

So, we can very easily manipulate shapes or manipulate our reinforcement. So, that we those things are available to us in our final products. So, additional inserts can be easily done or additionally attachment can already be added In this particular case that is resin transfer molding, suppose between 2 or 3 different layers we want additional attachment that can be placed in the lower half of the mold along with the different layer of the fiber prior to the injection of the resin in to the mold cavity, this is another advantage with resin transfer molding.

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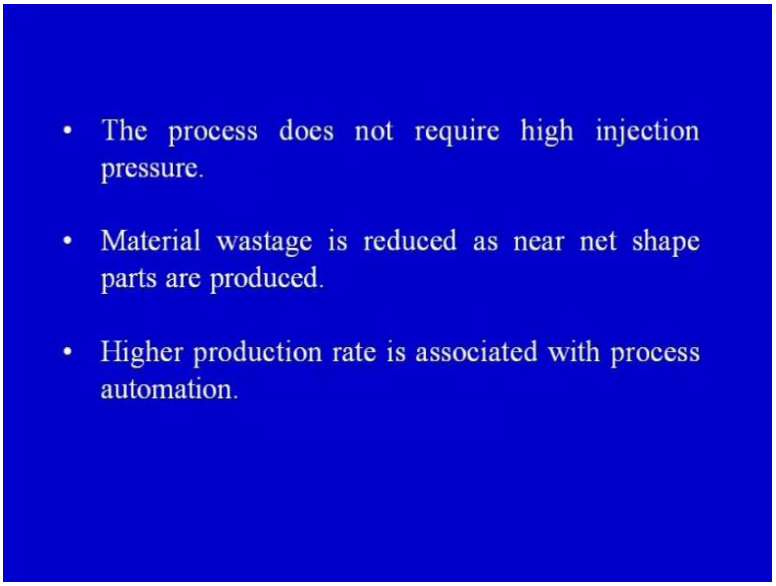


The process does not require high injection pressure so that is another advantages because, if you require very high pressure the machine would be the machine capacity has to be increase. So, the layer we can use low hand machine for apply the resin in to the mold cavity. So, the process does not require very high injection pressure. Material wastage is reduced as near net shape are produced near net parts are produced. So, there is no wastage we can cut the desire dimension of the reinforcement before placing them in to the lower part of the mold. So, we get least wastage in case of resin transfer molding higher production rate is associated with process automation.

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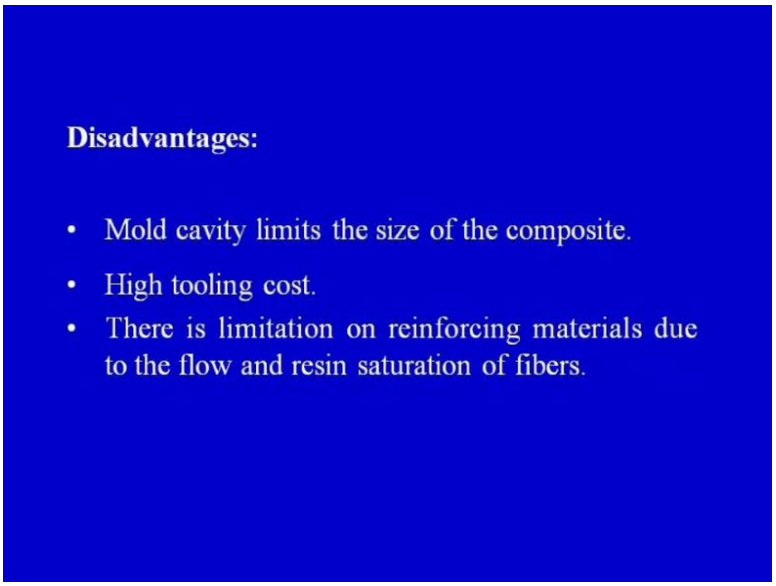


So, I have already told in the previous slide with the process can be manual semi automatic and fully automatic, now depending up on the requirement if we choose fully automatic process the cycle time would be lesser and the production rate would be very very high, having so many advantages, there are few disadvantages of the resin transfer molding which you can see in screen, mold cavity limits the size of the composite because, we have a mold cavity which as to be closed mold process, because it is a closed mold process, we have a closed mold cavity.

So, the size of the mold cavity dictates the application of the resin transfer molding. So, we cannot have a very big shape resin transfer molded product. So, shape is one of the or very size and shape is one of the limitation of resin transfer molding which is not the limitation in case of hand layup process. So, if we are if we have to make a huge product we would certainly go for hand layup process or a combination of hand layup and spray layup process and certainly in case of closed mold process size is a limitation and resin transfer molding is a closed mold process therefore, we cannot process very large size and very complicated shapes with a resin transfer molding.

So, on your screen you can see the disadvantages mold cavity limits the size of the composite. So, depending upon the size of the mold cavity we will get the final product of the composite. Tooling cost is also high because, we have to make closed mold and we have to provide a very good surface finish on the mold because of that same surface

finish would be translated into the final product and we have seen one of the advantages in the resin transfer molding that it has got good surface finish on both sides of the or both surfaces of the composite product, because it is made between the top and the bottom half of the mold.

So, tooling cost is high because mold has to be having very good surface finish, there is a limitation on reinforcing materials due to the flow and resin saturation of fibers. So, we have to very judiciously select the reinforcement that we are placing on the lower half of the mold because, already we have seen there is one problem of fiber wash the fibers may get washed with the high pressure of the resin.

Another disadvantage can be in terms of selection of the reinforcing material, if the reinforcing materials are very very light and it is randomly oriented the resin may push the fibrous material into the one corner. So, this is on the execrated scale, but still there may be some kind of damage we can say some kind of problems associated with the reinforcing material also has given on the screen resin saturation of fibers, if we have a if we want to have a very high volume fraction of fibers in the final composite product it may. So, happen all the fibers may not get adequate impregnations or resin may not be able to wet all the fibers optimally or totally.

So, if all the fibers do not get totally wet there may be a problem when the composite product is used under loading conditions the same reason we have resin has not gone met as the failures side. So, there are few problem associated with the reinforcement material also in case of resin transfer molding.

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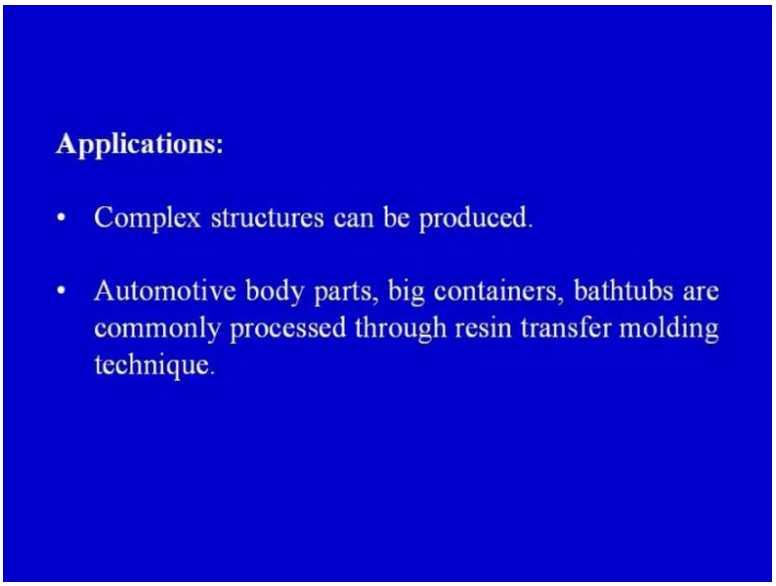


Now, what is the applications of resin transfer molding complex structures can be produced depending upon the we can say the complex city of design of the mold that is possible with resin transfer molding, we can get fairly complex structure which are not possible may be with some of the other process is like pultrusion filament winding we are the part complex city is one of the limitations, but here we can have a better part complex city as compared to other process is. So, complex structure can be produced.

Now, automotive body parts big containers bath tubs are commonly processed through the resin transfer molding process to bathtubs each one of us might have seen that the shape is fairly simple. So, that type of shapes can be very easily made by the resin transfer molding. So, we will keep the fibrous reinforcement in the lower half of the mold that the 2 halves of the mold would closed then from the port the resin would be injected and the resin and the fiber mixture would be allowed to cure and after the curing process under the application of heat we would open the mold and finally, get out the get the product out of the mold.

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So, this is very simple process of producing the composite parts coming on to the next process, that we are going to discuss today that is called the autoclave molding. In autoclave molding also what we are trying to do, we are trying to combine the 2 things together that is the reinforcement and the matrix, the matrix is in the form of the resin and the reinforcement can be fibrous reinforcement.

So, in autoclave molding we are finally, going to get the composite product. There is different type of products of autoclave molding process or closed molding process. So, in case of autoclave we have this is an open mold process. So, we can have different types of closed molding and autoclave molding processes. So, autoclave falls under the category of open mold processes.

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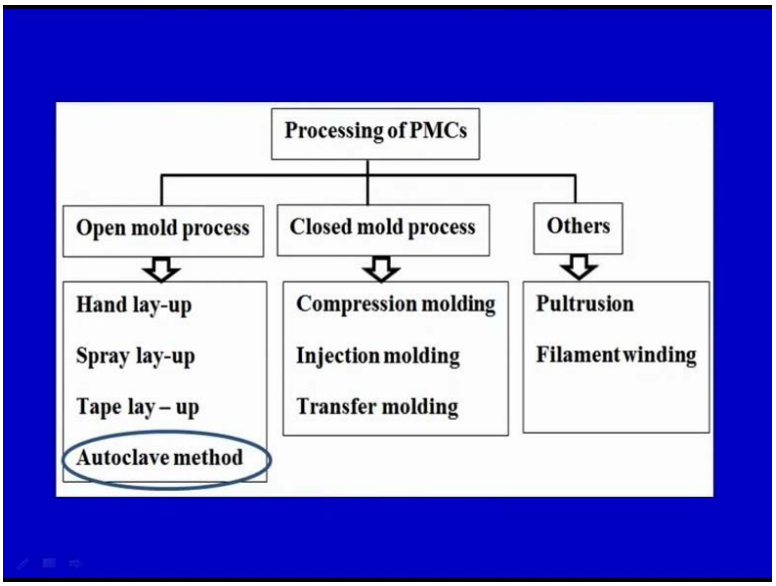


So, if you see on your screen we have open mold process and closed mold process because, this is a last lecture on polymeric matrix composites. I would just like to summarize the process which we already which we have already covered we started off with hand layup process spray layup process, we have seen other processes like pultrusion and filament winding then we have seen the closed mold process such as the compression molding injection molding transfer molding or we can say the resin transfer molding.

So, just now we have finished our discussion brief discussion on resin transfer molding process and which is closed mold process and autoclave method it can be open mold process also it can be a closed mold process also, depending upon the application we can have open mold autoclave process or we can have a closed mold autoclave process.

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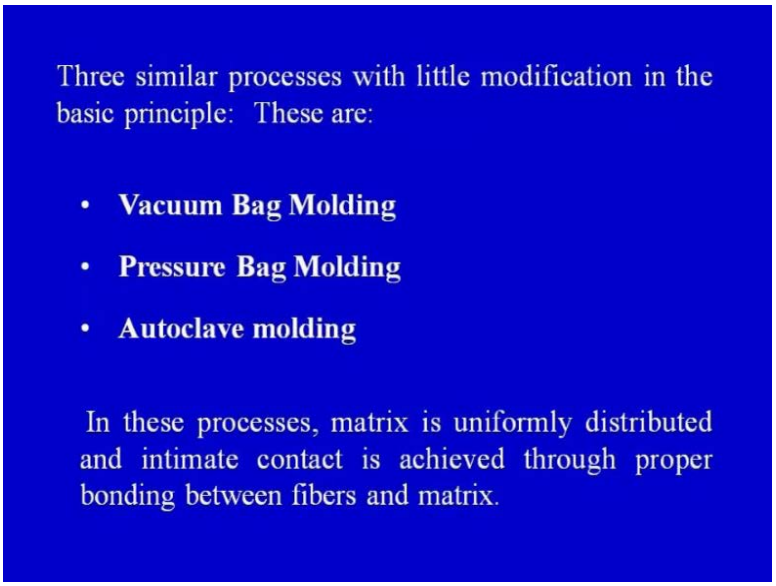


So, there similar processes are with little modification is the basic principle and now these are vacuum bag molding pressure bag molding and autoclave molding. So, in today's lecture our focus is on autoclave molding, but the basic principle of these three process is nearly the same in case of vacuum bag, pressure bag and autoclave, we are applying the pressure and we are have we are applying heat also.

So, under heat and pressure we are going to convert the basic raw materials that the fibrous reinforcement and the resin into a final composite product, in these processes matrix is uniformly distributed and intimate contact is achieved through proper bounding between the fibers and the matrix we are seen in the previous case resin transfer molding sometimes, resin may not be able to impregnate all the fibers reinforcement, but here, there is an advantages in case of auto clave molding that we have a full impregnation of the fibers with the resinous materials and we get good interference characterize good(()) efficiency and final composite product that we get can be we can say better mechanical load as compare to those composite product where the impregnation of the fiber is not taken place optimally.

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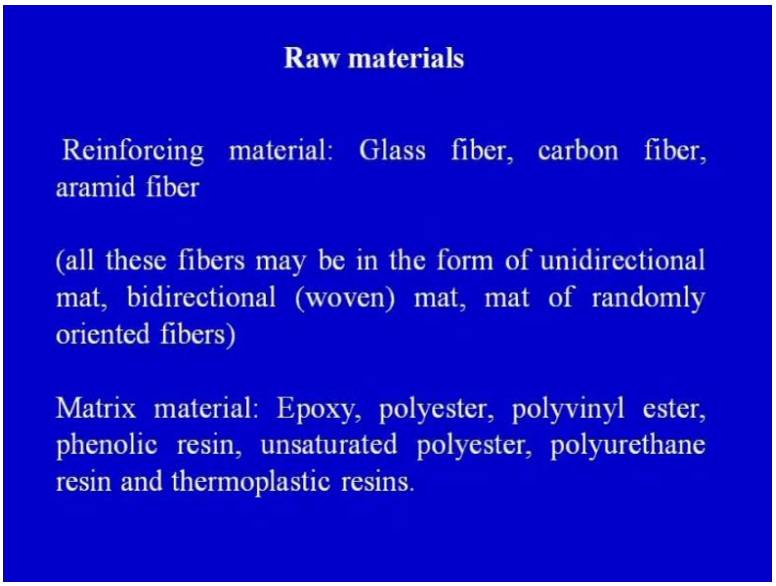


So, the raw materials in case of autoclave molding are glass fiber or carbon fiber or armed fiber all these fibers may be in unidirectional mat by directional woven mat or mat of randomly oriented fibers. So, we can use the reinforcement in different types as is clear on your screen. So, we can have a metric material also different types of matrices can be used in auto clave molding process. What are these matrices? We can have epoxy we can have a Epoxy, polyester, polyvinyl, ester, phenolic resin.

On your screen, you can see there are wide verity of reinforcement that can go in to auto clave molding processes there are wild verity of metric materials, that can be going in to the sorry autoclave molding process, we have we can say the process is versatile we can get different type of composite product.

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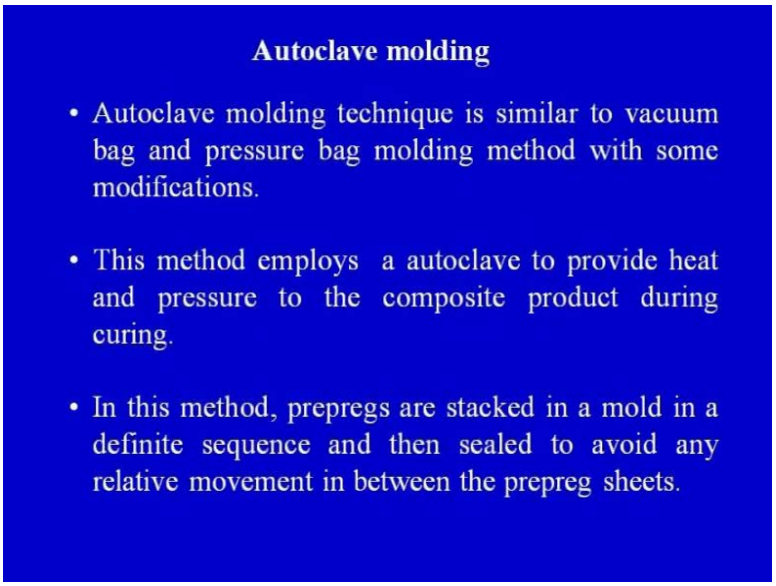


With the help of this vacuum bag molding or auto clave molding, auto clave molding autoclave, molding technique is similar to vacuum bag and pressure bag molding technique with some modifications. These are three process is which have similar principle or the principle is we can say slight modification here and there and we get the composite product this method employs a autoclave to provide heat and pressure during the curing. So, in this particular case we would be applying both, we can say process parameter or the operating variable the 2 process parameter are the temperature and the pressure.

So, in this case both would be applied to convert the raw material in to the final product. In this method prepregs are stacked in a mold and in definite sequence and then sealed to avoid any relative movement in between the prepping sheet.

So, we have already seen in this model of chapter on pre pregging in which we have seen, that prepregs are generated these are the basically materials for the subsequent processes. So, how the prepregs are made we have seen. So, these prepregs which are made are now stand one of the other these are the resin saturated fiber already we have the resin and fiber in the prepregs is prepregs by layer stacked together they are seal by any plastic film some time nylon can be use to seal the stacked prepregs and the pressure and temperature is applied so that, the resin cures fully and we get the composite product avoid it. Initially, a release gel is applied on to the mold surface to avoid sticking of

polymer to the mold surface. We have to easily remove the final composite product which has been made out of the mold cavity.

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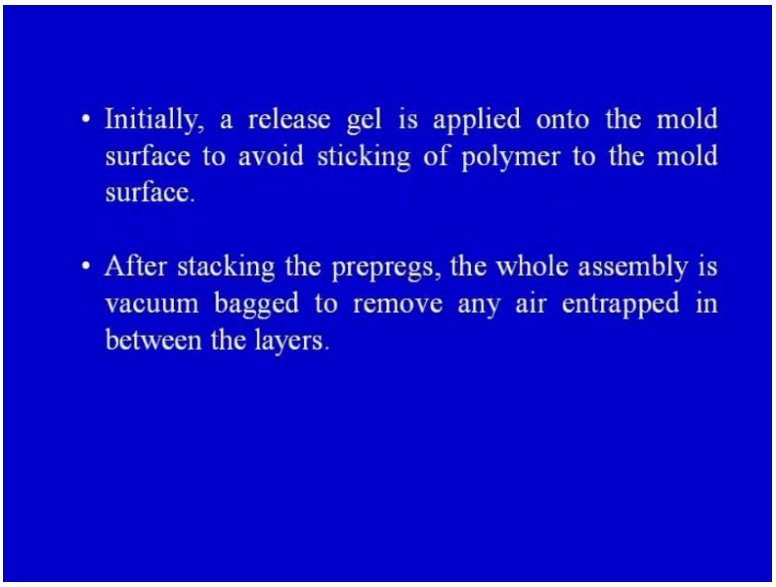


Therefore, we have to initially supply a release gel or we have to apply a release gel on the mold surfaces for easy extraction of the final air composite product out of the mold cavity. After stacking the pre prigs the whole assembly is vacuum bagged to remove any air entrapped in between the layers. Now, these prepregs are stacked one above the other we have to apply vacuum to take out any air which is already present between the stacked layers.

So, we apply vacuum and all air will taken out, if the air is there we do not remove the air finally, when the curing process would take place final curing is take place, these air bubbles would be present in the final composite product and would influence or deter oater the mechanical properties of the final composite. So, this air has to be taken out and sometime vacuum is used to be re moved the air which is present between the layers of the prepregs. After a definite period of time when it is ensured that all air is removed the entire assembly transferred to the autoclave.

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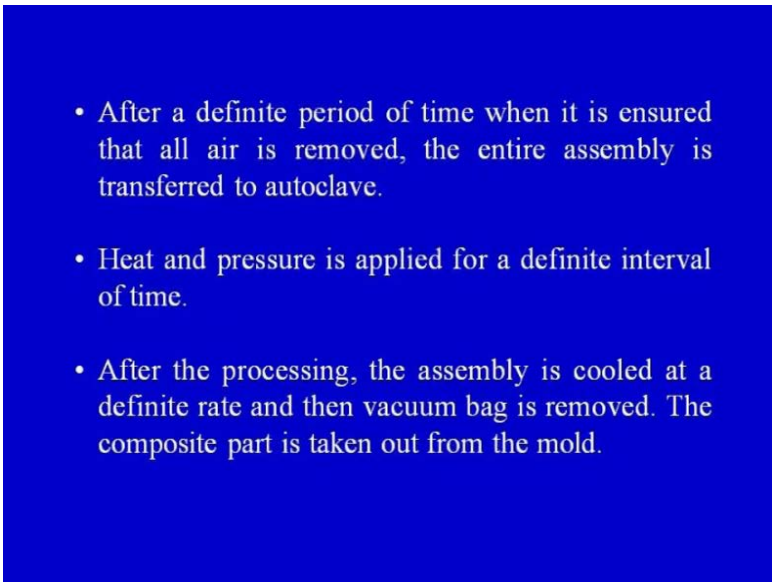


So, autoclave is a device in which we can maintain the pressure and the temperature, heat and pressure is a played for definite interval of time after the processing the assembly is cooled at a definite rate and then the vacuum bag is removed. The composite part is taken out from the mold. So, the process is fairly is simple, but the dusting futures are that in this case in the raw material is used in the form of the prepregs and these prepregs can be made up of different types of fibers ass.

We have all ready seen, these prepregs can if made of a different types of metrics material, these prepregs are staked to gather one about the other depending up of thickness of the final products and the shape of the final product, they are staked one above the other and than of plastic film is this hole assembly of the prepregs or the layers of the prepregs are the staked prepregs are pot in to the film or on vacuum film and vacuum is applied 2 remove any attract year in between the prepregs after the all the year has been removed this is this assembly are this laired structure of the prepregs, or stake prepregs are put in to the move mold are in to the autoclave has the temperature has and the pressure control when we apply, we have temperature and the pressure the final curing of the unsaturated polymer takes placed after the final curing we give some time for the cooling and finally, the vacuum film is removed and we get the final product.

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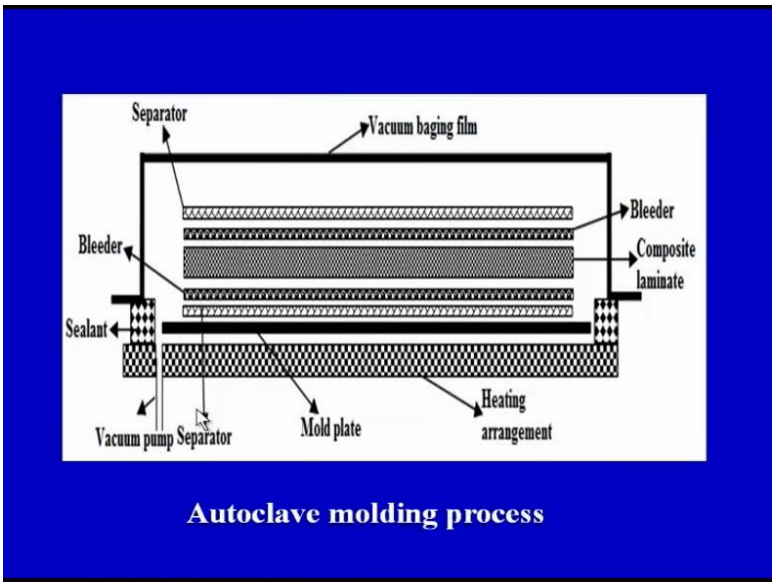


On your screen, you can see the diagram we have a mold plate this black potion on your screen this is the mold plate these are the 2, you can say bleeder this is one bleeder this is another bleeder and then there the separators, this is the separators and this is the composites.

So, this is composites, this particular composite is the layered prepregs may be 8 layers of prepregs or 10 layers of prepregs, 12 layers of prepregs of the depending upon the final thickness of the composite products required. So, we have a vacuum pump fear you vacuum would be applied to remove all the ante rapt hear in said the layered assembly of the is parts and the finally we apply, after the curing process is taken place because of the heating arrangement that is there we can say there is a we can see there is a heating arrangement, also these are all heating arrangement are heating quails, which are pot along said the mold.

So, we have the heating arrangement also and this is the vacuum back film which is the show, this is vacuum back film when the vacuum back would be applied this film would gets stake to the assembly and finally, once the curing processing is taken from the play film would be re moved and we will get the final composites product. So, each part has goat its own applications are its own role in the total process.

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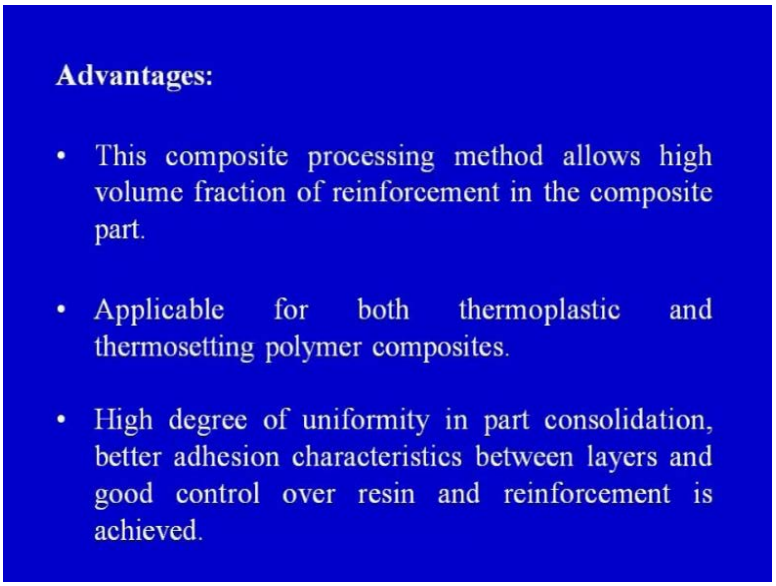


Now, what are the advantages is of this process, this composites processing method allows high volume fraction of reinforcement in the composites part. Because, the prepregs are all ready, we can say having that as invoice material with them we can control the fiber volume fraction when we making the prepregs and when were using the same prepregs for making the final composition products, we can very easily have a very high volume fraction of the fiber in the final composites, this can be applicable for both thermoplastics and thermosetting polymer composites.

So, it has got vide versatility higher degree of uniformity in parts consolidation some time when wear can solidation with the help of the hand roller and we are applying, we can say they apply the pressure manually the can salvation may not be uniform, but hear wear consolidating with the help of externally applied pressure which is uniform of over the hole assembly.

So, high degree of uniformity in part consolation so, uniform pressure is applying better adhesion characteristics between the fibers are between the layers and good control over the resin and reinforcement of is achieved. So, the control that we can exercise in a autoclave molding processing in better as compare to hand lay process or the spray layer process.

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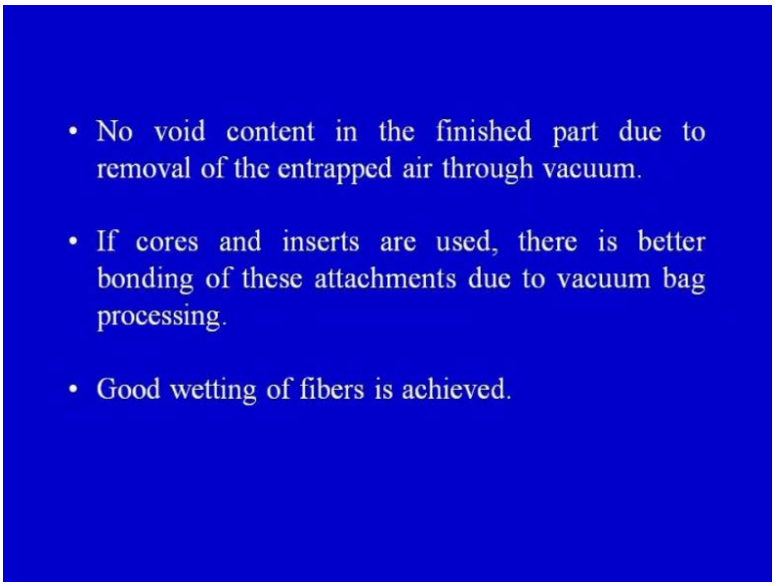


So, better control over that enforcement and over the matrices is possible in case of the autoclave molding process, no void contained in the finish part dive to the removal of the entrapped air through the vacuum, as we have all ready seen vacuums is an applied to remove the ant raped year. So, in this particular method of autoclaved molding there is very less chance are the probability of the voids are porosity are any air enter aped in said the different layer is very very less.

So, we will get a completely uniform product without any words in case of autoclave molding process if course and inserts are used there is better bonding of these attachment due to the vacuum bag process.

So, if additional attachment would have to be put reinforcement in the final product using the vacuum this further gives very good quality on your screen, you can see if course and inserts are used that is additional attachment have to be placed in the composite material, there is better compounding of these attachment due to the vacuum bag processing. So, we have better bonding of these inserts with the final product good wetting of fibers is achieved in this particular case.

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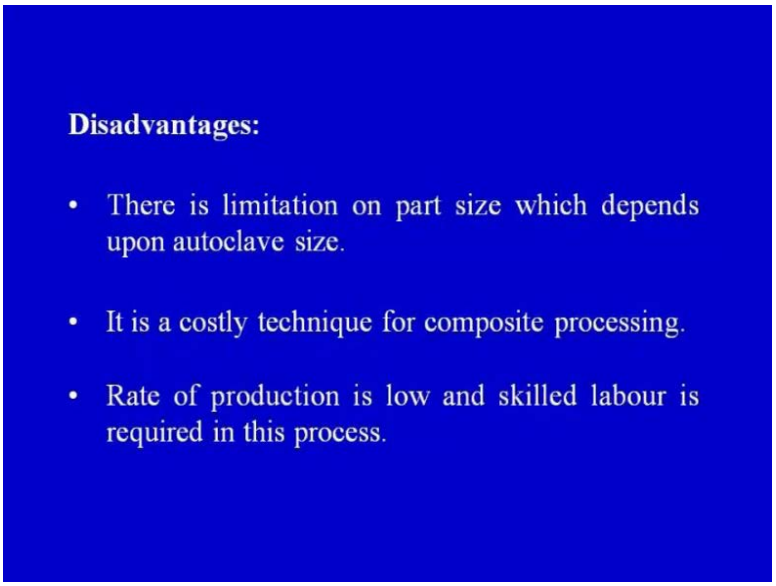


Now, what are the disadvantages? There is a limitation on part size which depends upon autoclave size, Now depending up on the size of autoclave the size of the final product is dictated, as in the previous process that is resin transfer molding, we have seen the final size of the product would depend upon which type of the mold we can using the shape and size of the mold that we are using.

So, in case of autoclave molding also the size of the product would depend on the size of the autoclave, it is a costly technique for composite processing as compared to hand layup or spray layup process vacuum bag molding be may be vacuum bag molding or resin transfer this vacuum bag molding and the autoclave molding may be costlier processes similarly, resin transfer molding may be costlier process as compared to the hand layup process.

Rate of production is low and skilled labor is required in this process, as we have to apply the vacuum and we have to place the prepregs. So, the process takes a little bit of time. So, the rate of production can has compared to the other fully automatic process is limited in case of autoclave molding.

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Now, what are the applications of autoclave molding, the process is mainly used in applications requiring high strength to weight ratio. So, we can again emphasis that wherever, the fiber volume fraction is higher or the process which gives us high fiber volume fraction can results in high strength to weight ratio. So, in this process also we have seen the fiber volume fraction is higher as compared to some of the other process is therefore, the high strength to weight components can made using the autoclave molding process.

So, aircraft parts marine military space craft and missiles parts can be made by the autoclave molding process. So, with this we come to the end of this particular module on processing of polymeric matrix composite.

So, we have covered 10 different aspects in which we have covered the materials aspects of the polymeric matrix composites, what are these materials, where are they used, how are they distinct from other engineering materials.

We have seen how the process is which are used for processing of polymeric matrix composites are classified these are open mold process closed mold process and other than we have seen some of the very important process is which can be used for the processing of polymeric matrix composite.

So, we have may not be able to complete all the process, but our focus has been to address at least those processes which are very commonly used for processing of polymeric matrix composites in some other process, we may not been have able to go into the depth or the details of the process, because of the time constrain, but still our focus has been to understand the basic mechanism of the process or the basic procedure of the process.

How, the process actually takes place we have seen, what are the different setups used for that process we have try to understand the procedure used for the process that what are the steps involved in the process. We have to understand the advantages of the process, we are trying to understand the limitations for that process and finally, we have seen that was this process can be applied.

So, this particular module on processing of polymeric matrix composite will has provided inside into the various techniques used for the processing of polymeric matrix composite. In our subsequent module, our focus would be on other types of advanced materials and we would see that which is the important process is which are used for those materials.

Thank you.