**Processing of Polymers and Polymer Composites**

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**Lecture – 23**
**Resin Transfer Molding**

Friends welcome to session 23, in our course on processing of polymers and polymer composites. We are in the process of covering the various processing technologies, techniques routes adopted for pressing of polymer composites. In the first 2 weeks we have focused on processing of polymers.

Now, our focus is on processing of polymer based composites. If you remember we have already covered number of processes which are used for processing of polymer composites. We have covered hand layup process, spray layup process, compression molding injection molding, reaction injection molding, structural reaction injection molding, that sorry in the previous class we have covered, another process which is autoclaving or autoclave molding process.

Some of you may be wondering some of the learners may be thinking that; why there are so many processes? What is the need of having so many processes? Now if you can answer this question on your own it is good, but if you have do not have a exact answer to this question, I think the first thing that we need to understand is the family of the polymers and the polymer composites. If you see there is a wide variety of polymers that are available. Broadly we have classified them into 2 categories; that is thermosetting and thermoplastic polymer.

But there are other classifications also. Since our course is not only on the material science aspects related to the polymers. We have only restricted our discussion to thermosets and thermoplastics only.

But if you go in to further details, you will find out that there are other classifications of polymers also. Similarly, you see the reinforcement. We are seeing there are carbon fiber glass fiber aramid fiber, then there are natural fiber, sisal fiber, grewia optiva, jute, the gas, banana, silk. So, there is a wide variety of fibers available. As well as there is wide family of polymers available.

Then there are shapes that we can produce only with the particular type of process. There are side limitations. There are quality restrictions. There is volume of production; that is the number of parts per hour number of parts per day number of parts per week. So, these are the criteria. Just we can if you want to highlight them point wise, maybe the first point can be the wide variety of materials available. Second point can be the shape requirements, complexity of the final product. Third requirement can be the size of the composite product. The 4th requirement can be the number of products that we need to produce in an hour or in a day. And the last requirement can be the quality of the file product that we are trying to make.

So, all these 5 parameters ask for wide variety of processes which can be used for processing of polymer composites. Because there can be a common question, that we have to combine a polymer and a fiber together, what is the need for going for a so many different types of processes?

Now, each and every process we will have it is own applications spectrum. And will be used for a specific type of products only; that may be based on size shape complexity quality parameters remaining same that I have already highlighted. And in that light only we are going to cover another process today; that is the resin transfer molding process.

We will try to understand the process with the help of a sematic diagram. We will also try to understand the process with the help of a animation which is available from a commercial company which uses resin transfer molding process. And I think once the diagram is clear to you; the animation you observe properly that what is happening; I do not feel that there is any doubt that you will not be able to appreciate the process which is used for fabrication of composite products.

So, let us start our discussion on resin transfer molding process. And before going to that I would just like to take you back in history; that we have already covered transfer molding process in case of polymers. So, this process will also be similar to the transfer molding process, but with the little variation that here. What we have to do what additional requirement is there when we are talking of composites? So, when we are talking of composites, the specific requirement is that we have to combined the fibers and the polymers together.

Whereas in transfer molding, we have only seen that there are only polymer. We can add some ingredients in to the polymer, and then it is pushed through the sprue into the mold cavity and the polymer takes the shape of the mold cavity. And finally, we open the mold and take out our product.

So, here we can see that in resin transfer molding process, the difference is we have to incorporate the fibers also with the polymer. So, that we get a composite product and it is not only a neat polymer product. So, for neat polymer product we call the process as the transfer molding processes. Because that difference must be clear to you when we are trying to understand the processing of polymers and polymer based composite. The transfer molding is slightly different from resin transfer molding.

And resin transfer molding is the terminology that is specifically applied to the composite fabrication or processing of polymer matrix composite products.

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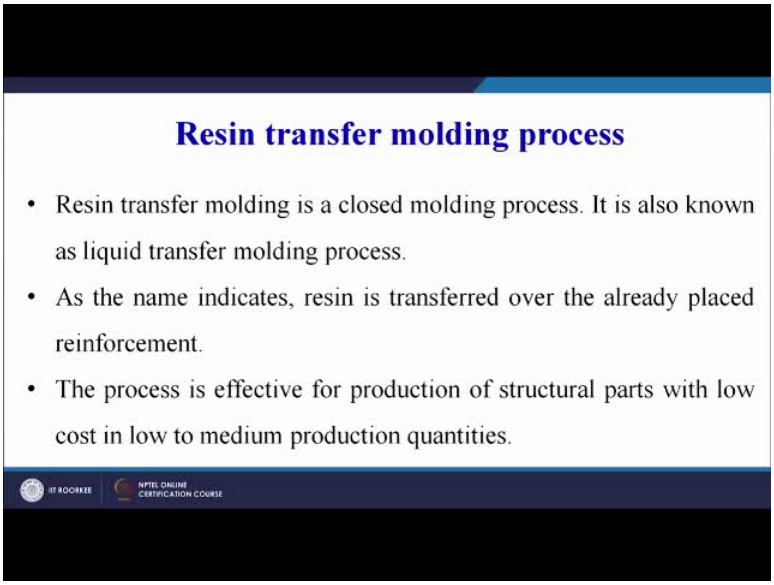


So, let us start our discussion now. The resin transfer molding process is a closed molding process. It is also known as liquid transfer molding process. So, we will be transferring our resin into the mold cavity, where we will have preplaced fibers already existing there. So, those fibers are already preplaced their they are already available there. Only thing is we have to supply the resin or the polymer, and the polymer and fibers then will combine together to make a composite product.

So, resin transfer molding is a closed molding process. It is also known as liquid transfer molding process. As the name indicates resin is transferred over the already placed reinforcement. The process is effective for production of structural parts, with low cost in low to medium production quantities. And this last point I have explained just today in the beginning of today's session; that what is the need of having so many manufacturing process for manufacturing of composite products.

And the third point substantiates what I have already said, that for low cost some time cost is also an important criteria. And for low to medium production quantity. So, I have already highlighted that volume of production or the quantity of production is very, very important. So, resin transfer molding process we will be used for low to medium production quantity.

Similarly, if you remember hand layer process also has a long production cycle. And therefore, it used for low quantities only where one of products or maybe small number of products have to be fabricated.

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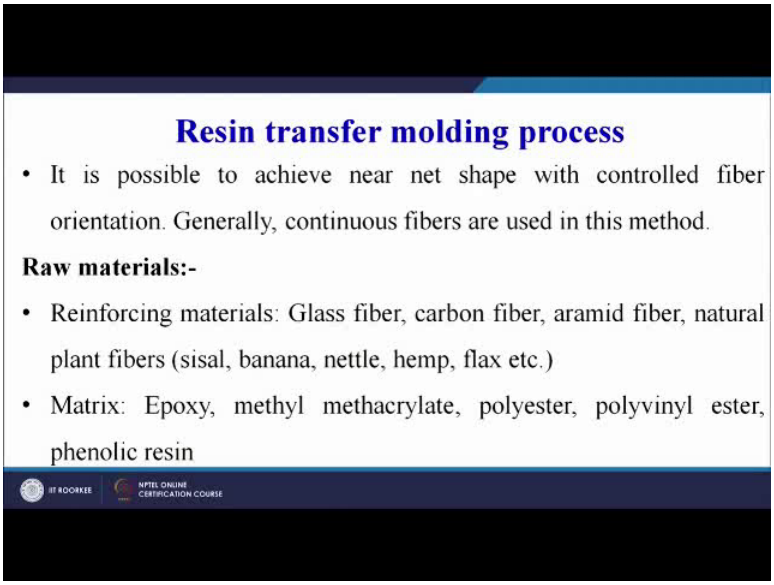


So, in resin transfer molding process it is possible to achieve the near net shape with controlled fiber orientation. Now 2 terms have come here in the sentence. The first one is near net shape. So, what we want is we will see in the animation? We will directly get our final product near net means near net. So, net means; the exact, but near net means

slightly close to the exact. So, we can get the near net shape of the composite product using the resin transfer molding process.

Then the second point is the controlled fiber orientation. As we are preplacing our reinforcement in the mold, and then we are injecting our resin into the mold, we can control the direction of the fiber precisely.

So, the 2 things are available or are the important points related to resin transfer molding or the advantage related to resin transfer molding; that we can get a near net product point number one, and we can get a control fiber orientation using the process of resin transfer molding. Now, what are the raw materials that can be used. We can use glass fiber carbon fiber aramid fiber, though mostly these are the 3 fibers are used for making of composite products.

Currently there is a trend towards natural fibers also. So, sisal banana nettle hemp flax these are also fibers, which can be used or we can do research on these fibers and try to figure out their applicability in context of resin transfer molding process. And the matrix is usually epoxy methyl methacrylate polyester polyvinyl ester phenolic resin. So, mostly the examples here given are thermo setting resin. So, we can say that resin transfer molding process is may be more suitable if our polymer is a thermosetting polymer.

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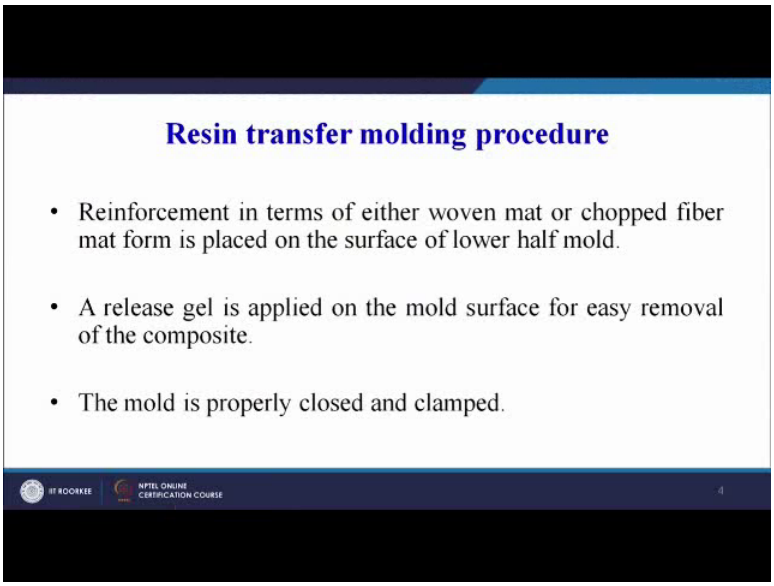

Resin reinforcement in terms of either woven mat chopped fiber mat is placed on the surface of the lower half mold. This we will try to understand with the help of a schematic diagram also. So, the reinforcement is preplaced inside the lower half of the mold, release gel is applied on the mold surface for easy removal of the composite. This step is mostly common in all the processes that we are using. Starting from hand layup we have already discussed, spray layup we have already discussed compression molding injection molding, and then we have seen in last class we have covered in the last session our topic was the auto clave molding.

In autoclave molding also, we have seen the application of the release gel. So, this is common in almost all processes. So, release gel is applied on the mold surface for easy removal of the composite film or the composite product.

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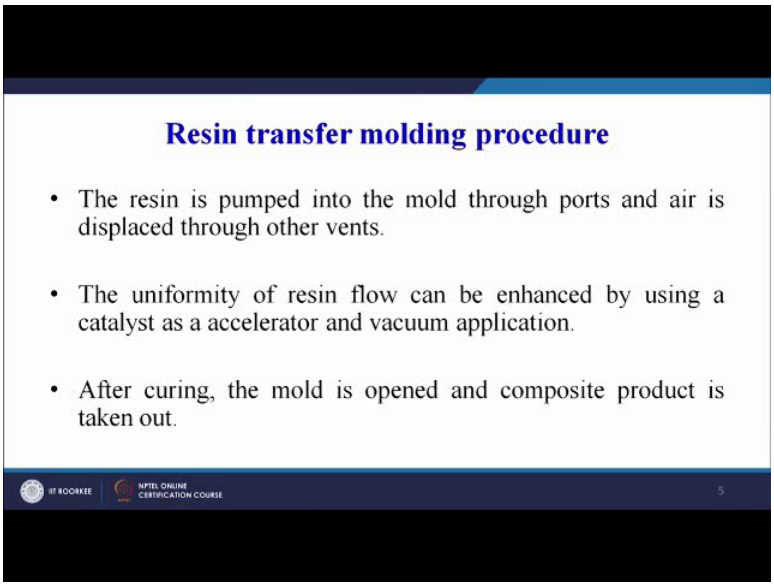


The mold is properly closed and clamped. The resin is pumped into the mold through ports and air is displaced through the other vents.

Now, there is bound to be some air present inside the mold cavity. Because the mold will not be completely filled by our reinforcement. So, before closing the mold what we have done we have put our reinforcement there which is in the form of a mat or a woven mat or a chopped stand mat. So, we have only placed the reinforcement in the mold. Still the resin has to come. So, there is some empty space where there is chances of air. Now that air has to be removed through the vents. So, from one side suppose if the polymer or the

resin is entering into the mold cavity, from the other side we have to provide the vent through which the air can move out. Many times we can force the air out also by applying the vacuum.

So, the uniformity of resin flow can be enhanced by using a catalyst as accelerator, and application of vacuum which I have already explained. So, we can add accelerator if you remember in our spray layer process on top of the hand-held spray gun; there was a catalyst which was also entering into the spray gun and the fiber was coming the resin or the polymer was coming and there was the arrangement for catalyst also in order to accelerate the rate of curing.

So, that is one additional thing that uniformity of resin flow can be enhanced by using a catalyst as an accelerator and vacuum application. And sometimes we may add certain additives which can we can manipulate the viscosity of the resin also. So, once our reinforcement is already there in the mold, here we have already removed now we will inject our resin inside the mold cavity. Now both the ingredients are present in the mold cavity we have our fibrous reinforcement also in the form of woven mat or chopped strand mat, and we have input the resin also there. Now these 2 will combine together to from the composite material. And the curing process will take place. After curing the mold is open and the composite product is taken out.

So, the curing process may take some time, and then we have to give some time for cooling also. And finally, we will take out our product by opening the mold cavity.

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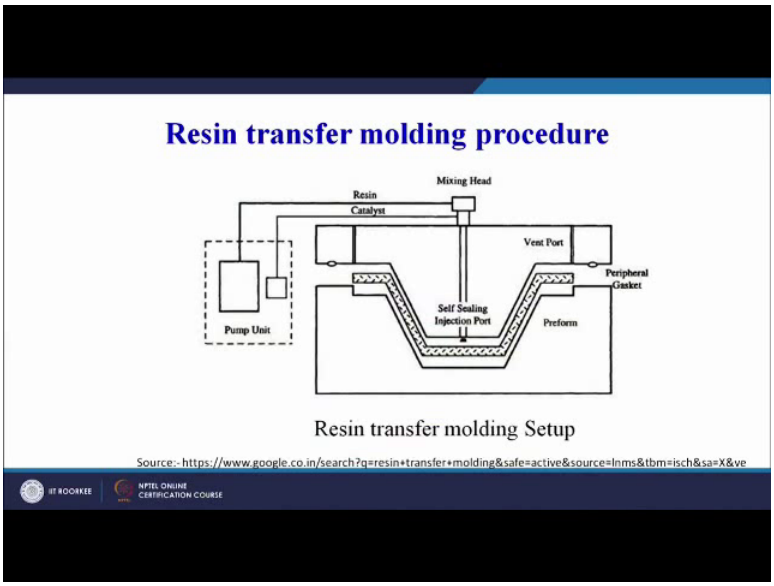


The diagram again from google images, resin transfer molding procedure you can see. There is a pumping unit which can this is a resin storage. So, we can pump the resin we can pump the catalyst this is the mixing head; where we will mix our resin and catalyst. This is our mold the mold is in 2 halves. This is one half of the mold, and this is the upper half of the mold. And you can see when the 2 halves of the mold will close in between we will have a cavity, which is the exact replica of our final product.

So, our final product will be formed as per this opening or this cavity, which is being formed between the 2 halves of the mold. This is the upper half of the mold, this is the lower half of the mold. And here we can see the short fibers here and this is our reinforcement. And it is preplaced inside the mold, or it is placed at the bottom half of the mold. So, this is our preformed, in this case we are calling it as a preform. This is our preform. And when the mold will close the curing we will take place.

Now here we can see, the resin come from here it will be injected from this point. This is self-sealing injection port, from here our resin will enter into the mold cavity. And there is a vent port once the mold once the mold will close. This will act as a venting port through which the air will come out, and the air can come out from this venting port also.

So, the steps are quite simple. We have already placed our reinforcement, which is in the form of a fiber mat. At the bottom half of the mold, then the mold will close. The air will

move out of this vent ports. And finally, we will supply a mixture of resin and catalyst from the mixing head into the mold cavity.

Now, in the under the closed position, when the 2 halves of the mold are closed, in between we have fibers. We have the polymer which has come from the mixing head, and the curing process will take place. And once the product is solid and stiff, we will open the mold and take out our product. So, that is the basic working principle of the resin transfer molding process.

Now, let us try to understand it with the help of a video.

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So, here we can see this is phase 1, a micronized binderies applied on the fabric. So, you can see.

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This is a fabric coming from here black color of fabric moving down this is a micronized binder; which is coming from this hopper.

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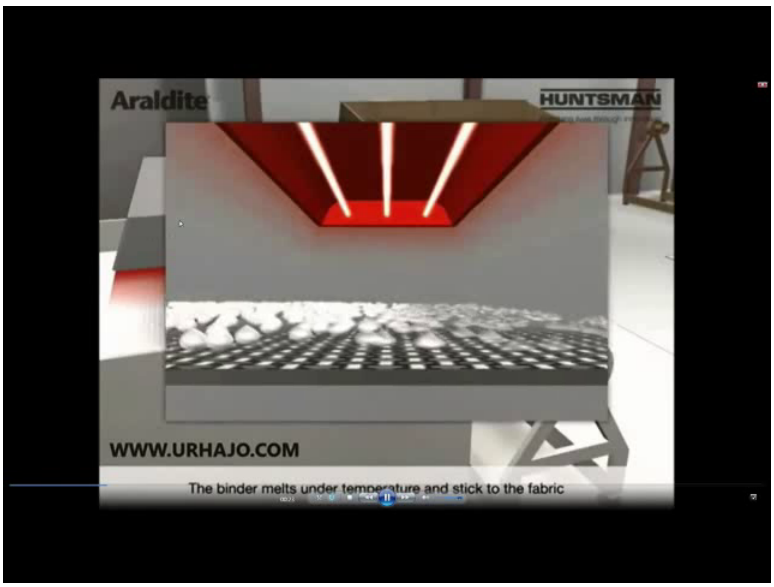


Then we are supplying the heat this is the heating arrangement, and this is the layer of fiber that is moving and this is the binder being heated.

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And then we are collecting it in the form of a role or preform. This a preform and here we will see preform fabrication.

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We will cut it as per the desired sizes. Several bindered fabric plies are cut and stacked together. Depending upon thickness of the final product required we will select these layers.

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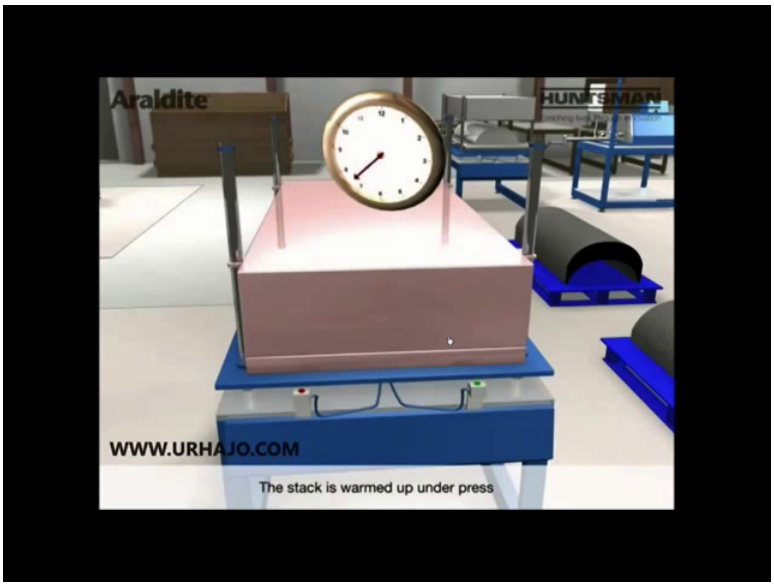


And now this is our fibers reinforcement. The stack is warmed up under press. So, we want to give it a desired shape. As we have seen this process can be used for making near net shape products. So, here the stack is warmed up under press, and we have given a definite shape to this fibrous form. This is fibers, may be 4 layers or 6 layers or 8 layers. It has now come out.

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And this is our fibrous preform; that we will keep in the mold now. This is the final mold, you can see the shape.

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A preform is introduced in the mold. The vacuum pump removes the air and trapped. So, this is a vacuum pump it is trying to remove the air and trapped air, the resin is injected now.

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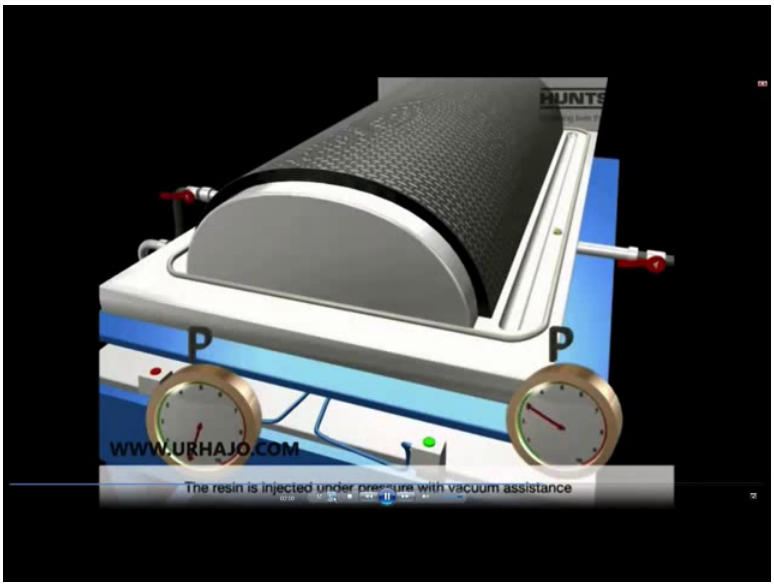


We will see how the resin is injected, under pressure with vacuum system this is a resin that is coming.

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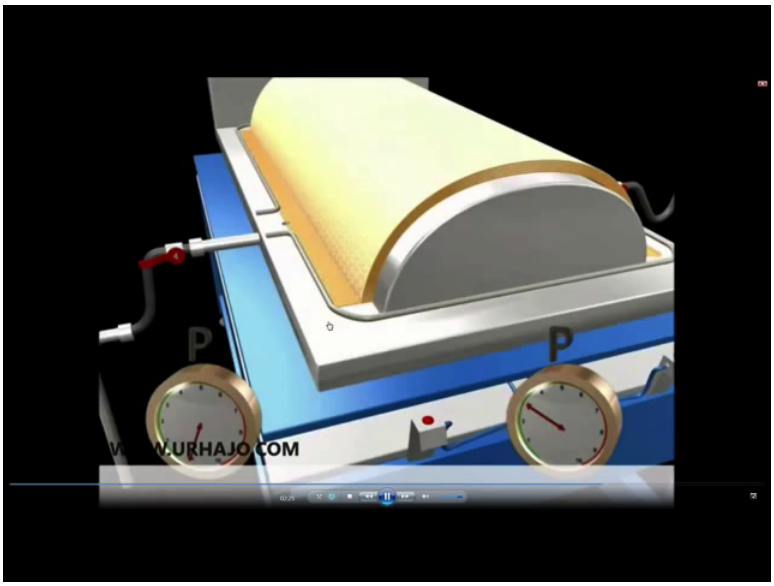


It will impregnate the fibrous preform that we have already introduced inside mold cavity; you see here the vacuum is stopped, when the resin exits the mold.

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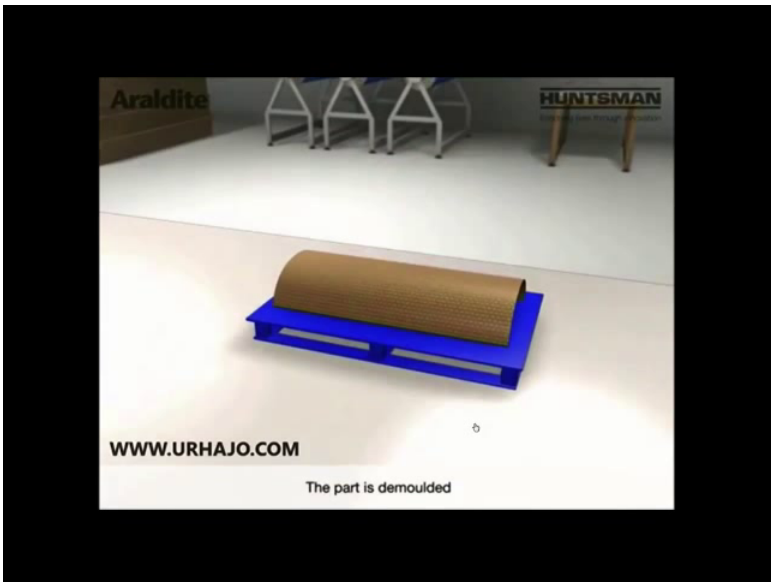


The part is demolded, and you can see. Once again let us see the whole process.

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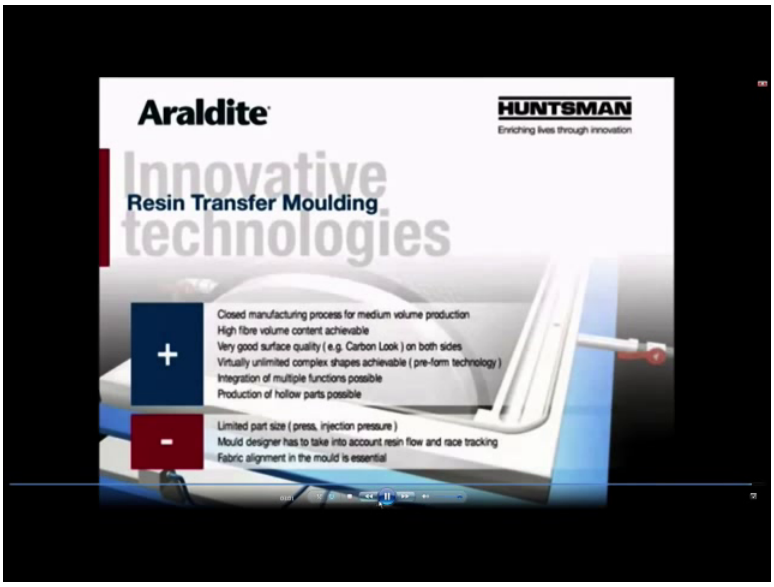


I think then it will become absolutely clear. First is the binder application. This is the layer of fibers that is coming, the fiber is moving.

In this direction this binder is being applied now why the binder is being applied because we want to stack up the fibers we want to get a desired thickness of our fibrous preform. The binder melts under temperature, and sticks to the fabric there is a heating arrangement this is a fiber layer.

These are the binder micronized binder it is being heated. And it is sticking to the layer at the binder fabric is ready to be used. Now this a bindered fabric. So, at first stage we are producing the bindered fabric.

At second stage we will be making our preform. Now this bindered fabric is coming it has binder and the fiber. Now we are cutting it and laying it up. Depending upon the thickness this is a fibrous preform that we are producing. Several bindered fabric flies are cut and they are stacked together. Now they will form a preform. This preform we want to get a desired shape. So, the stack is warmed up under press, and it will take that desired shape.

So, this is now our preform. It is cooling know now. The binder acts as an adhesive which stiffens the preform on cooling. So, there may be a question that why the binder has been applied.

So now phase 3 in the resin injection. A preform is introduced in the mold. The vacuum pump removes the air entrapped in the preform. So, the air has been removed now. The vacuum pump is closed. Now the resin is being injected under pressure with vacuum assistance, and the resin will impregnate the fibers.

So, this in impregnate the preform. The vacuum is stopped when the resin exists the mould. The mould is heated up, and the resin polymerizes. A complete curing of the product takes place, and the part is demolded then. And this is our final product that has come out. So, we have fiber and polymer both in this product and therefore, this is a composite product.

I think with the help of this animation. The learners might have been able to understand the whole process very clearly. There may be a doubts doubt or to which we can definitely answer.

The main components of the resin transfer molding are; resin and catalyst container pumping unit which pumps the resin combination of resin and the catalyst into the mould cavity. There a mixing chamber resin injector and the molding unit. So, most of the parts are related to the injection of the resin only. And therefore, we name the process also as the resin transfer molding process.

Now, what are the important controlling parameters in order to get a good quality product.

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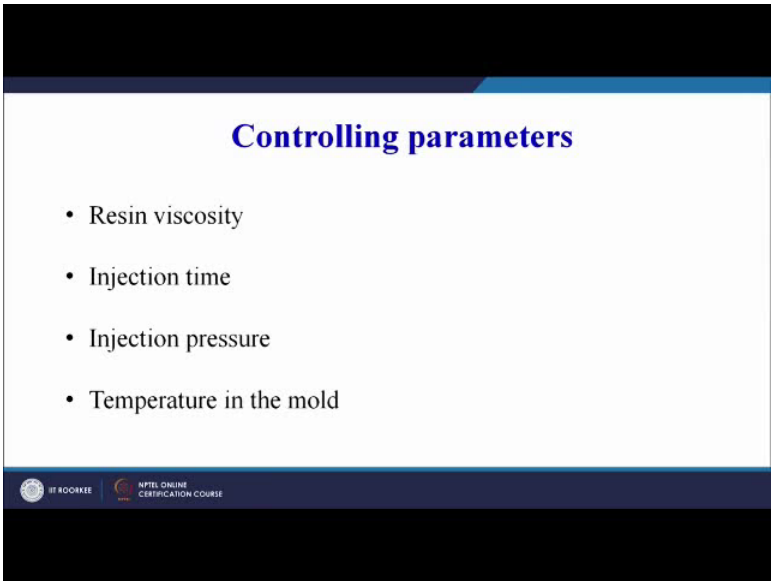


Now, first one is a resin viscosity. We have to ensure that the when the resin enters into the mould cavity, it is able to impregnated the fibrous preform properly. If the resin is not able to impregnate the preform properly, we will get a defective product and that we will lead to low productivity of the organization. And therefore, the resin viscosity or the control of the resin viscosity is very, very important. And if you remember in one of the previous today only in the previous discussion, I have told that we have we have add certain agents in the binder in order to manipulate it is viscosity. So, that it is able to properly impregnate the fibrous preform inside the mold cavity.

Second thing is the injection time, that we need to control. The injection pressure also needs to be control, and the temperature inside the mold. So, the main part is the temperature and the pressure which we can control in order to get a good quality product.

Now, what can be the advantage of this process? The composite parts have good surface finish on both surfaces of the product, because it is a closed mold process. So, we will get good surface finish on both sides of the composite product. Any combination of reinforced materials including 3D in any orientation can be achieved.

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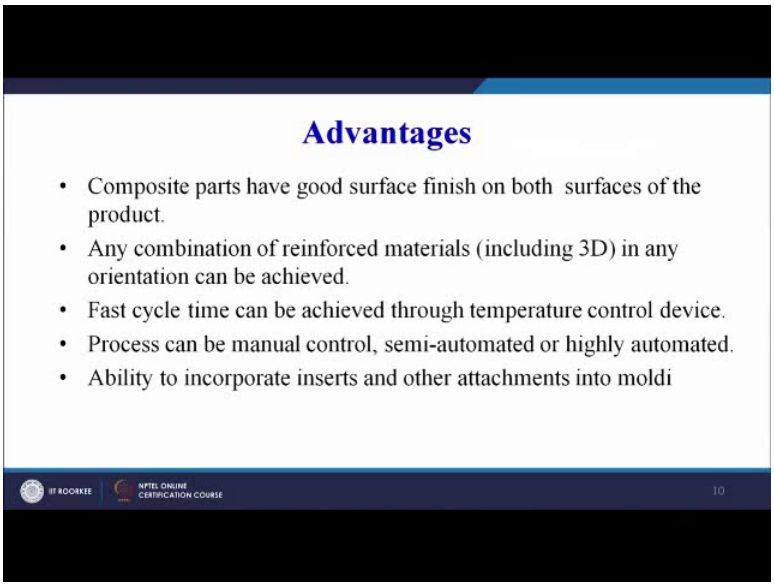


Now, any combination of reinforce materials in 3-dimension third dimension also, we can achieve why this is possible because we are doing some work, or we are doing some preprocessing of the fibrous preformed before putting it inside the resin transfer mold. So, we have seen that we are first putting some binder micronized binder on the fiber layer. And then that binder we are heating then we are stacking up then we are giving a shape to the or 3-dimensional shape to our final product, then we are introducing it into the resin transfer mold.

So, therefore, there is a advantage there is a versatility available with this process, that we can use 3 dimensional ships also. And moreover, we can have combination of layers we can make hybrid composites also; that out of the 4 layers 2 are made by carbon fiber composites and 2 are made by carbon fiber, and 2 are made by glass fiber that kind of hybridization is possible using this process.

Fast cycle time can be achieved through temperature control devices. As we have told that temperature and pressure are the 2 important parameters that we need to control. And if we can precisely control our temperature and optimize the temperature at which we are heating our product inside the mold we can definitely have a fast cycle time.

Ability to incorporate inserts and other attachments into the mold. So, that is important. So, we have we can see that wherever this is possible wherever we are preplacing our

reinforcement, there is a advantage that we can preplace our inserts or other may be metallic parts inside the mold during the molding process.

The process can be as I think, I have missed process can be a semiautomatic or automatic as we have seen in the animation; that there are fair chances of fully automating this process. Now, the disadvantages as are common enclosed mold processing techniques that the mold size is a limitation.

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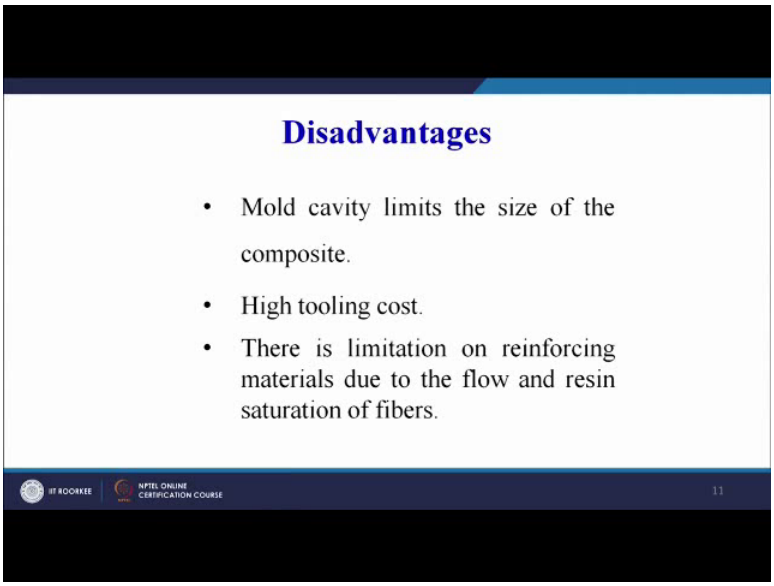


Now, mold cavity limits the size of the composite, high tooling cost. So, the tooling cost is high we have seen the steps involved in the complete process. And therefore, the tooling cost is slightly higher.

There is a limitation on reinforcing materials due to the flow of the resin and saturation of the fibers. So, therefore, the viscosity of the viscosity of the polymer or the resin becomes very, very important.

Now, what can be the applications of this whole process? One thing one thing.

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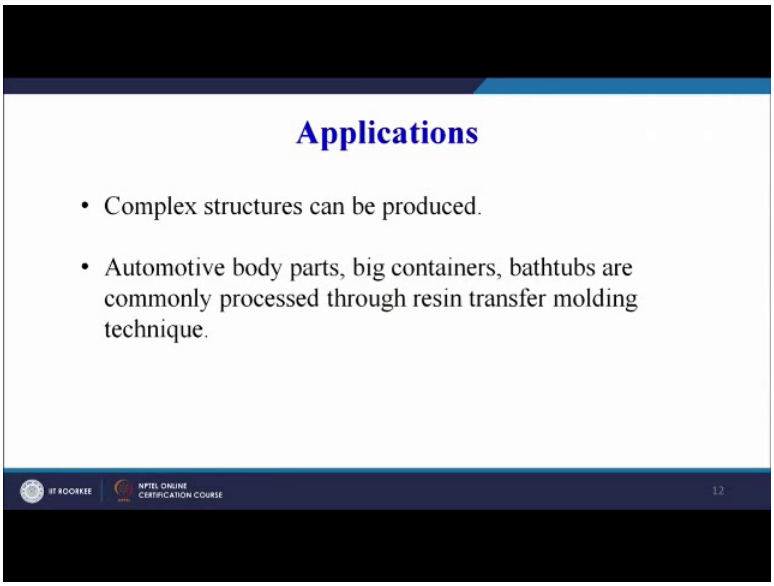


As we have seen in the advantages that complex structures can be produced the main applications are automotive body parts big containers bathtubs are commonly process through the resin transfer molding technique. So, all of us may be having bathtubs in our washroom. So, those type of components or products can easily be made by using the resin transfer molding process.

So, with this we come to the end of our discussion on resin transfer molding. And I firmly believe that with the help of the schematic that we have seen, and the with the help of the animation that we have seen. The learners might have been able to understand the intricacies involved in the process mechanism of resin transfer molding.

Thank you.