Processing of Polymers and Polymer Composites

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Lecture – 18
Spray Lay-up

[FL] Friends, welcome to lesson 18 in our course on Processing of Polymers and Polymer Composites. We have started our discussion on the various processing techniques that are used for processing of polymer composites. If you remember in the last session we have seen a process which is called hand layup process which is a completely manual process, in which the continuous reinforcement in the form of mat is used as reinforcement in a plastic matrix.

So, the plastic that is used in case of hand layup process is majorly thermo set and the examples, we have taken were of a epoxy and polyester. If you remember we have seen a video also which is freely available on You-Tube and we have seen that how layer by layer the layers of composite are laid up that is tagged up and we make a laminate.

So, it is made in a layer by layer by layer by layer form. So, the only difference that I for see in a hand layup process and a spray layup process is that in spray layup, we will have our reinforcement in the form of chopped fiber chopped means cut fiber means small fibers. So, in this case is spray layup our fibers will mostly be in the form of cut fibers or short fibers whereas, in case of hand layup process, we have used continuous fiber reinforcement in which the fibers were there in both the directions that is the warp and the weft.

So, if you remember I have given the example of a cloth mat form so as we as the shirt I am wearing it also has fibers in both the directions. So, similarly we can have the glass fibers or carbon fibers or Aramid fibers from the synthetic fibers family, we can have sisals fibers, we can have nettle fibers, we can have jute fibers from the natural fibers family. So, depending upon the family from where we have derived the natural where we have derived the fibers we can have continuous fibers.

Whereas in this case we will be seen we will try we will try to understand it with the help of a video also which is again freely available on YouTube. We will try to understand that

how was spray layup process is done, but the major difference will be the fibers in this case will mostly be short fibers and the polymer how we combined the polymer and the fibers together is different in case of spray layup as compared to the hand layup process.

So, that is the major difference and we have seen that hand layup process is limited in terms of complexity of the product that we can produce. So, that is one limitation of hand layup whereas, in spray layup that complexity slightly reduces or we can say that the spray layup process can be used for more complex shapes as compared to a hand layup process. So, that is the; another advantage of a spray layup process. So, we will try to understand the differences between the hand layup and the spray layup process and we will try to understand the intricacies involved in the spray layup process.

So, let us start our discussion with spray layup process. So, this diagram I think this figure will be shown in almost all presentations that we are going to cover.

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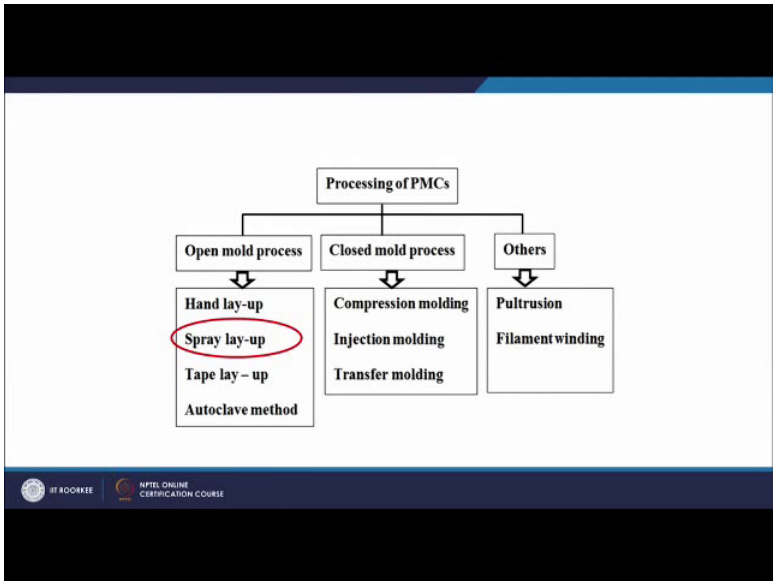

And this shows that this process falls under which category open mold category. So, it is not a closed mold process, it is a open mold process as you remember in case of hand layup process we have seen the 2 plates of a 2 metallic plates of mold in the example we have seen, where there and in between we have done the layup layer by layer by layer we have added may be 4 layers and applied the polymer because it was the thermoset; so it was available in the gel or the viscous form and then we put we have put the top plate, on

top of the bottom plate in between the laminate was there and then we applied the nut and bolt fasteners and applied the pressure and finally, our composite was ready.

So, that was because that was continuous fiber and the mold was open to the environment and we have also see in the curing may take place for 24 hours. Suppose today we have done the lamination and we have placed the laminate in between the 2 halves of the mold, we will get our cured, solidified, rigid, composites the next day after 24 hours. All though we can accelerate the rate of curing by putting it in a woven or a autoclave, but that is also possible, but normally it may take 24 hours for the curing process to happen under ambient or the normal conditions of temperature and pressure. So, that is one important thing.

So, here also we will see that the mold will be open. So, it will not be a closed mold process, there also the mold was opened it was not closed from all sides it was close only from bottom and top from sides it was open. Similarly in spray layup also we will see that the mold will be open and we will spray our material the constitutes onto the shape and finally, the product will be ready.

So, again the spray layup process is also a open mold process.

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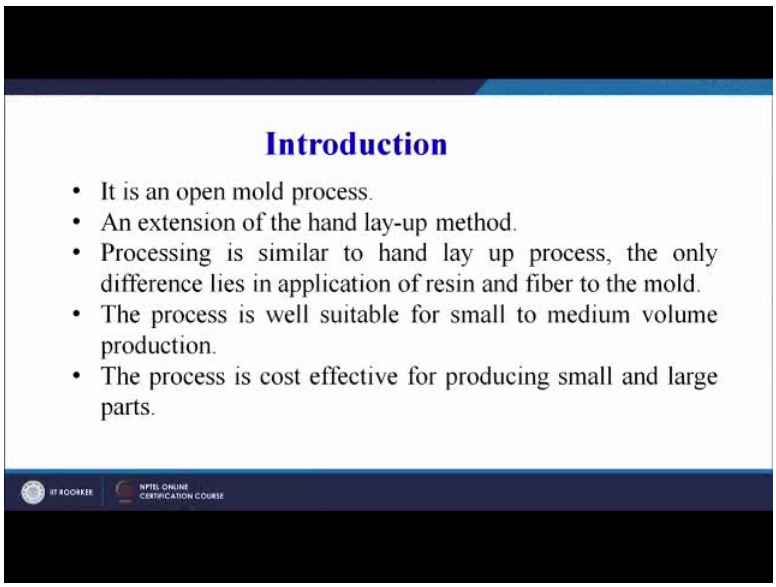

Again the first sentence just to emphasize the point again and again, it is an open mold process, an extension of the hand lay-up method in the very beginning today I have tried

to explain what is the difference between a hand layup and a spray layup method, basic phenomenon in both the cases is same that is we have to combine the 2 constituents of the composite material together and the 2 constitutes being the matrix and the reinforcement.

So, here also, but the method of combining the 2 will be different in case of hand layup process, it is different in case of spray layup process, it is different we have already understood that in case of hand layup process, how we are going to combine the reinforcement and the matrix together and today we will try to see that how the reinforcement and the matrix will be combined together in case of a spray layup process.

Now, processing is similar to hand layup process, the only difference lies in the application of resin and fiber to the mold. Now if you remember in hand layup process we have taken a bottom plate mold, then we have sprayed the release gel, then we have put a thin plastic film on the surface then we have put the first layer of the fiber that was in the woven form or the mat form, then we have put the viscous matrix or the polymer or the plastic on top of our layer of fibers, then we are applied pressure or maybe we have applied it over the fibrous; fibrous reinforcement or the fiber layer.

Then we have put the another layer of fiber again we have applied the resin on that layer, again another layer again we have applied the resin may be 4 layers or 6 layers or 8 layers or 10 layers whatever layers we want to layup we have laid those layers up, in between we have applied the resin and finally, we have put another thin plastic film on top of that and finally, the upper part of the mold and finally, we have fast and it use in the nut and bolt arrangement that was a simple process of hand layup of combining the fiber and the polymer together.

But here how we will combine the fiber and the polymer together will be different and that will try to understand with a help of a diagram, the process is well suitable for small to medium volume production. So, in case of hand layup it is mostly suitable for low volume production, but here low volume means that the number of products made per day the number of products made per week is less in case of hand layup process.

Whereas in case of spray layup process that is medium to high or small to medium the process is cost effective for producing small and large parts. So, large parts can also be made and today we will see the manufacturing of a boat using the spray layup process.

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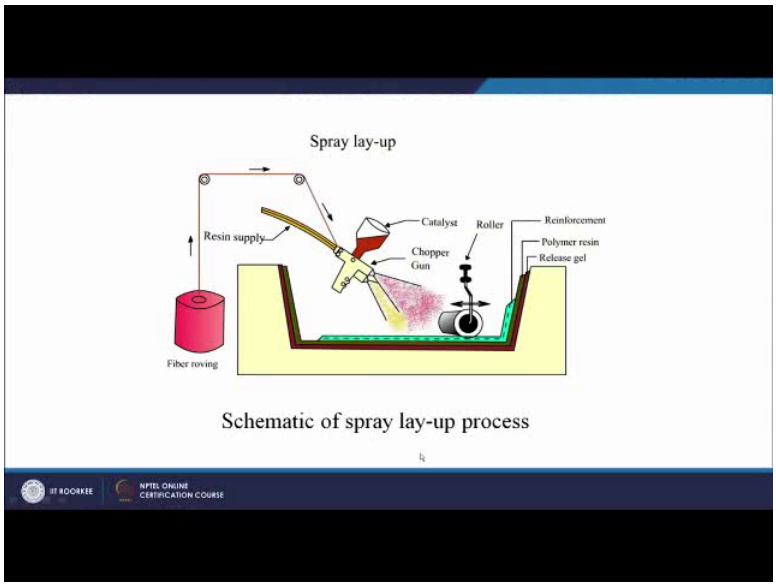

On your screen you can see now a very simple diagram of a Spray lay-up process. We can see here the mold remains the same this is the mold then there is a release gel it is shown with the different color, if you focus on the arrow you will see a release gel is sprayed on the inner half of the mold.

Then there is a polymer resin, then there is a reinforcement, both are coming together and this is a roller for consolidation, there is the catalyst coming from here there is a resin coming this yellow color is the resin tube through whichever matrix or the polymer is coming, the catalyst as I have told in the previous class also in case of thermosets, we have to use a hardening agent or a hardener. So, the hardener is coming from here that is the catalyst, it acts as a catalyst, this is the resin or the polymer supply this is a fiber roving and through this we are getting the fibers.

So, basically 3 things are going as a constituent here; one is a polymer, another is a catalyst or the hardener another is a fiber. So, 3 things going together in the chopper gun and as the name suggests chopper; chopper means it will cut the fibers into small-small pieces and this type of process will be use for short fiber reinforced polymer composite. So, chopping gun will chop the fibers the polymer will and the fibers will combine together and the mixture will be sprayed on the mold.

So, here just to explain we have shown the 2 parts the resin and the polymer separately, but in actual practice there will be a combination which will be sprayed on the inner part

of the mold. So, this is the schematic of the spray layup process, now we can see in one go we will be achieving a particular thickness of the product. If we want to have more thicker or thicker product we have to adjust the operating parameters the flow of the resin the flow of the fiber the amount of catalyst entering into the chopper gun. So, all these parameters we need to combine.

Moreover in some exceptional circumstances we may even like to go for 2 passes that in single pass we may deposit our material and then in the second pass we can again deposit the material. So, that we get a thicker product, but the only limitation and the problem in this case will be that how the 2 layers will bound together and what would be the bound strength of the 2 layers deposited by 2 different passes.

So, that is another challenge that has to be overcome in order to make a good quality product using the spray layup process. So, here we can see that this is similar the mold is also similar the only thing is how we are combining the fiber and the polymer together and in this case it is combined together in the chopper gun. Now whatever I have tried to explain with the help of a diagram let us try to understand it with the help of logical sentences.

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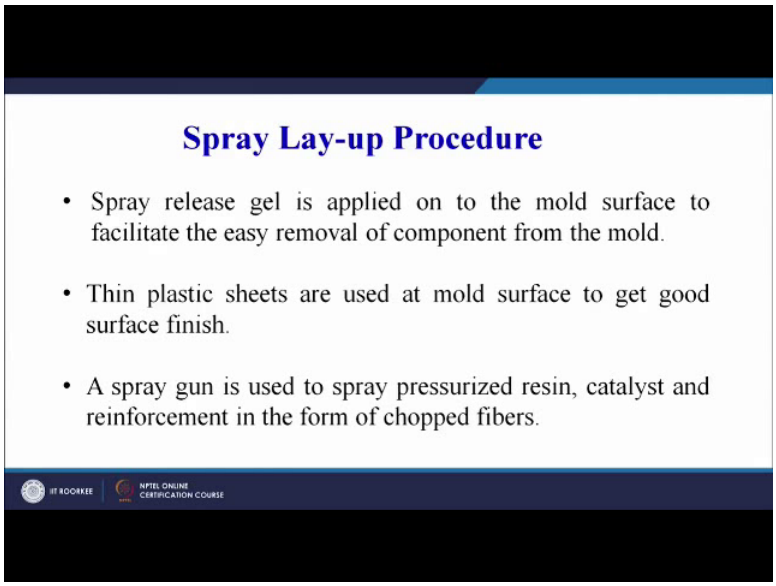

Spray release gel is applied on the mold surface similar to hand layup process only to facilitate the easy removal of the component from the mold. If we do not spray the release gel there is a tendency that the composite product which has cured finally, may

stick to the mold surface that we do not want therefore, we supply or we apply the release gel before starting our process.

Thin plastic sheets are used as mold surface at mold surface to get good surface finish. Another arrangement that is used to avoid the sticking of the product with the mold surface is the application or the use of the thin plastic sheets before the start of the process, a spray gun has in our diagram we have used the term chopper gun a spray gun is used to spray the pressurized resin catalyst and the reinforcement in the form of chopped fibers. So, the fibers that will be useful or that will be used in case of spray layup process will be shot fibers only.

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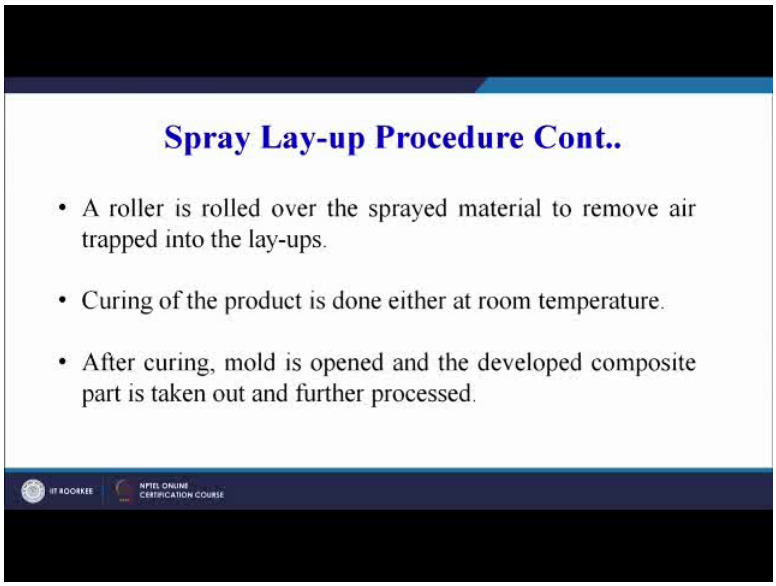

A roller is rolled over the sprayed material. So, once with the help of a spray gun we have sprayed the material on the mold surface.

Now, we have to consolidated with the help of a roller. So, roller is rolled over the sprayed material to remove the air trapped in the layups now, but as I have already told you in the hand layup process also there is a tendency of the air bubbles or the voids being formed during the processing of the material, there are tendency there is a tendency that we may get a poor quality product because of this air bubbles therefore, we need to remove these air and trap mat or air bubble in order to get a good quality product and in this the rollers come very handy.

So, roller is rolled over the sprayed material to remove air and trapped in the layups, curing of the product is done either at room temperature or it can be done at a higher temperature also. So, that depends on the product cycle the processing cycle that we have developed or that we have designed for that product, if you want to make the product hardly we want to have a high productivity we may go for a autoclave curing also sometimes and in normal circumstances if the time is not a constraint we can go for room temperature curing process also. After curing the mold is opened and the developed composite part is taken out and further processed.

Now, some of you may be wondering that mold is opened is not clear to us because in the diagram, it was shown that we are only applying the material in the inside the mold and there is no secondary or the second half of the mold there a mold is only in one half. So, in order to get a good surface finish on both the surfaces, now you can see that in case of the mold that we have taken the surface the bucket surface will give good surface finish, but the inner surface may not be that good.

So, sometimes what is done that another part of the duplicate part of the mold is placed inside placed on top of the laid up portion. So, that the other surface also gets good quality. So, during the opening process we lift this second half of the mold and then we take out the product, but still it remains a open mold process only because the laminate is open to the environment it is not closed.

So, sometimes in order to get a good surface finish on both the surfaces we may go for may be a 2 part mold as we have taken in the case of a hand layup process. If you remember the hand layup process the diagram that we have seen there are 2 metallic plates and in between we are doing the layup. So, here also if you see that we can put another half of the mold on top of this and finally, we can take it out and get good surface finish on both the sides of the final product.

So, therefore, the term opening is coming into picture. Now let us try to see this manufacturing of a boat by spray layup this has been taken form YouTube all of you as I have already told you that there are number of very good videos available, we are only selecting a very few just to aquantive with the process.

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So, this video is also available the source is also given here you can watch this again and again and try to appreciate the process, which has been used for making a boat by the spray layup process and I would like you to be slightly attentive and see that how a big structure has been made.

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This is the boat you can see the size of the boat and now the process is going to start.

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So, first of all we require a mold. So, the mold will be prepared in this case it can be a wooden mold.

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The machining is being done in order to develop the mold. So, this is you can see a cad drawing of the mold on the screen of a computer.

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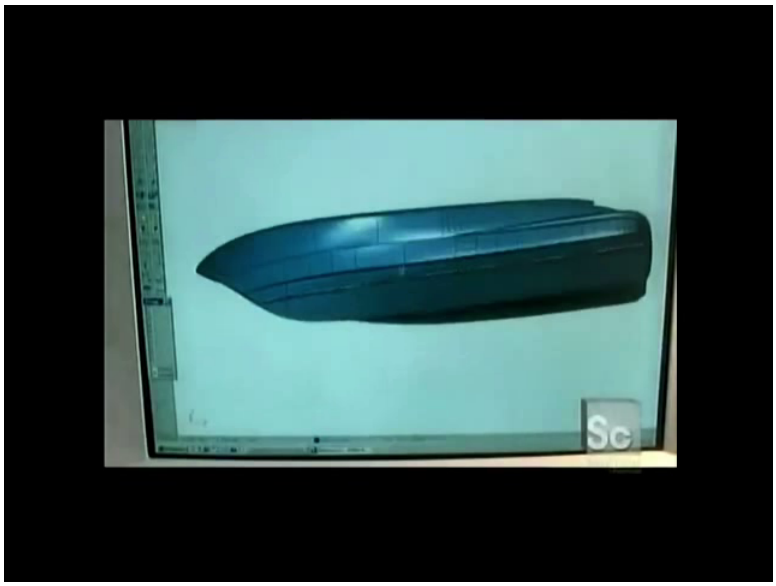

So, once you have this mold ready see the mold this is a you can gauge the size of the boat by seeing the people who are working to finalize this mold.

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So, the wooden mold is being created and you can see in the last class I told you finishing of the mold is very very important.

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Because whatever we do in order to improve the finishing of the mold that is helpful to us in getting a good quality product; so this is you can see sprayer release agent is being sprayed.

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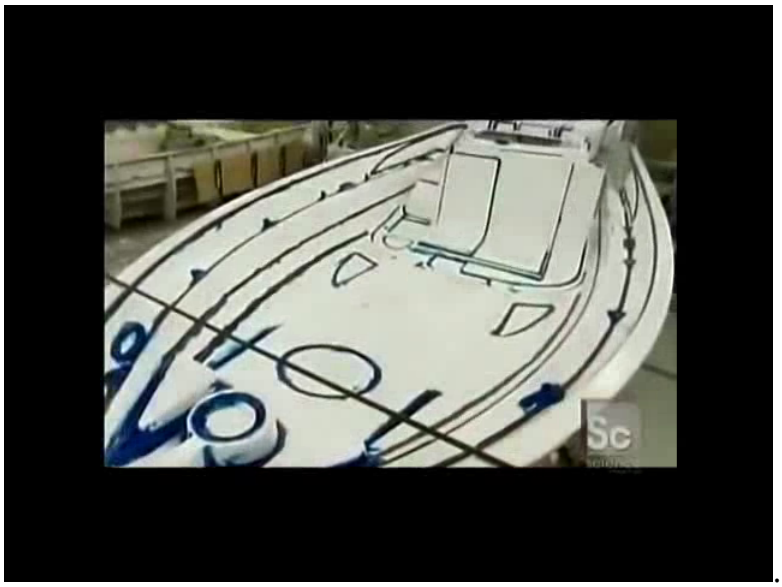

So, that our composite that is developed or formed do not stick to the mold, first of all we spray and this is the spray gun which is depositing see the fiber coming glass fiber roving, this is the glass fiber roving that is coming, it is entering into the spray gun, the chopper gun it is being chopped and the material is being deposited on the mold.

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And this is you can see small glass fibers and with the help of roller the consolidation process is being done, this is a roller or rolling arrangement and this is the consolidation being done with the help of roller, you can see the size of the boat and finally, sometimes we can do curing also and this is maybe a glass fiber tape after the rolling process, the again consolidation; this is a glass fiber tape at some specific sections in the boat to further consolidate.

Now, after curing this is ready. So, it has to be removed from the mold and this is being lifted the red portion is the mold which was fabricated from wood and this is the boat that is ready. So, this is the primary forming in which the shape of the boat has been made ready.

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Now, we will cut certain section see we have cut a different section the; another section has been cut all this will fall under the secondary manufacturing.

So, this is the basic structure of the boat that is ready the basic structure made up of glass fiber and polymer and then the other additional fittings electrical fittings and electronic fittings all those can be done and the boat can be made ready for operation. You can see the quality of the manufacturing process, similar videos are available on YouTube here spray lap up process has been use and this is a heat you can see the final heating, being carried out final finishing. So, that is all related to the manufacturing of a fiber reinforce plastic boat and spray layup is one of the process which has been used for manufacturing of the boat.

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So, you can see the size does not matter when you are using a hand layup or a spray layup process. So, very big size large size products can be made using these processes. So, these processes are widely used for manufacturing of different types of fiber reinforced plastic parts. So, source I would again like to highlight kindly note the source and you can again go to this source and try to look similar type of video the same video again and again and try to appreciate the process, that how the process can be used may be I may not have been able to explain all the details related to the process, but looking of the video you can further get certain insights into the importance of this process.

Now, again coming to the theoretical aspect of spray layup process you can see the type of raw materials that can be used. So, epoxy polyester polyvinyl ester similar types of raw materials that we used for hand layup process.

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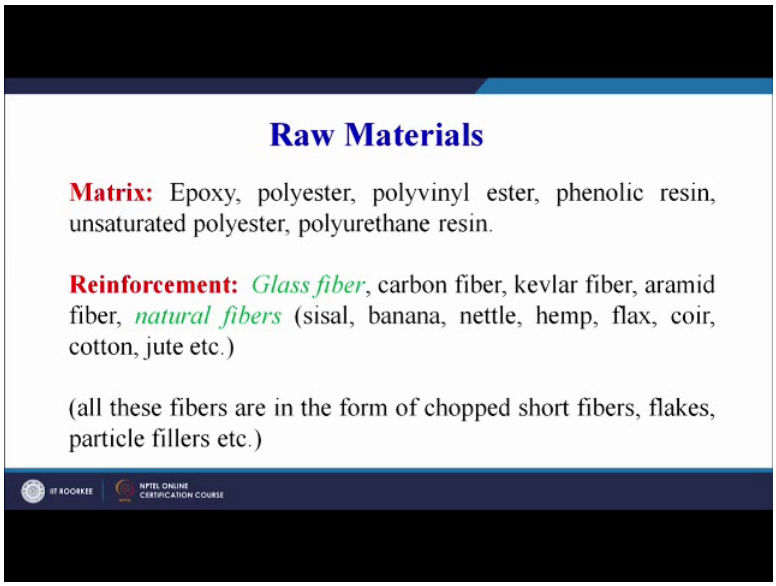

So, majorly thermosetting type of polymers are used for spray layup process the reinforcement can be glass fiber as the case we have seen in the video, carbon fiber, kevlar fiber, and aramid kevlar aramid are the same fibers natural fibers can also be used for spray layup process like sisal banana nettle hemp flax coir cotton jute.

So, there are number of natural fibers which can also be employed for making the product using the spray layup process. So, all these fibers in the form of chopped short fibers flakes or particle fillers etcetera can be if you remember in the hand layup process we have seen that these fibers have to be continuous fibers in both the direction in the woven mat form, but in case of spray layup the fibers have to be chopped into shot fibers. So, that they are we are able to spray them onto the mold or the surface of the mold.

What can be the advantages of this process, now I think all of the learners may have been able to differentiate between a hand layup process and a spray layup process, the major difference is that in case of hand layup process we use continuous fibers or the mat fibrous reinforcement in the mat form whereas, in case of spray layup process we use in the chopped form other difference can be based on the application of the 2 our bringing together of the 2 constituents. That is how we are combining the fiber and the polymer, in case of hand layup process we are stacking up laying up the reinforcement layer by layer and then applying matrix in between in the form of polymer.

Whereas in case of spray layup we are using we are we are inputting our reinforcement into the spray gun, we are putting our polymer into the spray gun, we are putting our catalyst into the spray gun and in within the spray gun all the 3 constituents are getting mixed and the mixture is being sprayed on to the mold surface. So, the method of joining the reinforcement and the matrix is different in case of hand layup as well as the spray layup process.

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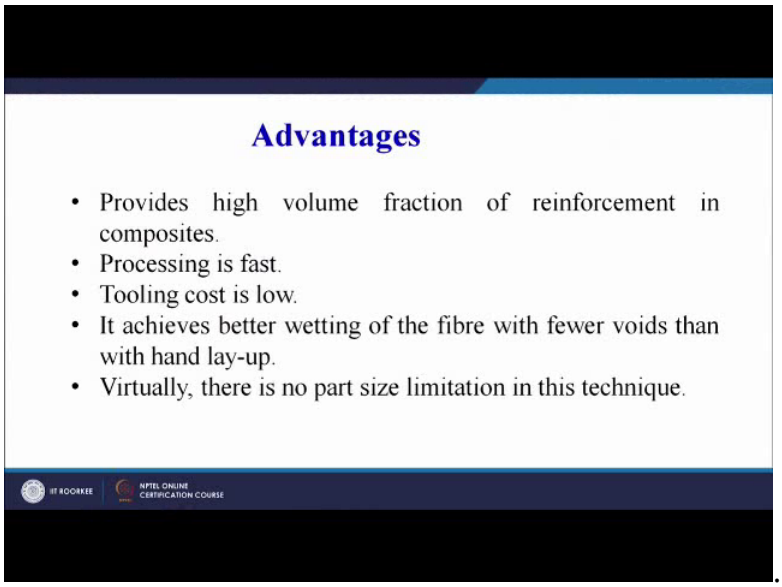

So, the major advantages are it provides high volume fraction of reinforcement in the composites. So, volume fraction is a new term I think I have explained it in when we were discussing the basic concept of composite materials. So, the volume fraction is the amount by a volume of the fiber present in the composite.

So, volume fraction can be of matrix also it can be of reinforcement also the example I have taken is of the reinforcement. So, volume fraction can be 60 percent by volume of fibers, it can be 55 percent by volume of fibers. Similarly the rest will become the matrix. So, in case of spray layup process we can get very high fiber volume fraction, which is good for us if we remember in the last class I have told you why do we roll the polymer out of the laminate the excess polymer sorry, why do we roll out the excess polymer from the laminate in order to ensure that we have high fiber volume fraction where fibers are the may load bearing members of the composite.

So, we do not what excess resin inside the composite. So, here also automatically we get good fiber volume fraction because of the nature of the process. The processing is fast in this case as we have seen it can be automated tooling cost is low; because we have to make a mold as in our video we have formulated a wooden mold. So, the mold cost or the tooling cost is not that high it achieves better wetting of the fibers with fewer voids than with hand layup process. So, that is another we can say advantage of the spray layup that the word content or the air bubbles or air entrapment is minimum in case of spray layup process as compared to the hand layup process.

So, a virtually there is no part size limitation in this technique. So, you can have we have seen the size of the boat. So, there is no part size limitation we can make very large products with the spray layup process what are the limitations.

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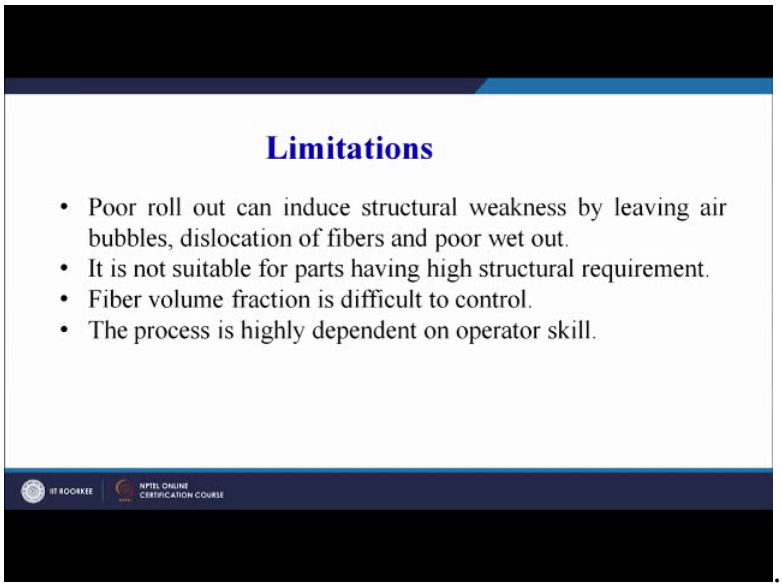

Let us quickly go through the limitations poor roll out can induce structural weakness by leaving air bubbles dislocations of fibers and poor wet out yes if you are not able to control our parameters properly we may lead to a pure quality product in the form of dislocations of fibers or the fibers getting not wet by the adequate supply of the polymer or there can be air entrapment, but if we are able to control our process properly we are able to optimally and judicially select the operating variables we can very easily get a very good quality product as we have seen our video also it is not suitable for parts having high structural requirement.

So, since the fiber is short fiber. So, we have not expecting very high strength from parts which are being made by the spray layup process; fiber volume fraction is difficult to control as we are spraying and there is as you have seen that once we are consolidating the fibers are also getting displaced. So, there is tendency that the non uniform distribution of fibers in the product may lead to may be different properties at different positions.

So, fiber volume fraction at different sections may vary whereas, in case of hand layup process that problem will never occur because we have continuous fiber reinforcement in the form of cloth or a form of a mat and then we are applying the resin on top of it. So, the fiber volume fraction at any given section of a hand layup process will more or less be same. So, the variation will be less whereas, that variation is more in case of a spray layup process the process is highly dependent on the operator skill also because he has to spray and see that how he has to move at what skill at what speed he has to move or he or she has to move.

So, that we are able to deposit the right amount of thickness at the right place at the mold surface. Finally, coming on to the applications spray layup method is use for manufacturing lower load carrying parts like small boats as I have already told you for high end structural applications hand layup process will be more suitable as compared to a spray layup process, but for low load carrying parts like small boats bath tubs fairing of trucks duct and air handling components sometimes storage tanks can also be made furniture components can also be made using the spray layup process.

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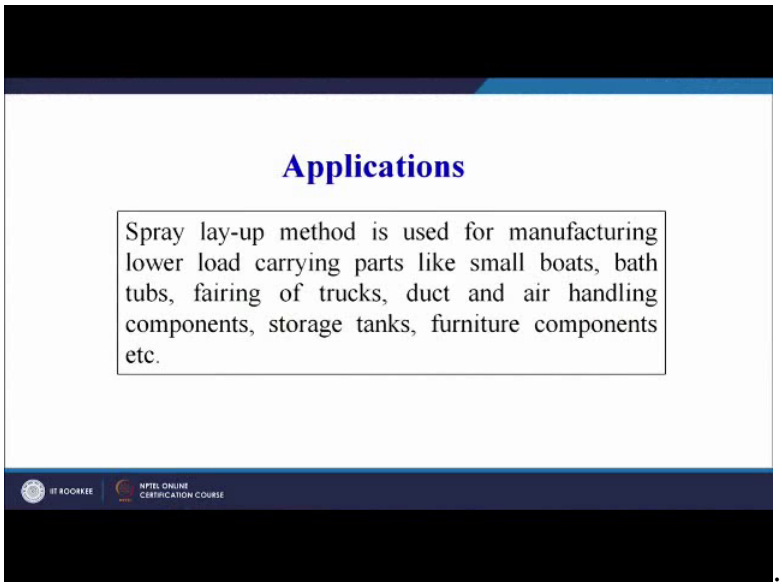

So, if you see the videos available on YouTube if you go through other internet content that is available on spray layup process, you can yourself see the application spectrum of spray layup process. So, with this we come to an end of our section on spray layup, in our next session we will discuss a different process for processing of polymer based composites.

Thank you