Introduction to Composites
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Lecture - 23
Resin Transfer Molding Process

Hello welcome to introduction to composites today is the 5th day of the ongoing week. And we have been discussing different wet processing methods for thermoset composite materials. Today we will discuss 2 more or possibly 3 more different types of processes, which are wet in nature and which are applicable to thermoset composites. And the first process we are going to discuss will be RTM, which is a short form for resin transfer molding.

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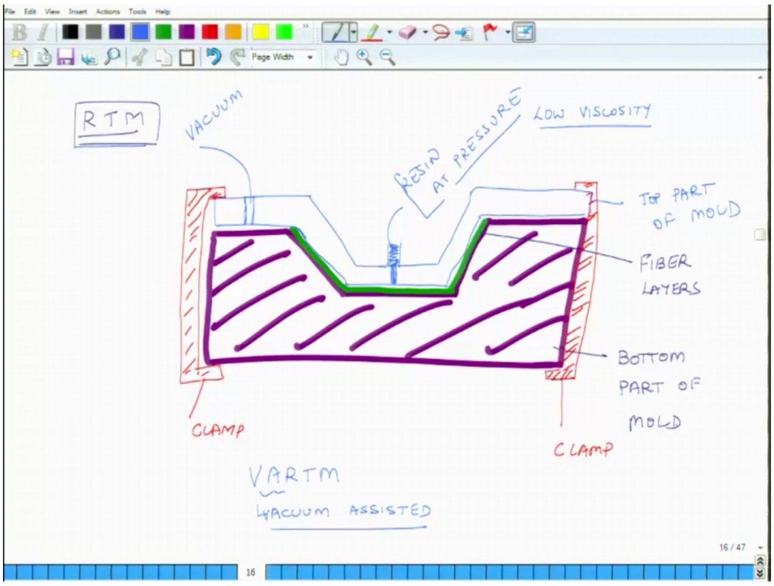

So, a limitation of the vacuum bag molding or bag molding processes is that the fibers when you apply a lot of pressure, they tend to dislodge from their original position and there is a chance that the orientation of the fibers. In the system especially if you use pressure external pressure may not be same as what you intended, because the as you apply external pressure. The fluid in the thing flows at a higher velocity with high pressure and it tends to change the orientation of the fibers.

So, RTM is one method, which can which helps us produce good quality composites in a way that the fibers do not get overly dislodged from their original position. So, let us look at this picture as to how the composite material is produced in the RTM process. First thing which we have is a bottom part. So, let us say this is the bottom part of the mold.

So, this can be made of metal or some strong plastic which can take a lot of temperature and things like that and then of course, on top of this mold you put all the release agents and the gel to ensure a good finish and once you are done with that then you on top of it you put the fibers, but in RTM you do not put prepregs.

So, we do not use prepregs in RTM we use dry fibers. And we put them we put all the layers. So, suppose they are 10 layers we put all the 10 layers and step by step, but between 2 layers we do not put any matrix. We just deposit all the layers in the intended orientation and sizes and that is all we do. So, these are fibers or rather better will be fiber layers and this is our bottom part of the mold.

Quantum part of the mold and then what we do is we have a top part. So, you can call it top part of the mold. So, let us say this is the top part of the mold and of course, there is a gap between the top part and the bottom part and we clamp. Now in this picture I have made the bottom part very thick, but anyway the point is that we clamp the top part and the bottom part using some sort of a mechanical device. So, this is my clamp.

So, we clamp it all around and we have a similar clamp on this side. So, what this ensures is that everything remains in orientation and things do not move and of course, from the top part we have there some gap between the bottom and the top and there is air in there. So, we have an outlet for air and these we connect to vacuum, but we have still not shown how the metrics get added and this is where. So, the matrix is injected in this mold once all the layers have been put through some outlet.

So, this is this may be the path for matrix material resin. So, resin is injected and it is injected at a pressure, but the pressure is not very high in the sense that when this resin flows through the fibers. It does not flow at very high velocity it flows relatively slowly get modest pressures and as a consequence, the fibers do not get disoriented from their original configuration. And to ensure that we make sure that whatever resins we use they have low viscosity.

So, you mix the resin with the hardener and you inject and this resin with the hardener should have low viscosity only, then it will flow easily through all the network of fibers it wets everything and of course, this is assisted there is also vacuum to remove all the air and once it has wetted everything then you apply heat and you do not apply a lot of pressure and in that state you let it cure. So, as a consequence you get a high quality, high finish product, of course, finishes on top side and bottom side with low porosity and also the fibers are not disoriented more than what can be tolerated.

So, this is all about RTM now I had said that there is a special version of RTM known as VARTM VARTM and this is vacuum assisted RTM. So, in vacuum assisted RTM it is the same thing, but you do not send the resin at high pressure. You just slowly let it flow, you do not inject it at high pressure you only rely on vacuum to draw the resin and as a consequence the orientation of the fibers is even better it is even better.

But then you have to make sure that the viscosity of the fluid is extra low. So, that it flows nicely and smoothly and it wets everything. So, this is resin transfer molding. The second process we are going to discuss is filament winding.

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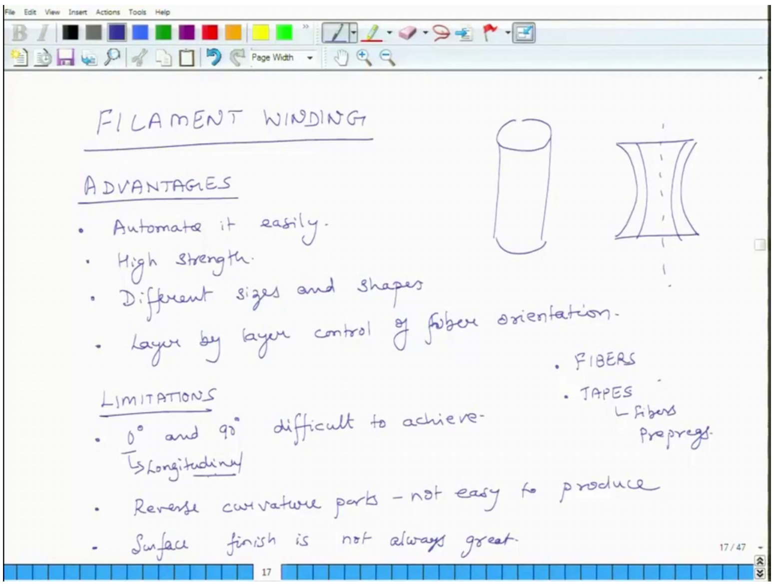

This is filament winding, I think the best way to explain this filament winding is by seeing a picture because then you will get a very clear idea of how this thing is done.

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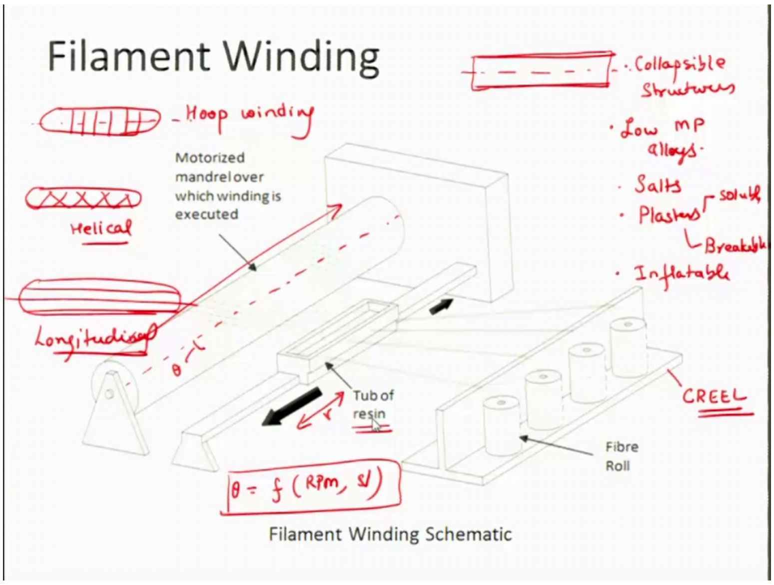

So, this is a schematic which talks about filament winding. Now what you have here, are a large number of fiber rolls and this entire set is known as a creel. So, you have a creel in, which you have different roles of fibers.

So, filament winding is typically used to produce structures or objects which are axisymmetric which are axisymmetric. So, you have a you have fibers coming from creel and at the other end you have a mandrel. So, what is a mandrel it is basically? So, suppose you want to make a pipe then what do you do you have a hollow rod or a shaft. And on top of that you can wind the fiber and if you can then later somehow remove the shaft from the center, then you have a hollow pipe made up of composite ok.

So, that is what the principle? So, the mandrel is something which is axisymmetric in nature and it is made in a specific way such that it can be very easily removed. So, how do we make a mandrel, we can make it from collapsible structures; collapsible structures.

So, once the thing is done then the inner mandrel collapses, it can be made of wood or metals bed which can be which collapses at some specific locations. And then everything falls apart and only the outside thing is left or you can make it from a low melting point alloys.

So, low melting point alloys in the sense that it is melting point should be less than the decomposition temperature of the composite or you can make it from some salts eutectic salts or from some clusters which are either soluble or they are breakable is they are easy to break.

So, these things or you can make it from some inflatable materials. So, for instance you have a stiff rubber and you inflate it and then on that inflated structure you wind and then later you deflate it. So, internal stuff goes away.

So, this is how you make the mandrel and mandrel the shape of the mandrel the cross section of the mandrel decides the cross section of the final product. So, what do you do? So, you have fibers coming from different reels and they pass through a tub of resin they pass through a tub of resins. So, they become wet and then they are pulled by this mandrel, which is rotating they are pulled by this mandrel which is continuously rotating.

So, the fibers wind around the mandrel and as this is happening this type of resins it moves back and forth. So, you start depositing materials along the length of the entire mandrel. So, in this way you can have an axisymmetric structure, which is made up of continuous fibers. So, here the trick is that you have to use continuous fibers you cannot have this with short fiber compared you know short fibers. And you use this and you can have this fiber winding in different patterns.

So, suppose this is. So, you can have fibers which are bound like this. If what when will this happen this happens, when the tub of resin velocity is extremely small. If it is extremely small then, the fibers which will wind around the mandrel will be more or less at ninety degrees to the axis of the mandrel. So, this is called hoop winding or circumferential winding hoop winding or circumferential winding.

Another way you can have winding is at an angle. So, you can have different angles. So, this is angular or helical and this angle. So, if you if this is the axis of the mandrel and this angle theta this theta can be controlled by controlling 2 parameters and what are those 2 parameters? So, theta is a function of RPM and this velocity v these 2 things ok.

So, the RPM is extremely high this angle will be closer to 90 degrees. If this RPM is very slow and velocity is very high this angle will be closer to 0 degrees. So, it is so you this can be mathematically controlled based on geometry.

So, you can have hoop winding helical winding or you can have even a longitudinal winding now in longitudinal winding the fibers are like this, but of course, you can never have fibers exactly at 0 degrees, but you can get close to that because at 0 degrees it means that mandrel is not moving, but it has to move otherwise the fibers would not get deposited.

So, this is there. So, you can have maybe in the inner surface fibers. So, this is longitudinal. So, you can have different layers of fibers some fibers could be at 45 degrees some could be at 90 degrees some could be at 0 degrees based on what your structural needs are you can have this. So, what is happening is that once all the fibers have been bound and there is tension in the fibers. So, it is tight right it is tight and also there is not a lot of air in this system then you somehow expose it to heat and you let it cure.

So, this is what filament winding is all about. The couple of limitations of this process and also there are a couple of advantages. So, let us look at some of these limitations and advantages of filament winding process. So, the first so let us look at some of the advantages. So, it is you can automate it easily; it is not a very complicated setup. The second thing is that the products which are which come out of it are of high strength because the fibers in it are in tension. So, they are not loose in the matrix and there is little air in the system.

You can have different sizes using the same setup, you can have a small part, you can have a large part, you can have parts of different cross sections as long as they are symmetric you know axisymmetric. So, different parts sizes and shapes all you have to do is change the mandrel. And you can have layer by layer control of fiber orientation, limitations; what are the limitations? Limitations are 0 degrees and 90 degrees difficult to achieve and 0 degrees is longitudinal and longitudinal is more difficult compared to 90 degrees.

The second thing is all axisymmetric parts may not be easily producible. So, for instance you can produce parts which look like this, but suppose I have to produce a part which is like these excuse me. So, this is an axisymmetric part, but suppose I have to make a part, which is something like this this is not easy to produce. I can make a mandrel and I can wind it that is not a problem, but taking out the mandrel becomes tricky because the mandrel will get stuck ok.

So, producing such parts are not easy to produce. So, reverse curvature parts not easy to produce other one is that surface finish is not always great is not always great. So, these are some of the limitations of these parts. So, you can use this process either for using fibers I mean, I am talking about continuous fibers or you can use this processing is that also if you have tapes you know that also you can do and these tapes could be just fibers or even prepregs. If it is a prepreg it does not have to go through the path of matrix right does not have to go through path of matrix path ok.

So, this is about filament winding and the last production method, we will discuss today is known as pultrusion.

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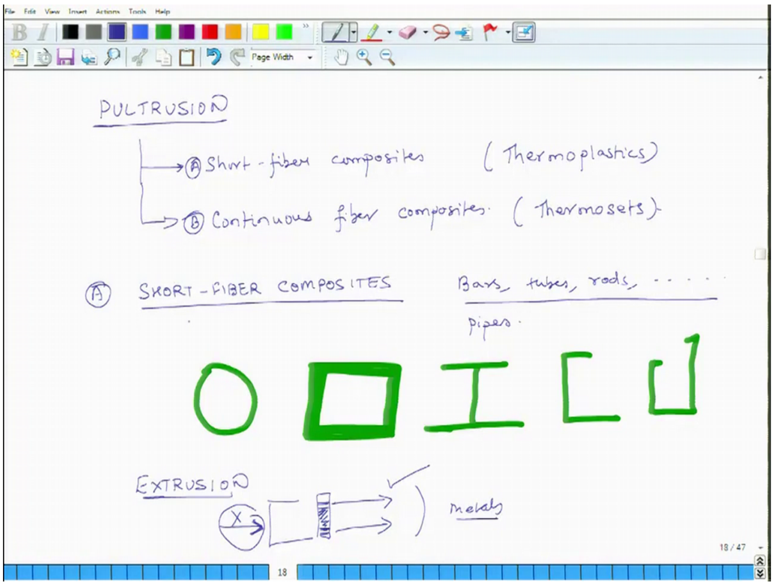

So, this pultrusion is also used quite a bit for thermoset plastics. So, what happens in pultrusion? So, actually using pultrusion you can make 2 types of composites one is with short fiber short fiber composites. And the other one is with and the methods are different continuous fiber composites.

The short fiber composites, which you are produced, when we use this pultrusion process are typically thermoplastics and we will understand it later why. And these continuous fiber composites, which are typically made from pultrusion process they are typically thermosets thermo sets. So, we will first discuss A and then we will discuss B ok.

So, how do we use pultrusion as a process to produce short fiber composites? So, what do we use these type of composites. So, typically we use this type of this process to produce bars, tubes, rods and stuff like that. Basically in all these members the cross section of the material of the part does not change with length.

So, you can have pipes. So, you can have different types of section. So, you can have a cross section like this, you can have across a box cross section and how it is produced we will discuss that you can have a I cross section, you can have a C cross section, you can have some other types of cross sections ok.

So, in our mechanical engineering courses you may have heard of a method known as extrusion. So, what happens in extrusion is that you have a tool, which has a cross section like the one which is of the final product and you push the material through that tool and at the other end you pull the material. So, you have a tool which has a circular cross section right. So, the material can come out from these holes everything else is closed and you push the material from this side and from this side you pull it. So, you get a tube like this ok.

So, similar so this is the extrusion process this is the extrusion process. So, this is used typically in metals in pultrusion. So, in metals you actually push the material, you push the material you do not pull it from the other side most of the force is applied on pushing the material through the orifice of the right cross section. In a pultrusion rather than pushing you do not push, it you actually pull it that is why it is known as pultrusion?

So, in case of short fiber composites so, we are still discussing a short fiber composites. So, in case of short fiber composites what the raw material is raw material iron pellet us. And these pellet us have fibers short fibers.

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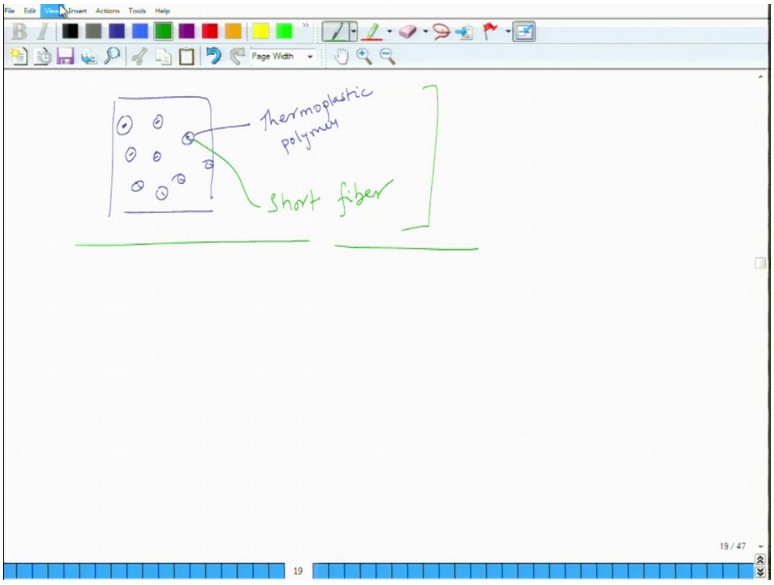

So, these are all pellet us and they are surrounded by matrix and this is what. So, these are all pellet us they are surrounded by matrix they are separate. So, this matrix is thermoplastic matrix. So, it is a thermoplastic polymer and these short fibers. So, this is my short fiber this short fiber is a lot of times; it may be glass sometimes may be it may be have some other fibers. So, each pellet has some short fibers in it bound by matrix.

So, what you do is you melt all this and then you push it through a hole you push it through a hole of the right cross section and as it comes out it becomes somewhat solid and you keep on pulling it. And that is how this pultrusion process happens for short fibre composites. For long and continuous fibers it is a little trickier, were here short fiber basically you are pushing this pulling pushing this material through a this you know flow anything through a hole and then as it comes out it becomes cold.

So, it has some form and you pull it for long fiber the process is a little more complicated and we will see a picture. So, that we understand it better.

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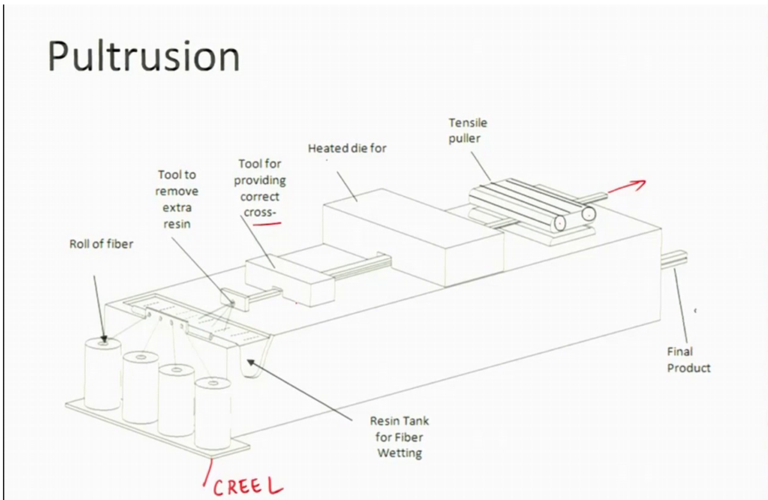

Basic Schematic for Pultrusion Process

So, this is the schematic for the pultrusion process. So, what you have is here is you have all these reels of fiber. And these reels produce you have continuous fibers and this entire set is known as creel. And these fibers go through a bath through of resin. So, they become wet and this resin and then there is some tool to remove extra resin. So, it is wipes off extra resin. And all these fibers then collectively go through a tool which gives it the right shape and as it comes out at the other end it is having that shape, but it is still very soft and flexible.

So, it goes through a heated die, in the heated die it actually gets pressed and at high elevated temperature and the form is assumed. And then as it comes out it has solidified it may still be not totally cured, but it is has sufficient amount of stiffness. So, that it can be pulled. So, you keep on pulling it from here using these rollers and as it comes out it acquires that shape and this process continues. So, in this case the fiber is aligned with the length of the cross section length of the cross section.

In short fiber composite the fiber is not necessarily aligned with the direction of the pipe or the cross section, but in long fiber continuous fiber composites the length of the part and the length of the fiber they are aligned. So, this is the pultrusion process and this essentially concludes our discussion on different ways for manufacturing thermoset composites. Tomorrow we will discuss some other ways, but not necessarily related to thermo sets, but related to thermoplastics and other types of composites. So, that concludes our discussion and we will meet, once again tomorrow to complete this discussion on different production processes associated with composites.

Thank you.