Nature and Properties of Materials
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Lecture 22
Composite Materials 3

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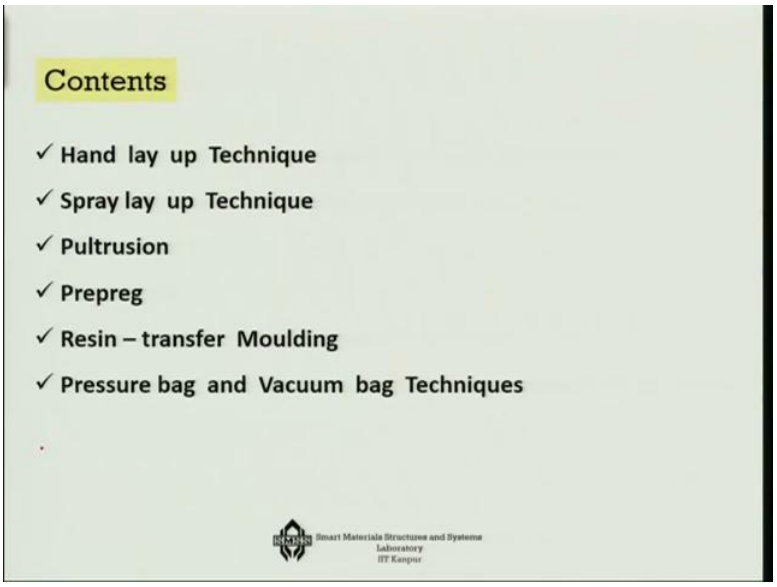

Today, I am going to talk about how you can make composite laminates with the help of composite material. There are several techniques that are there, so I am going to talk about 1st about the hand layup technique, I am going to 1st talk about the Hand layup technique. And then I will talk about Spray layup technique, which is slightly faster, Pultrusion process, Prepreg making, Resin transfer moulding and finally Pressure bag and Vacuum bag techniques.

So the earliest method of making composite is through the Hand layup technique. And in this technique as the name suggests that you have to apply the gel coat to the open mould to avoid faster sticking of polymer to the surface. So let us say this is the mould surface for example, this is the mould surface. And on the mould surface you first apply the gel coat and then you make the reinforcement or sometimes we called the reinforcement to be something like the fibre-based mother Prefab structure.

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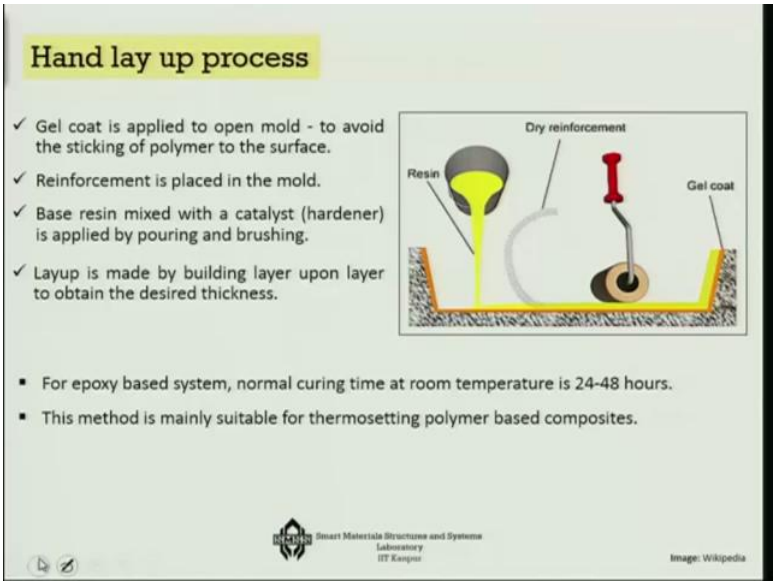

So that reinforcement you then place it to the mould, so that is the yellow part the orange colour part that you have here and then over that you pour the resin, so that is the resin you are just directly feeding the resin. And the base resin is often mixed with the catalyst hardness and so that it gets hardened very fast, so this is the dry reinforcement okay. And ones you are applying the dry reinforcement, over that you are placing the resin.

And this layup you can do it layer by layer by layer, which means if first apply one gel coat, apply one dry reinforcement, put the resin, then again the 2nd layer, like that you can build it up, so that is the process of Hand layup technique. And after this whole thing is done, then you have to keep it for curing. For epoxy-based systems, the normal curing time at room temperature is about 24 to 48 hours.

And naturally as the name itself suggests that the epoxy-based matrix you are using and this is mainly suitable for thermosetting polymer-based composite, where you just after you make the whole thing, you just put it on the oven to get it cured, so that way it goes very well and that is the usual hand layup process. You can do it layer by layer for example; here I can show you that this is one composite that we have developed in this manner.

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As you can see here that there are several such layers okay, this is a flat plate so there are long layers as well as cross layers several such layers so that which we have applied resins and this still the additional resin you can see, the extra resins are there at the ends of it okay. So and once you do that, then once it gets hardened, then you cut it into a piece like this type of a piece itself, this is a glass fibre reinforced plastic you get this through a Hand layup process.

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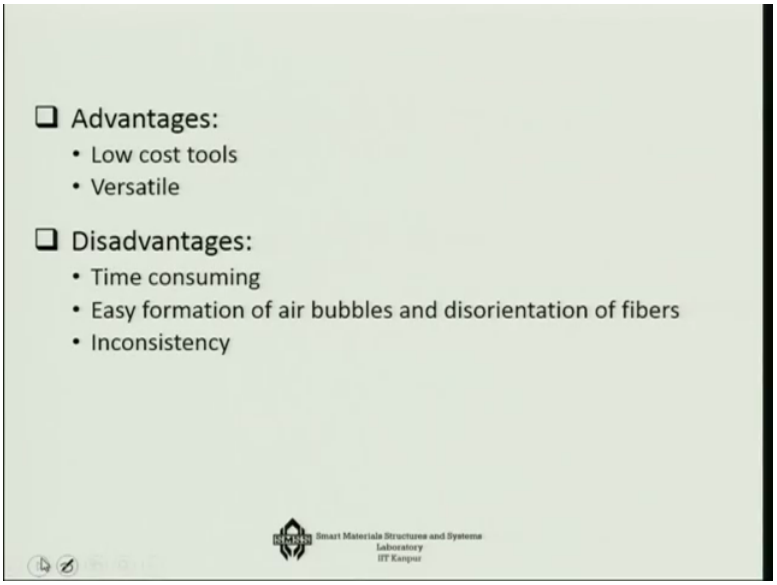

So what is the advantage and disadvantage of this process? Advantage is that it is low cost; you can do it like in a very small set up. It is very versatile, you can make your own mould shape and you can do this. But the disadvantage 1st of all is that this is a manual process, so hence it is time-consuming. And when you are doing this applying the resin, there is a these chances of air bubbles getting interact, so easy formation of air bubbles and disorientation of fibre.

If you look at once again this whole thing very carefully, you can see this disorientation of fibre, right. You can see that the fibres are not very straight when you are pouring the resin, it is getting displaced so you do not get a homogeneous distribution of the fibre, so that is the that is another problem in the hand layup technique. And also you cannot control the thickness very much, so there is a lot of thickness variation that can happen into system, so that is our hand layup technique.

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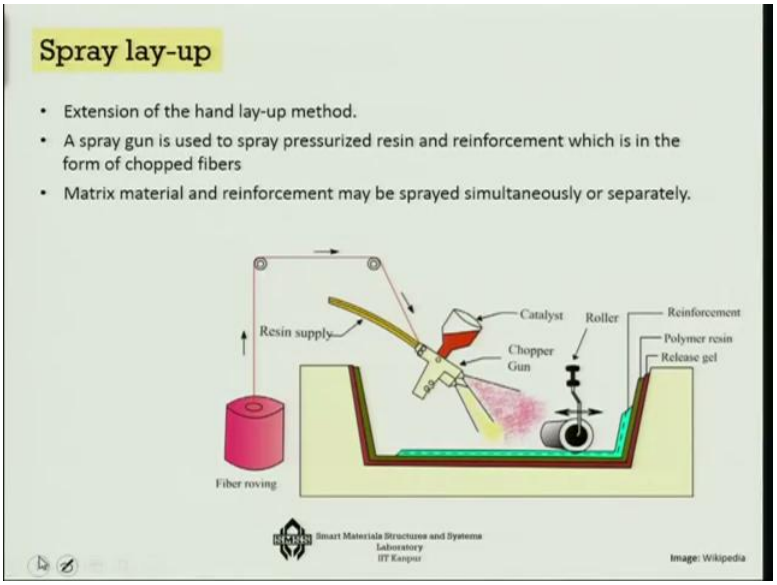

Slightly better technique is the Spray lay-up technique, so this is an extension of the hand layup. And in this case instead, of pouring the resin, what you basically do is that you take a resin supply through a chamber pipeline and there is a catalyst that is coming, so these 2 are getting mixed here and then the resin is coming out. Not only that, many a times what we do is that the fibres also like using a chauffeur gun many a time we also split the fibres through the same process.

And sometimes you use the reinforcements directly as has been shown here and this spray pressurized resin can actually get more uniformly coated okay and it is in the form of chopped fibre you can do it. And the matrix material and reinforcement, they get simultaneously spread or separately either of them and you then uses a roller in terms of making this a very kind of a uniform thickness.

So there are 2 types of reinforcements you can give, either is like a hand layup technique, you will be the reinforcement like prefabs beforehand as has been shown here or the other case is what you use is that you take the fibre from the roving as has been shown here and this fibre you just chop it here, there is a chopper gun and you spray this fibre along with the resin, so that the fibre in this case is not a continuous reinforcement, but it becomes a chopped reinforcement randomly aligned and sometimes you can even align it also towards a flow direction, so that is the Spray layup technique.

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The advantage is this is a continuous process, it is much better than the manual process, faster. Any materials can be used as the mould in this case and error can be corrected very easily by the re-spraying. Disadvantage is it is still slow and there can be inconsistencies, there is no control over the fibre orientation because you are just chopping the fibre and spreading.

Only one side finished and it is environmentally unfriendly, possibility one of the most important reasons why this is not used much because you feel you are chopping the fibres that is dangerous also because many of these fibres as you chop them and if you inhale it ingestion, it will be very dangerous for the health. So hence this procedure is not very environment friendly.

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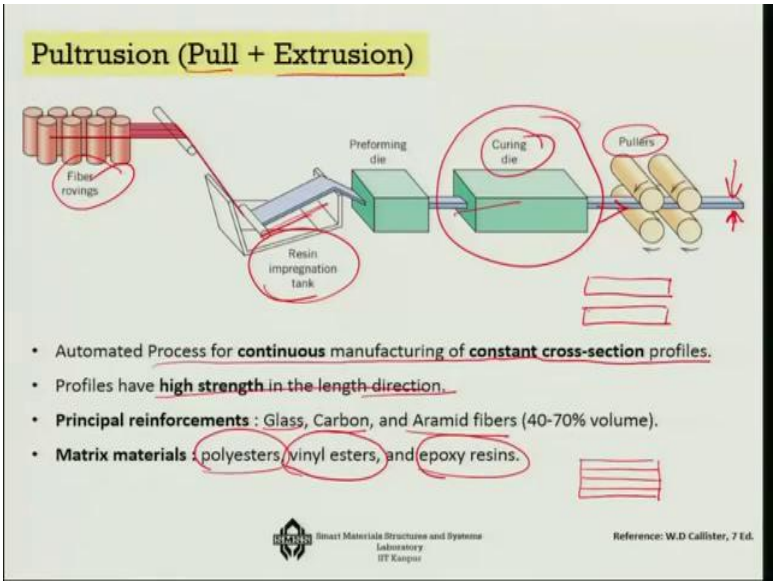

Now there is one way of making actually continuous fully automatic composite laminates and that is called Pultrusion process, which is a mixing of Pulling + Extrusion. So what you do in this process that you take the fibres from the fibre roving and then you can see that they are getting a resin bath here, so this is resin impregnation tank as the fibres are pulled through the tank, they are getting resin bath.

And there is a preforming die, where actually this additional resins are taken out, then it is going to the curing die, where it is getting heated and in the pullers just outside you are pulling this whole thing and also you are mentoring the thickness through that process and there is usually something like a chopper here. So if you want a certain size, you just simply chop it at this location so that you start to get plates out of it.

That is what the Pultrusion process is, it is just like if you think of it that this part is just like your pizza making process okay, so very similar that a continuous belt actually takes this fibre with resin and gets it cured and then pull it through the puller and then chop it. So this is an automated process for continuous manufacturing of constant cross-section profiles.

And the profiles are now that in this case the fibres are perfectly aligned, so suppose if this is my plate then all the fibres are perfectly aligned that is how you are impregnating them and you are pulling them so they have a high strength in the length direction, so that is the good part. The principal reinforcements are glass fibres, carbon fibre and Aramid fibres and you can get from anywhere from 40 to 70%, 70% is quite a high number volume fraction in this.

And the matrix material that is very interesting that you need not only work on epoxy resin type of thermosets, but you can work on polyesters, thermoplastic vinyl esters, et cetera, so that is what is the Pultrusion process. So what are the advantages and disadvantages?

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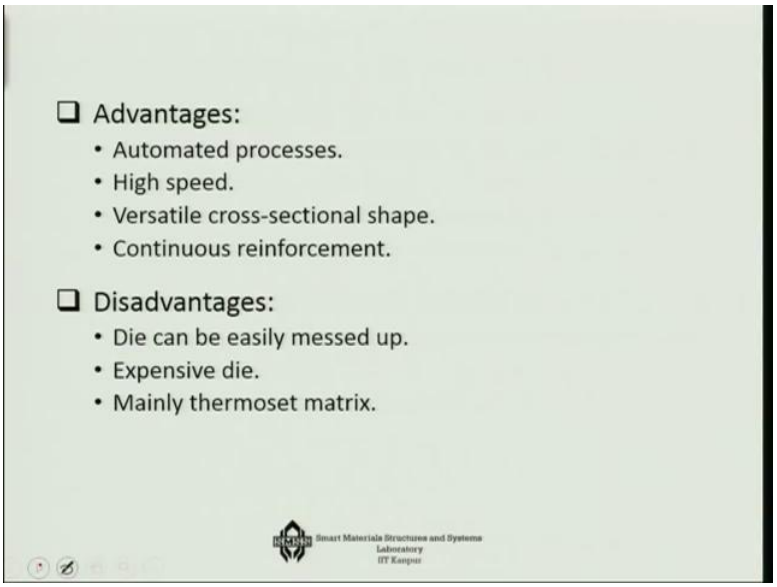

Advantage is that this is an automatic process as you have seen, it is a high-speed process and you can make versatile cross-sectional shapes and continuous reinforcements. Disadvantage is that the die can be easily messed up okay because you are putting it in the die bath and the die can get hardened for example.

And when the resin is pulling, that die can get contaminated, the dyes are expensive and mainly thermoset matrix is used in this case. So I think the greatest limitation is that the shape and size are generally of much defined shape, you cannot do too much of a complex shape. Suppose I have to make something like we will have it today, some something like a wheel rim, you would not be able to do it.

You will you will be able to get something like this type of a rectangle and then you can cut a wheel shape a circular shape out of it. So cannot make, there is no way you can make directly this type of a system.

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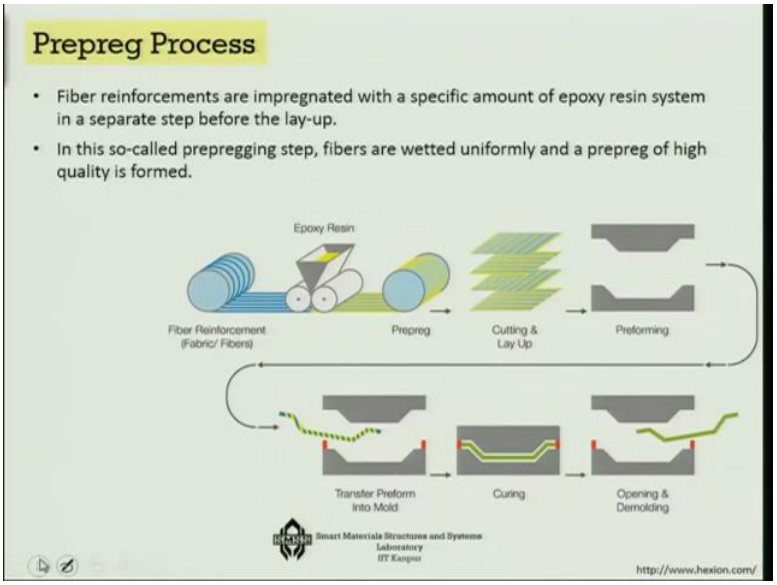

There is another way out which coming up in a good way, it is called a Prepreg process. So here the fibre reinforcements are impregnated with a specific amount of epoxy resin system in a separate step before the layup. So basically you can buy from the market these prepregs. Now in the so-called prepegging step, fibres are actually wetted uniformly and a prepreg of high-quality is formed.

And once you are forming this, you can see here fibre reinforcements, epoxy resin is coming up, you are prepregging okay and then you are cutting and layup is taking place, then you are preforming the whole thing okay and then transfer this preforming to the mould, then you cure it and finally you opening and demoulding it. So basically this preforming up to that stage, you are actually using this already impregnated laminates.

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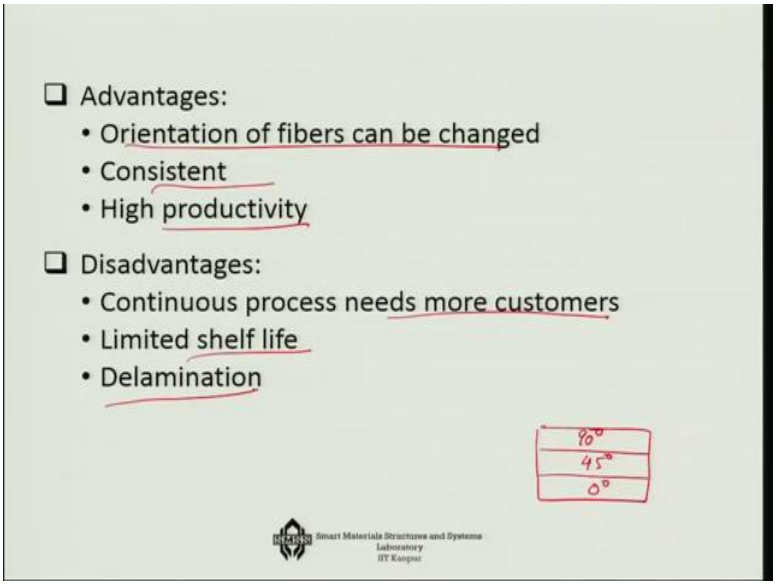

The advantage of Prepreg system is that the orientation of fibres can be suitably changed okay, so in one layer you can have like multiple layers. If I look at the cross-section, I can have multiple layers of multiple direction of ply, so that will be something like 0 degree, 45 degree, 90 degree, I can vary it, so orientation of fibres can be changed. It is consistent and it has a high productivity.

The disadvantage of Prepreg is that the continuous process needs more actually demand and it has a limited shelf life. That shelf life is limited because the resin can set any time and then there are possibilities of delamination the system. So basically we have thus seen the 3 or 4 very important technique okay. So Resin transfer moulding is another process that we use okay.

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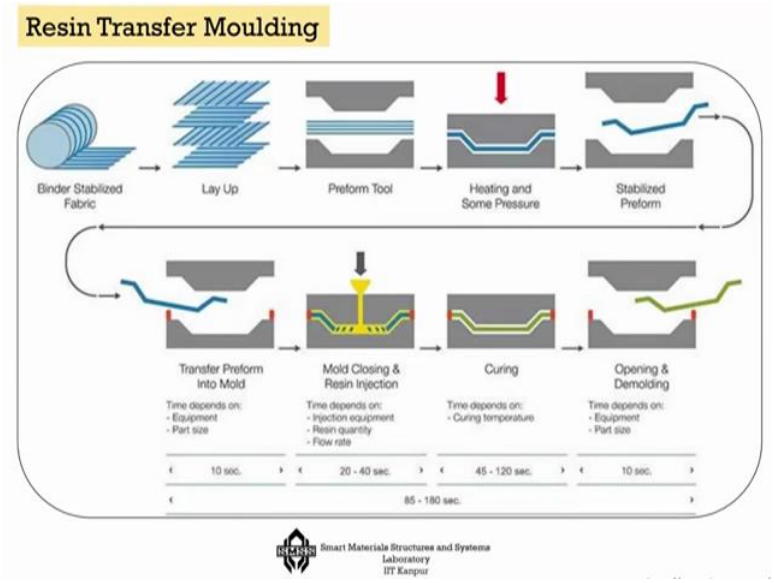

And in this case what we do is that we 1st take the fibres okay in a fabric form, you lay it up so that you actually make it of various angles like this is 0 degree and this is 90 degree, again 90 degree, et cetera. And then once you make all these 0 degree, 90 degree layers, then you put it into the preform tool. And once the preform tool you put it, you get it into the shape you like okay.

And then you stabilize the preform often with the help of temperature and pressure and then you take this preform in the transfer heat it into the mould, where you basically inject the resin into the system, so preform is injected with the resin and then you cure it and after curing you get the complete product that comes out of the system.

So in terms of time, this takes about 10 seconds for the preform to mould, 20 to 40 seconds for mould closing and resin injection, curing is about 45 to 120 and opening and demoulding takes about 10 seconds, so the whole thing takes close to 3 minutes or so, 3 to 5-6 minutes. That is the fastest procedure essentially the Resin transfer moulding. Now there are 2 additional things that one can do with the resin transfer moulding.

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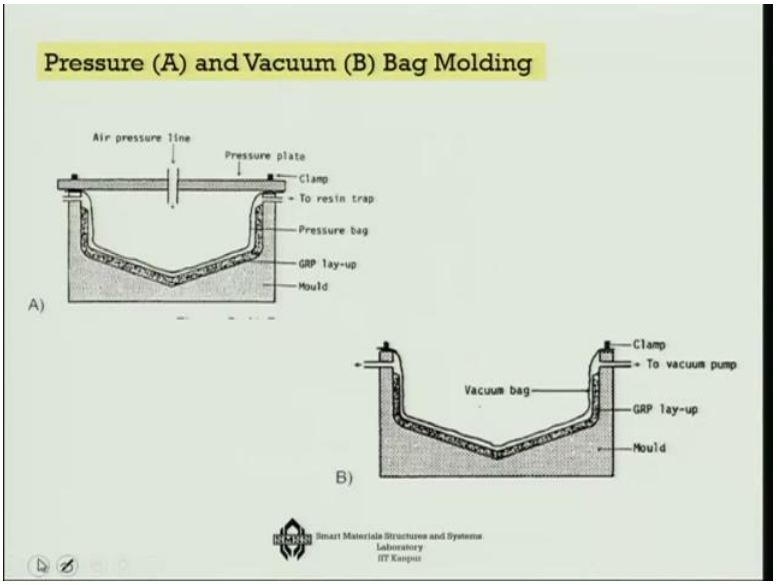

One is Pressure bag moulding; another is the Vacuum bag moulding. In order to improve the fibre volume fraction, suck out the additional resin and make it more compact, you can either use air pressure bagging. So here once you have the mould, you apply the air pressure okay, so you have a pressure plate here, which keeps this whole system into place, apply the air pressure and then there is a resin trap from which the additional resins actually come out of the system.

So inside, so this is your mould, this is the mould system, then you have the glass reinforced plastic layer and then you have the pressure bag, so through the pressure bag you apply the air pressure, so that is the pressure bag moulding. Even better is that instead of applying air pressure from outside, the pressure bag itself, you can make it as a vacuum bagging.

So and then you use vacuum pumps, so that you suck out that vacuum suck out the air, make it vacuum fully and then the outside air itself is going to pressurize it very uniformly, you do not have to pump air into it and then you get a much better finish, which is also known as the Vacuum bag moulding.

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Now I am going to explain you this entire process of making this carbon fibre laminated composite or for that matter any such laminated composite through hand layup technique and with the help of a video and this credit of this video goes to this Remmi team of Finland. So we have taken their video to explain you this whole problem, so let us just look into it how we will be doing this whole thing.

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So as you can actually see in this particular case that 1st of all you are cutting the carbon fibre and of particular shape that you want to do. In this case, they wanted to make a circular shape, but instead of making the whole circular shape they are cutting it into various pieces like 6 to 8 pieces okay and that help can be developed in terms of layers.

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So 1st you cleanup this whole space the so-called mould space and then on that mould so you actually apply some release agent so that it comes out very well and then you start to apply the glue and the carbon fibre. As you can see that carbon fibre here is getting applied and this is like it can be of 2 types, one is that you add only fibre or you add carbon fibres like in the prepreg form that means the carbon fibre is already having glues in it.

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Now once the required number of carbon fibres you have applied, then what they are doing is that they are applying this white film which is the release films, so that it comes out very easily and also the bigger you have to apply so that it gets cured very easily. And then you

have to apply the vacuum bagging, so basically they put the entire thing into the vacuum bagging system, just now we have discussed about the vacuum bagging.

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And you can see that how they have applied the vacuum bagging system and after they have made sit the whole thing, now what we have to do is that they have to make this whole thing in such a manner that they have to take this additional pipelines so that the extra resins, etc can go out. So now they have kept the resin and now they are actually going to take the whole set and they are going to apply this vacuum this thing into it.

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So they are as you can see that they are infusing the part with epoxy resin and you can see that it is gradually that vacuum space is getting actually filled up, the resin is impregnating the carbon fibre and they are getting the entire wing type of a cover system and it is pretty fast actually, so this whole thing has been like in about half an hour to maximum 40 minutes you can actually make it provided the mould and other things are ready.

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So thus they have done it, after this they have to put it for curing so they are just opening up the vacuum bag and taking the whole system out, the carbon fibre reinforced system and then you need to cure it. Now in some cases they put it in auto club where the both the pressure and temperature is applied and in some cases they only apply temperature and cure it.

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And here you can see that the entire product is there, all the things additional that you can do is to chop this into fibres, so that is the way you can actually make carbon fibre reinforced them. So this is where we are going to complete this composite manufacturing and in the next lecture we will learn about Smart Materials overview and types and their need.