Technical Textile
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Lecture - 05
Textile Reinforced Composites

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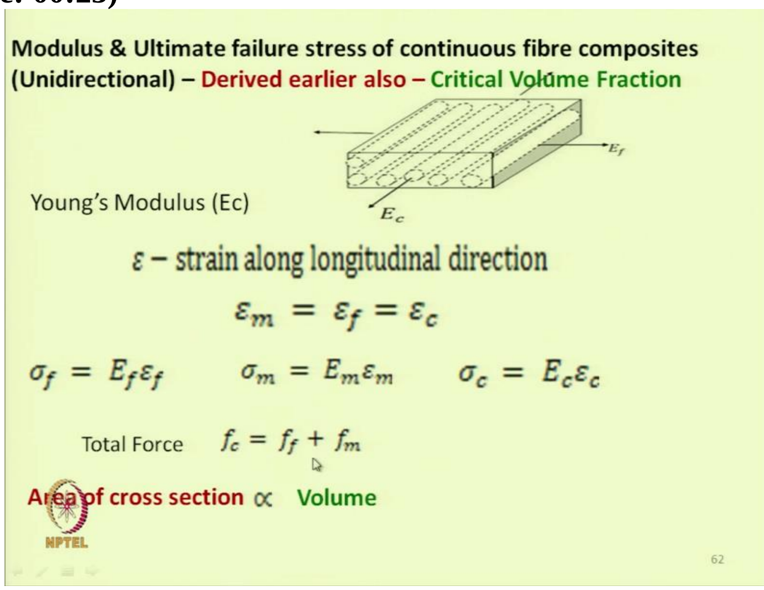

Hello everyone. So we will continue with the textile reinforced composite in last class we have discussed the critical length. And now we will discuss how to calculate the modulus and ultimate failure stress of continuous fibre composite, like unidirectional modulus and ultimate failure stress of composite knowing the stress strain characteristics of both matrix material and the reinforcing material.

Here the assumption is that the fibre are in continuous form and as it is continuous strain along the longitudinal direction for both the matrix and the fibres will be same as that of the composite. So epsilon m is the strain of matrix, epsilon f is strain in fibre and epsilon c is strain in composite. So stress can be measured by multiplying the modulus with the strain. So total force is normally it is an addition of the force on fibre and force on matrix.

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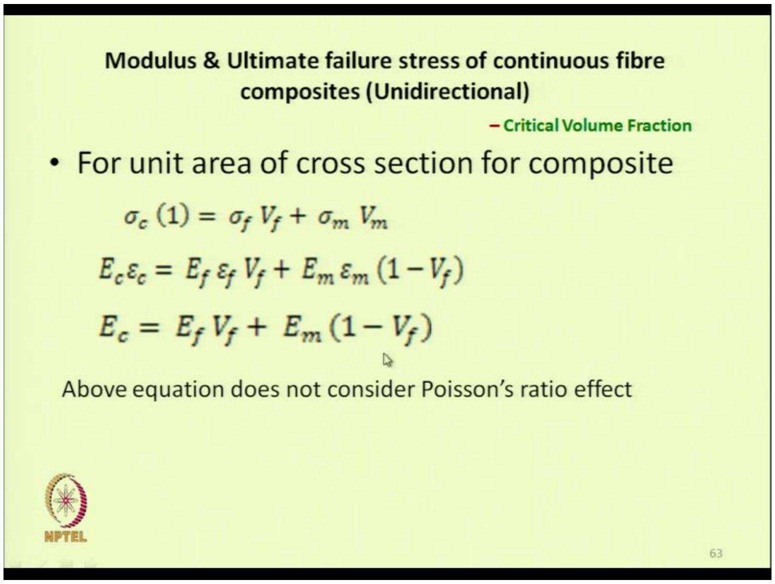

If we know the volume fraction of fibre, we can calculate the required or calculated the stress and calculated modulus of composite. So for unit cross sectional area of composite so stress on composite is equal to stress on fibre plus stress on matrix, if the volume fraction of the fibre is V f and volume fraction of matrix is V m. So the equation is the stress in composite equal to stress in fibre multiplied by volume fraction of fibre plus stress in matrix multiplied by volume fraction of matrix.

Similarly we can get the modulus of composite by multiplying the individual fibre modulus with the volume fraction of fibre and modulus of the matrix with a volume fraction of matrix which is 1 minus volume fraction of fibre here in this equation the Poisson's ratio is not considered.

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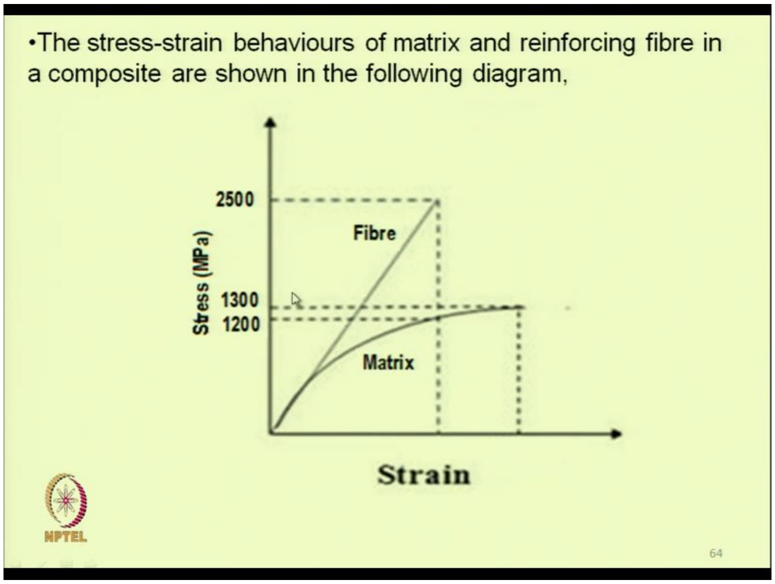

Now we will take the example of 2 situations, one is the composite with the ductile matrix another is with the brittle matrix. So composite as we know the 2 major components one is matrix another is the reinforcing material that is in case of textile waste composite, it is a fibre. Here if we see for example here the 2 stress strain curves are given for fibre and matrix. From this figure we can see the breaking stress of fibre is 2500 megapascal and breaking stress of matrix ultimate stress of matrix is 1300 megapascal as the matrix elongation.

So breaking elongation is higher than the reinforcing materials elongation. So they will not break at the same time while extending, although fibre the reinforcing material is taking maximum load but due to its lower extensibility, so lower breaking elongation fibre will break first. At that time the load on matrix will carry load it is less than the braking stress of the matrix. So that stress on matrix will be 1200. So this is just a typical example how the calculation will be done. 2500 is the ultimate stress of reinforcing material, 1300 is ultimate stress of matrix and 1200 is that the stress carried by the matrix when the fibres are breaking.

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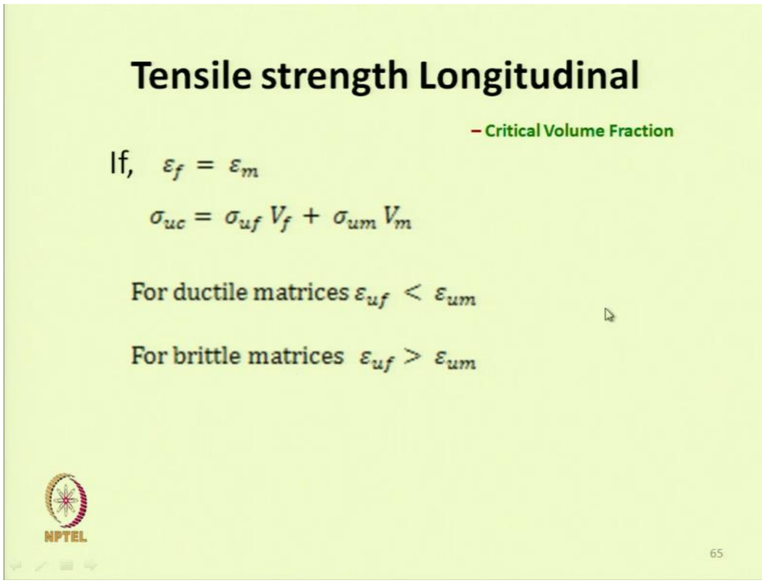

So this is required to calculate the critical volume fraction. So ultimate strength of composite is sigma uc, ultimate stress, which is the addition of the stress by the fibre and stress by the matrix. So we will consider 2 different situations, a ductile material where the ultimate strain of fibre is less than the ultimate strain of matrix. This is the diagram, here matrix is the extension is high, this is ductile composite's figure.

And we can have another composite which is brittle matrix. Typically the brittle matrix are the thermo set matrix where the matrix material, matrix elongation, the strain breaking strain of matrix is less than the breaking strain of the fibre reinforcing material.

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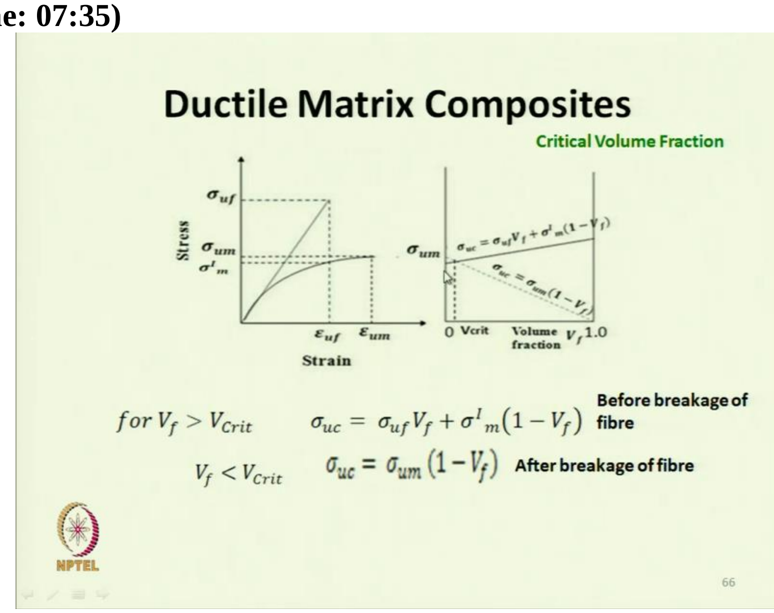

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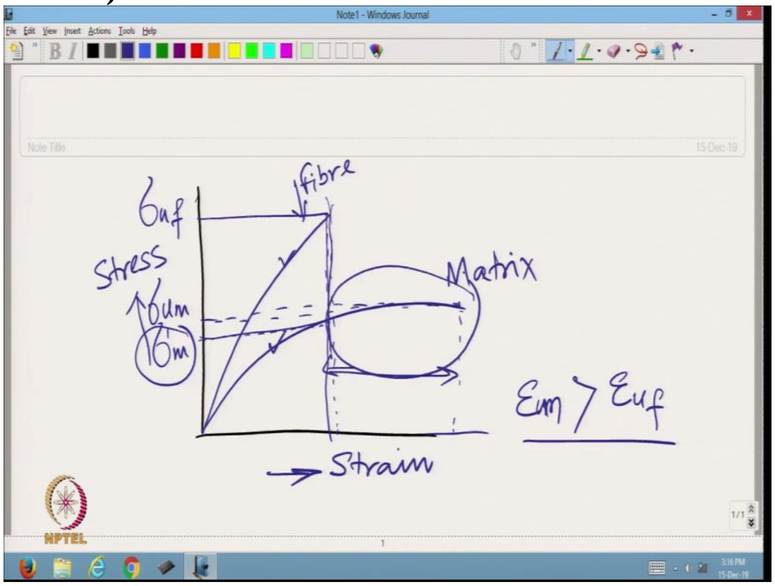

Now for ductile material if we see here as per this picture this is the stress strain curve of fibre which is reinforcing material. And here is the matrix. The ultimate strain of matrix is more than ultimate strain of fibre. That is why it is called ductile matrix. This is the stress of ultimate stress of fibre and this is the ultimate stress of matrix and here sigma dash m. Sigma dash m is the stress on matrix when the fibres are breaking the matrix is having higher breaking strain.

So in this condition we will consider 2 different situations. In situation 1 before the fibres are breaking, the load will be carried by both the fibre and the matrix. But after the fibres are breaking during this stage when fibres have broken the load will be transferred to only on the matrix. So let us see the situation before the breakage of fibres because fibre will break fast. In that case ultimate stress of composite is given by the ultimate stress of fibre because fibres are breaking ultimate stress of fibre multiplied by volume fraction of fibre plus this is the stress carried by the fibre.

And at that point the stress shared by the matrix is sigma f sigma dash m. That time multiplied volume fraction of matrix, in this situation is before the breakage of the fibre. So both fibre and matrix they are carrying their load but after the fibres are broken, so all the fibres are broken. So after breakage of fibre the load is shared by only the matrix. So then ultimate stress of composite will be the multiplication of ultimate stress of matrix and the volume fraction.

The plot here is that with volume fraction of fibre at starting point in X axis at the starting point the volume fraction of fibre is 0. And its maximum volume fraction of fibre is 1. So when volume fraction of fibre is 0, that means V f is 0, with ultimate stress by this composite is it will be equal to sigma dash m, which is the starting point the solid line this way. So at 0 we will get a point. This is the point equal to it is a sigma dash m is a starting point.

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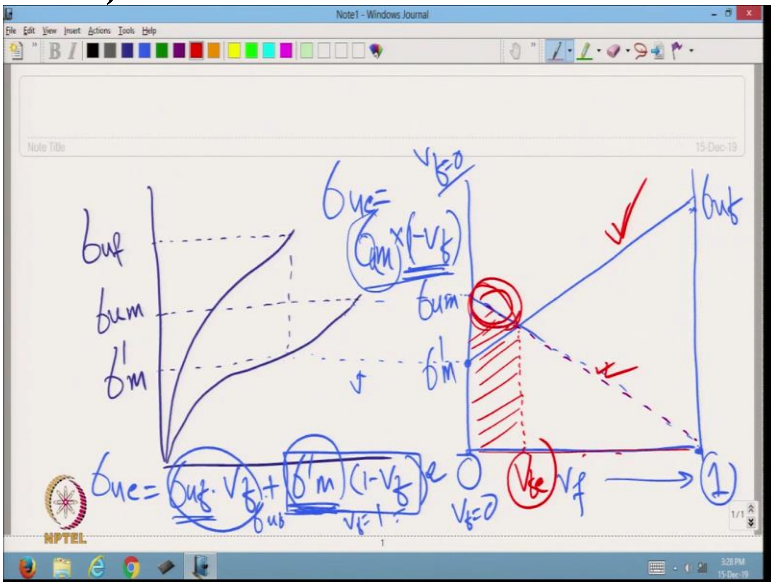

This is matrix and here in this situation if we draw the ultimate stress of composite versus the volume fraction this is volume fraction of fibre. At this point the volume fraction is 0. Here volume fraction is 1. So here volume fraction is 0. So at volume fraction 0 as per this equation, let me draw the equation, composite, because when the fibres are breaking the matrix is carrying sigma dash m, here if we put the V f = 0 so this will become 0 at 0 volume fraction.

And this will become 0. So it will be effectively sigma dash m. So before fibres are breaking when this equation is followed, so this is m. At 100% fibre, volume fraction is 1. So if you put the V f = 1 here V f = 1 then what will happen? This segment this section will be 0 because 1 – 1 = 0, this will become is 1. So this is the point. So if we join we will get a plot which shows the ultimate stress of composite when the fibres are not broken.

So when the both the composite that reinforcing material and fibres they are carrying load but in case when the reinforcing materials they have been broken in that case the ultimate stress of composite will be equal to ultimate stress of matrix multiplied by volume fraction of matrix that is 1 - V f here if we see at volume fraction of 0. So V f if we put V f 0 then this will become sigma m. So this is um, this will become sigma um you will.

So this is equal to this point and for 100% volume fraction when there is no, theoretical there is no matrix, 100% fibres are there so this value becomes 0. So this total ultimate stress will become 0. So we can if we join so you can join with different colors, so this curve is showing the ultimate stress before the breakage of fibre when both matrix and fibres are taking load but this curve is showing the condition where matrix only taking the load.

So if we see that at this joining point, this intersecting point, the volume fraction it is known as critical volume fraction of fibre, this is the critical volume fraction of fibre. So V critical, so this is the joining point. So before the fibres which we use, if it is less than the critical volume fraction fibre volume fraction less than the critical volume fraction then this equation will follow and if it is more than critical volume fraction then this equation will be dominating.

So we must use the fibre volume fraction more than the critical value fraction then only we will get the assistance of the reinforcing material. So from here we can calculate the critical volume fraction. So if it is less than critical volume fraction if we use the fibres smaller quantity fibre then we will see ultimate stress of composite will be dominated by the matrix only, not the fibre.

Because you can see here so at lower level, in these zone in this zone the matrix the composite stress will be higher because the stress of composite at any point along the X axis at any level of volume fraction will be the point where among these 2 equations 2 curves whichever is higher. So if the volume fraction is less than the fibre volume fraction sorry the critical volume fraction then this equation is dominating.

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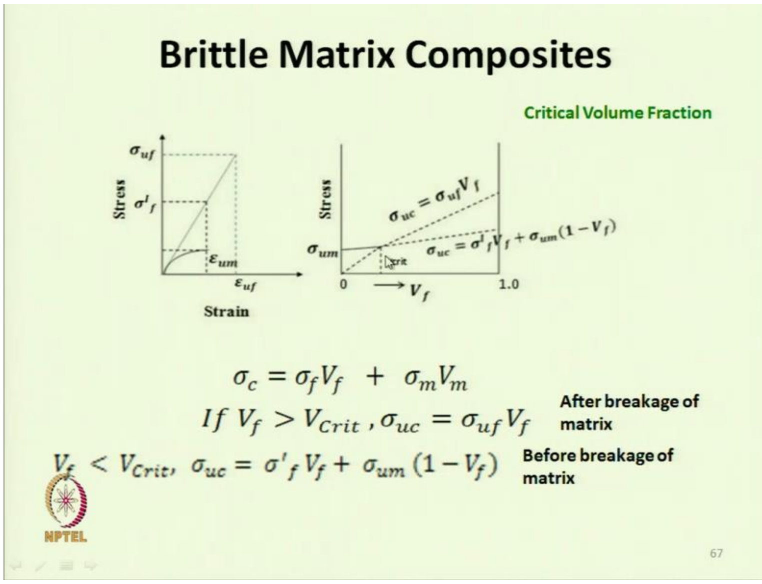

Similarly for brittle matrix the treatment will be in a similar way. The matrix is brittle. So both are stress breaking stress and breaking strain are less than the fibre. Fibre breaking stress here ultimate stress again it is at this point matrix breaking stress is at this point here and during the breakage of matrix the load carried by a fibre is sigma dash f and similarly we can get this graph where it shows that for brittle matrix,

If the volume fraction is more than the critical volume fraction then majority of the stress will carried by the fibre which is strong enough which is reinforcing material. So ultimate stress will follow this equation that is the stress of fibre. So it is ultimate stress of fibre multiplied by volume fraction that will be the ultimate stress of composite. So from these 2 figures we can calculate the volume fraction of both brittle matrix composite and for ductile matrix composite.

Here we can see the volume fractions selection is extremely important. We should know the volume fraction and accordingly we have to decide the fibre volume fraction. So critical volume fraction is important. So based on critical volume fraction we should decide the proportion of fibre, the fibre volume fraction, it should be more than the critical volume fraction.

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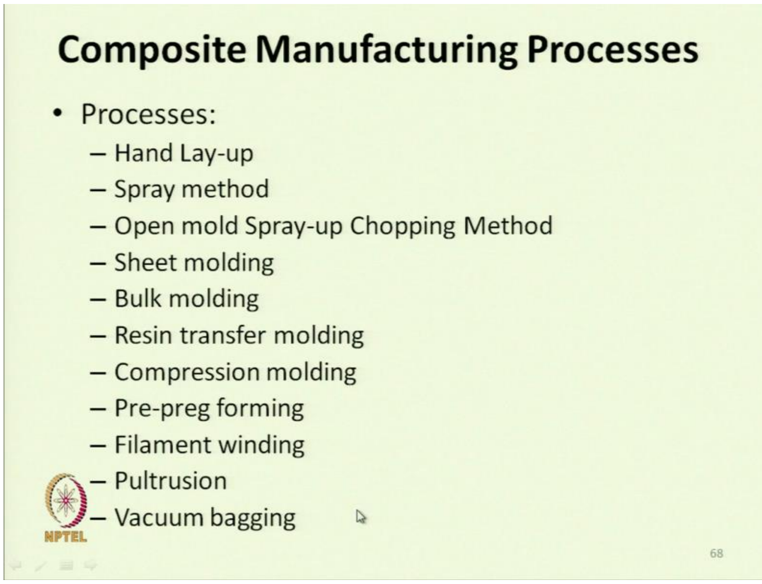

Now we will discuss here the composite manufacturing processes. There are different processes available most of the commercial process we will see at existing process they are based on the thermoset matrix. And obvious reason is that thermoset matrix is the viscosity is less. That is why in most of the existing manufacturing process, it is based on thermo set matrix. And thermoplastic matrix for composite making from thermoplastic matrix it is very difficult.

For that we need specialized system and those processes where we can use the thermoplastic polymer as matrix material in a composite we will discuss in next class. Here we will discuss all the manufacturing processes based on the thermo set matrix. First processes the hand layup process. As the name implies that hand layup means it is manually we have to mix the matrix with the reinforcing material.

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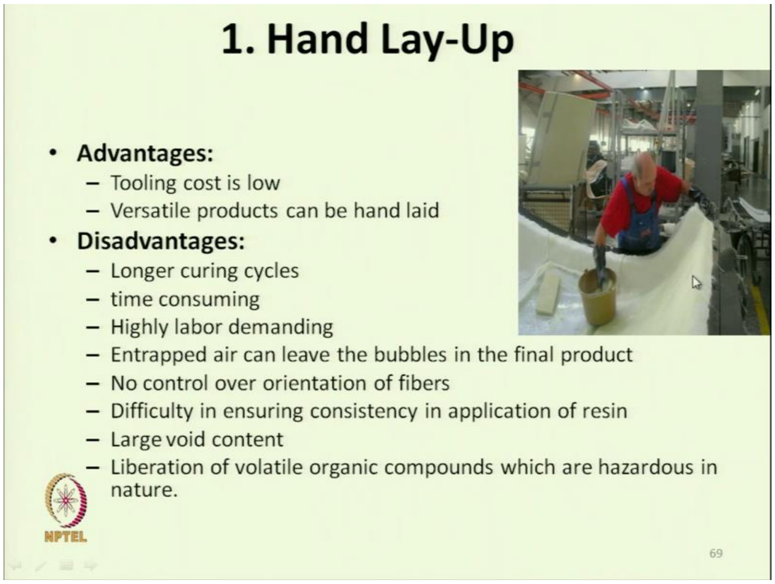

Here we can see here the person is laying up the thermo set matrix which is with low viscosity. There is a frame are which that this is the glass fabric and the fabric is laid on this frame and the matrix is laid on the poured on this glass fabric and the matrix penetrates into the glass structure and forms the composite. Here the resins they are laying up and after doing that manually they will press it by some rollers, so that proper penetration of matrix takes place.

As you can see from here the tooling cost is low, where there is no specialized machinery required. Versatile products can be hand laid, this is hand laying. So any sorts of products can be made because we have to only lay the reinforcing fabric and pour the matrix thermoplastic matrix. The main disadvantage of this process is that long curing cycle, we have to allow time to get the matrix solidified.

So it is time consuming high labor demanding, because we need large number of manual labor, because here we have to we are pouring the matrix and by hand we are trying to penetrate that matrix material. There are chances of the air bubbles in the final product. No control over orientation of fibres if we try to use the loose fibres then we do not have any control. But in this picture we are we can see it is glass nonwoven fabrics are used.

So it is difficult in ensuring consistency in application of resin because it is manually done. So the resin concentration at different places may be different. Large void content be due to the air bubbles which affect the quality of the matrix. And most important is that it is not covered. So liberation of volatile organic compound which may be harmful for human health the chances of this human health hazard is there. But the advantage is that it is a simple process.

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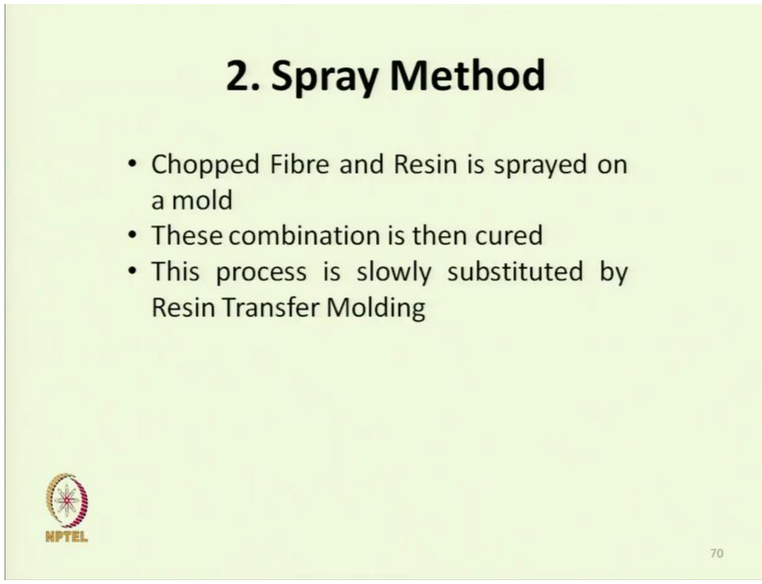

Next method is that spray method. Here instead of hand spray hand laying we spray with the help of spray gun both the chopped fibre and resin.

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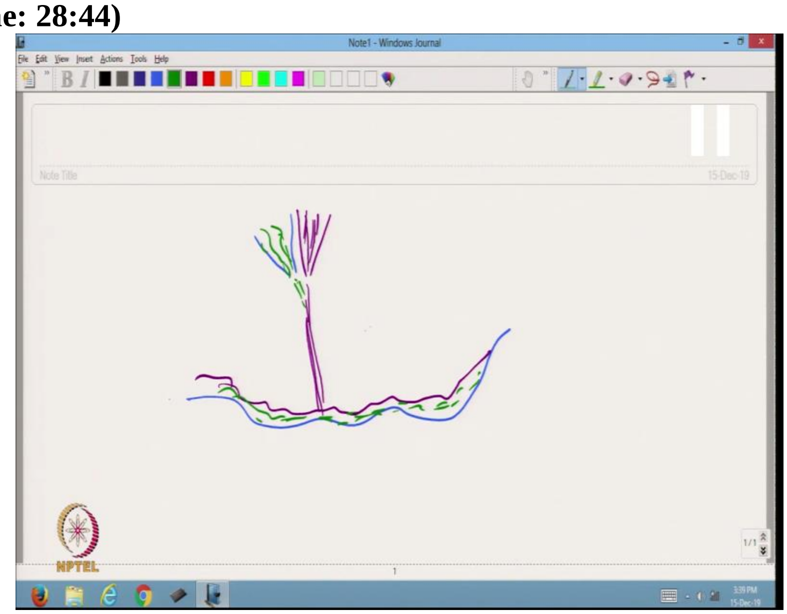

So we can see here from the, suppose this is the shape we want and we are trying. This is 1 spray gun and the chopped fibres are these are the chopped fibres are coming and we can use spray of the resin. So these are laying here and that can be laid and we can form the composite. So this type of composite formation is there. So the composite manufacturing process is known as spraying method where chopped fibre and resin is sprayed on a mold.

This combination is then cured this process is slowly substituted by the resin transfer molding. So because of the obvious reason here the chances of the air bubbles are there, void content is high. So in RTM, Resin Transfer Molding, the chances of white content is less but still due to its simplicity due to its flexibility we still use this spray method.

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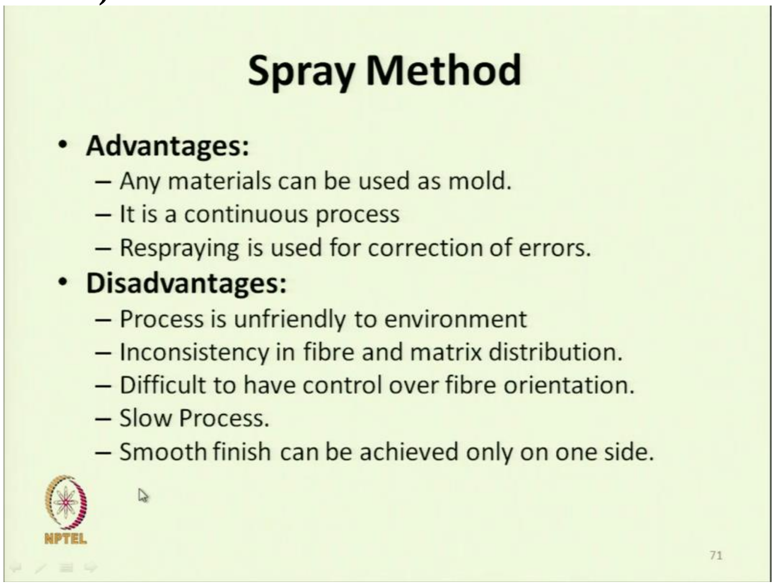

So the main advantage of this method is that any material can be used as mold. So we can have very complex molds shape. It is a continuous process not like hand laying method. This is a continuous process because the spray gun it can run continuously and in case of any correction required, so in case of any void content or any uneven thickness this spraying can be done to correct any error.

The disadvantages are that it processes unfriendly to environment as we have seen in the hand laying method, because the volatile material can get evaporated and mix with the environmental air. Inconsistency in fibre and matrix distribution because they are indirectly laid the mixing is done indirectly through spraying methods. So there is a chance of inconsistency. Fibre orientation it is not being controlled we cannot control whatever fibre laying are there.

So if we want unidirectional orientation it is not possible because fibres are deposited with the help of spraying gun. So that is why we cannot control. It is a slow process. Here we can see that if we want the smooth finish in both the sides it is not possible only the side where the mold is there the smooth finish is there but other side it is randomly deposited. So there will be some randomness in the surface.

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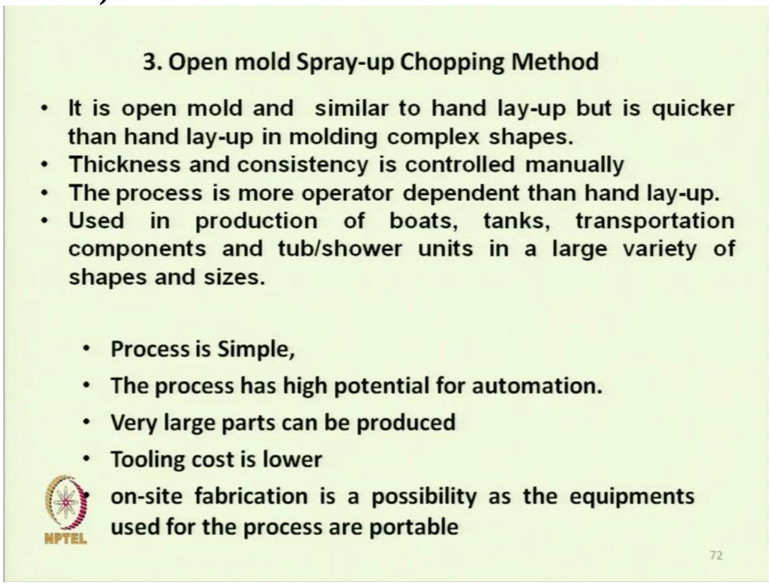

Next method is open mold spray up chopping method where the roving or fibres are chopped first and then mixed with the matrix material. It is a similar to the hand layer but it is a quicker method and we can develop a complex shape of composite. Thickness and consistency is controlled manually. Here the process is more operated operator dependent than hand layup because here the operator has to control both chopping and the spraying.

So these are used for production of boats, tanks, transportation components. So the main advantages are the process is simple, the process is high potential to automation, very large parts can be produced, tooling cost is lower. On site fabrication, that is more important, so in on site fabrication so if we want to fabricate some composite on site that we can do by using open mold spray up chopping method. So here we can see here.

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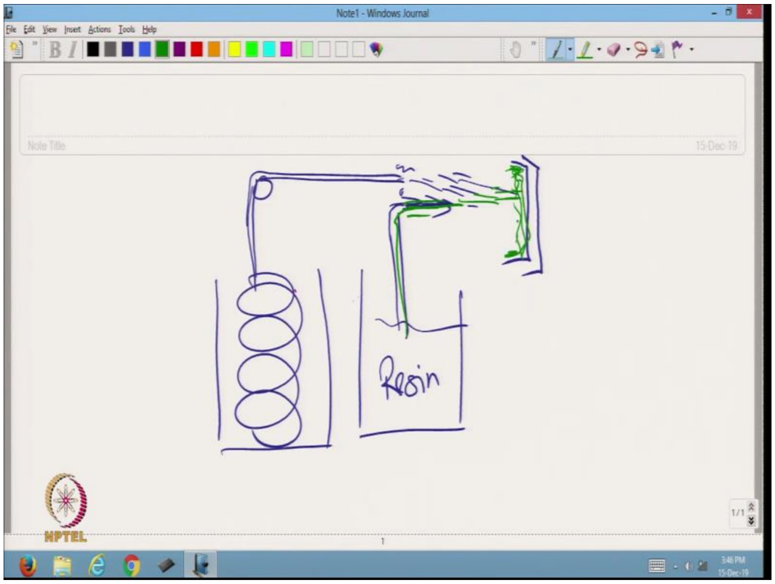

And suppose roving this is roving package, this glass roving or anything, here there will be chopping. This chopped and then this is a resin and this resin here pumped, with the help of pump and there will be a spray gun. And then there is a mold, this is mold and suppose this is resin material and they will be mixed here and it will be formed the composite will form here.

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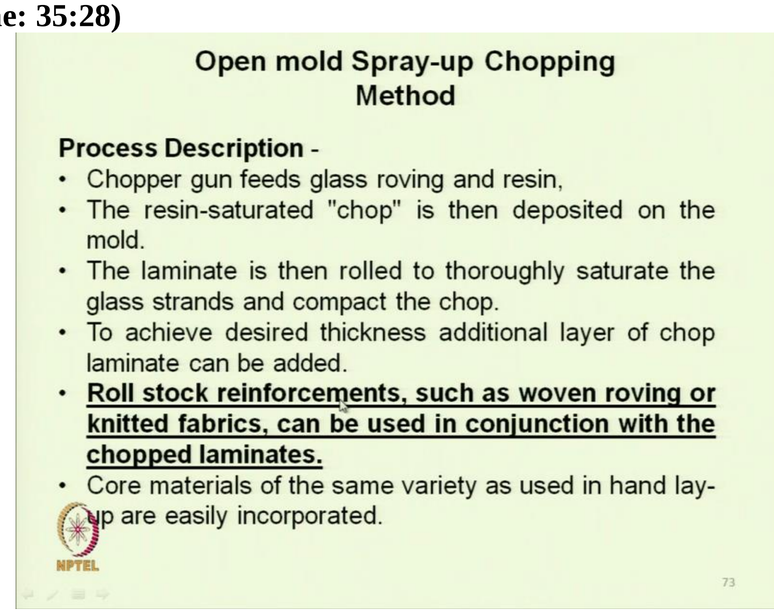

So the chopper gun feeds glass roving and the resin saturated this chopped glass is then deposited on the mold. The laminate is then rolled to thoroughly saturated glass strands and compact the chop so that there will be one roller which will compact the matrix and the glass fibre. To achieve the desired thickness additional layer of chopped laminate can be added. So you can keep on adding to have required the thickness.

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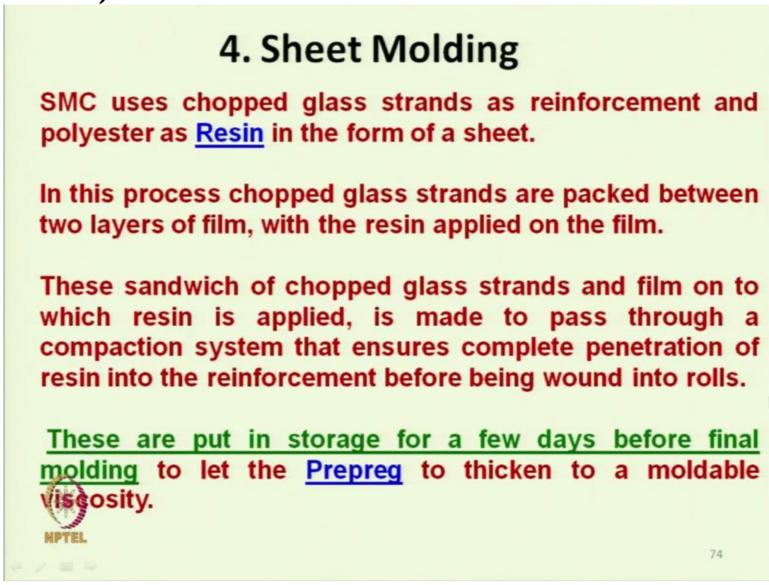

Next is the sheet molding. Sheet mold composite uses the chopped glass strands as reinforcement and polyester as resin, in the form of a sheet. So where we will get a sheet so in between the 2 sheets that is the protecting sheets. The chopped glass fibre and polyester resins are placed in this process chopped glass strand are packed between 2 layers of film. So 2 films will be there, these films are used just to separate the layers.

This sandwich of chopped glass strands and film on which the resin is applied is made to pass through a compacting system, that ensured the complete penetration of resin into the reinforcement. Now let us see there will be typically 2 films now this is one.

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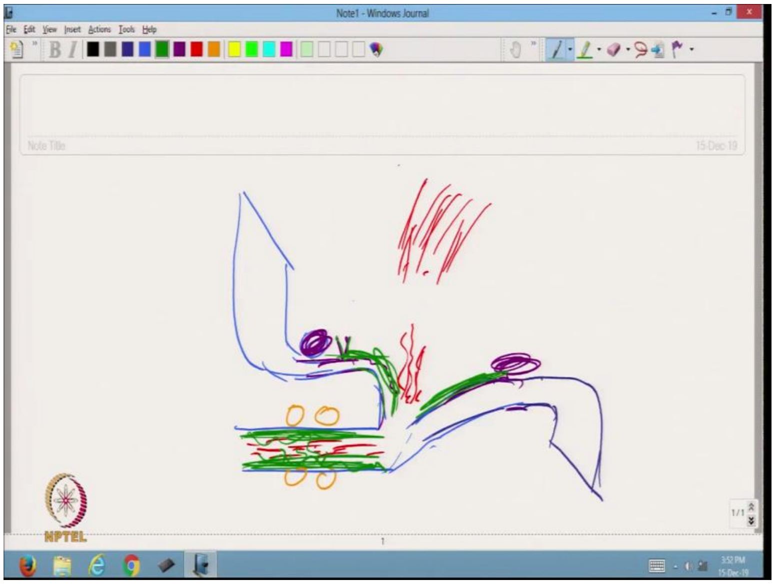

This is one film is coming. Now here we are applying some resin, one side this is resin is applied in the side and some knife will be their doctors knife which will control the resin thickness and another it is coming here the resin and this side it is resin side. Another film, suppose this, I am drawing the dark blue color this is another film is coming where again the resin is being applied on other side.

And in between 2 layers. So this is so this is resin here this side is resin impregnated. Now in between these 2 there is a glass, these are the glass rovings, and this glass rovings are chopped here and then mixed here. So ultimately what is happening there will be one layer at the top of this layer and this layer at the bottom. This is impregnated with resin this side, this side is impregnated with resin and in between there will be glass. This is one prepreg.

And then they are passed through the roller under pressure, they will get compacted the resin will penetrate inside the glass they will get mixed and till this time the resin viscous form. Before it gets solidified, we can form a role and keep it under cold condition when we require to form the composite we can take it out and solidify depending on our requirement. So these are put in storage for a few days before final molding to let the prepreg thickness it will get gradually to thicken because with the time it the viscosity of the resin will increase.

And then gradually it will solidify. The films function is that to separate 2 layers when we wrote form roll they will not get stick to that to each other.

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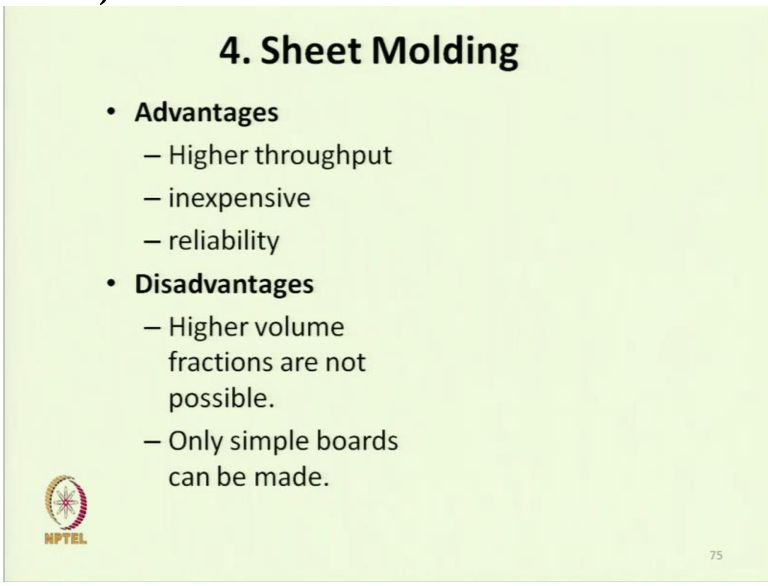

So the advantages are high throughput, inexpensive, and the process is reliable because we can get sufficient uniformity. Main disadvantage is that high volume fractions are not possible because of the fact that the proper penetration is required. And that is why if we use high volume fracture high volume fraction of fibre then proper impregnation will not be possible. Another disadvantage is that we cannot as the processes we cannot form any complex shape. Here a plain sheet or plain board can be made in this process because it is a sheet form. Third processes is that makes processes the bulk molding.

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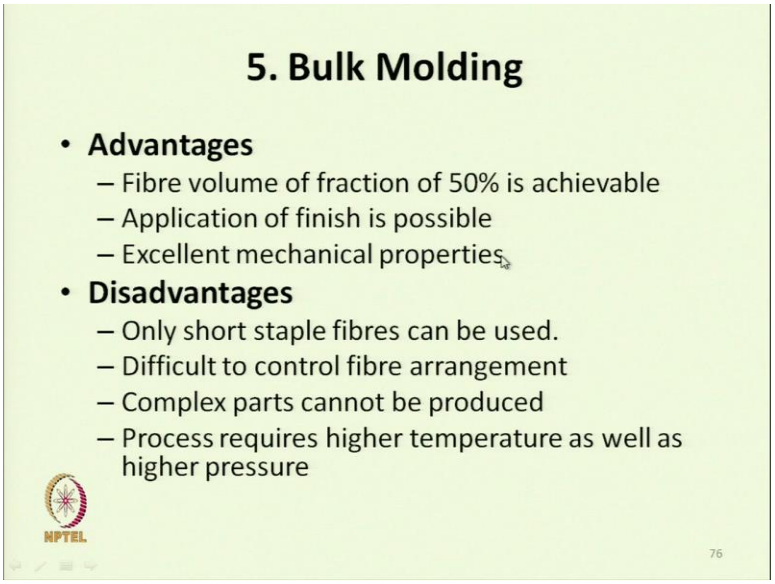

Here the fibre volume fraction of 50% can be achieved. We can have finished application; excellent mechanical properties can be achieved. The system is very simple here and this in this system we have to use the chopped fibre of the smaller length the chopped fibres.

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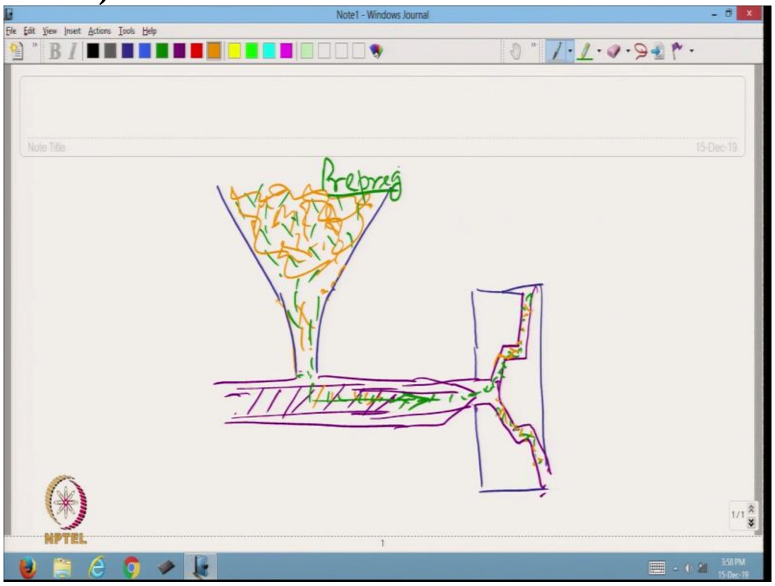

And matrix that prepreg these are the fibres and the matrix material they are mixed together and they are fed through the hopper this is a prepreg and there is a screw arrangement. This is a screw arrangement. With the rotation of screw this prepreg will be pushed in one direction and there is a mold, this is a mold of a known shape this is a mold where if we want a particular shape suppose we need a particular shape this type of material if we need we can, so this is a shape we final shape we are required.

So here due to the screw arrangement this prepreg will be pumped inside the mold and ultimately this will form the composite, required composite and here the chopped fibres and the resins are mixed. Only shorts stable fibres can be used, as already been mentioned. So continuous filament or long fibres we cannot use because long fibre if you try to use, so even staple fibre it is a longer fibre length then proper mixing is not possible.

So fibre arrangement cannot be controlled, complex parts cannot be manufactured and this process requires high temperature as well as high pressure. Because here we have to apply high pressure in this method bulk molding method we can use the thermoplastic matrix also in the form of powder. So for that high temperature is required in the mold. Next system is the resin transfer molding.

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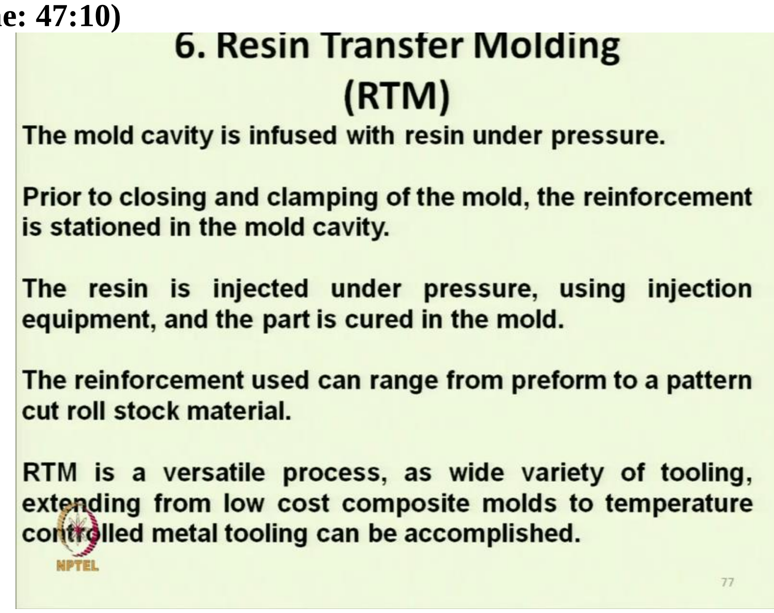

Here there will be a mold cavity and into the cavity of the mold the resin is infused at high pressure.

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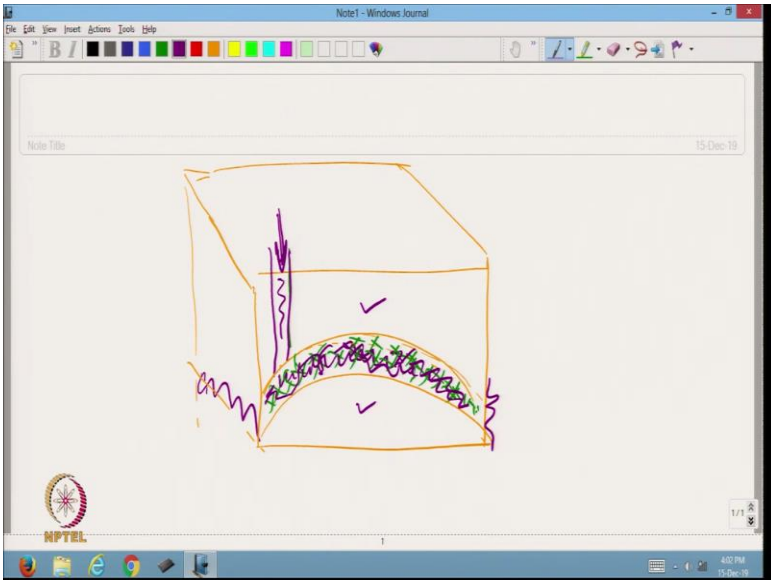

This is the mold, this is one side of mold, suppose you want hemispherical or curve shaped matrix, curve shape composite this is the shape here inside we have the reinforcing material, it may be textile fabric also, nonwoven and there will be one opening for resin injection, resin is injected here at high pressure and from the side there will be sealing and everything will be there and resin is injected at high pressure.

And in this system only thermoset resin can be used due to its low viscosity they will penetrate into the inside the structure of the textile material and after curing this molds, this is the one side of mold this is a male mold if you say it is a female mold, so after that we can remove the mold to get the composite. So prior to closing and clamping of the mold the reinforcement is stationed in the mold cavity, so that mold cavity reinforcement is already placed there.

So resin is injected under pressure. So we need high pressure for higher viscosity resin, pressure can be controlled here and after that the part is cured. The reinforcement used can range from preform to a pattern cut roll stock material. So it is a versatile process. The cost is cost of composite manufacturing is low here.

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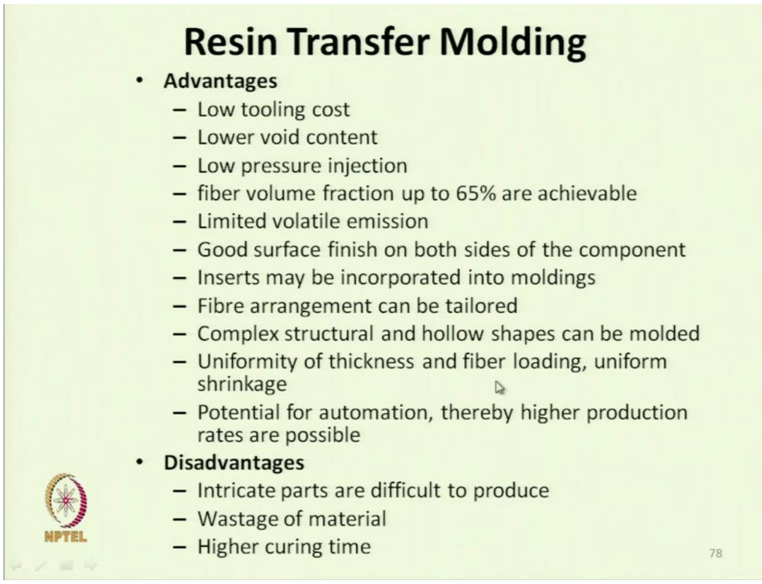

So low tooling cost, low void content because the composite that the matrix can be injected at high pressure. So void content is low, low pressure injection. So for low, very low viscose material. So injection pressure is required low pressure, so high volume fraction can be achieved. So as high as 65% volume fraction can be achieved, so limited volatile emission, that is important, than hand layout or open mold system.

So this is the volatile emissions were there. So RTM is environment friendly. Here good surface finish can be achieved on both the sides because both the sides are covered. There are other advantages. So complex structure can be produced, even hollow shape can be produced, if we can manufacture the mold. The main disadvantage is that the intricate parts are difficult to produce. So simple shape hollow and other shape, simple shapes can be produced, if we try to produce an intricate part. So this method is not suitable.

So material wastage sometime takes place due to the leakage and higher curing time is required. These are the disadvantages some.

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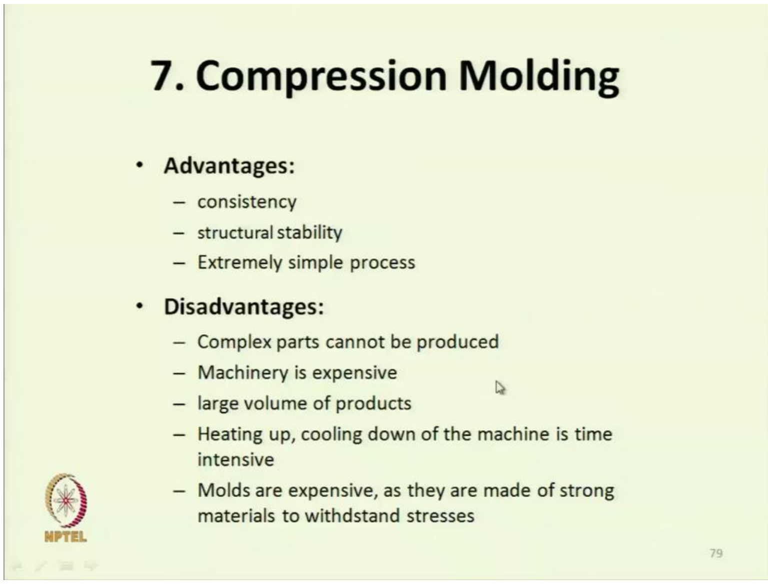

And compression molding is basically it is a simple technique but in compression modeling normally we use the thermoplastic matrix. The main advantages are its consistency.

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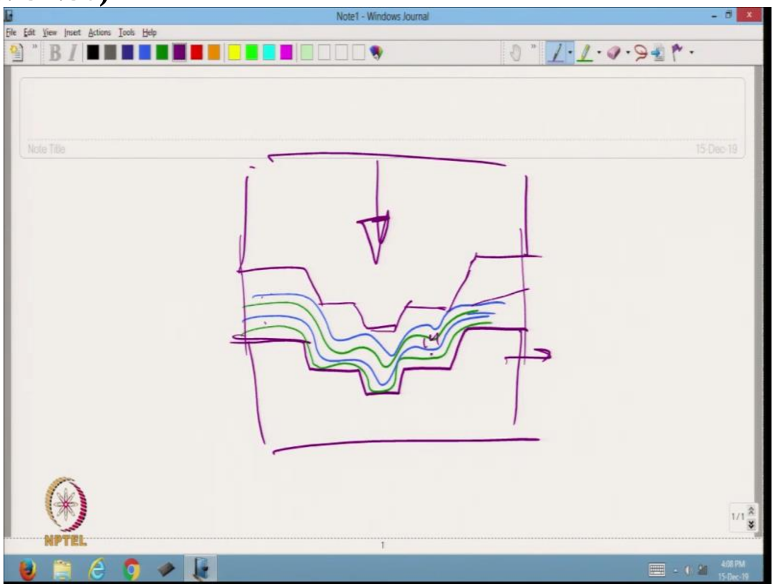

Hear the system is that there is a mold. So we can have a mold of any shape. This is a mold and at the top there will be another mold. So after that we can lay the reinforcing material along with the, this is the see one layer of matrix, this is reinforcing material, then we can put another layer of matrix, another layer of reinforcing material. So we can do many combinations and at the top there will be the other part of the mold.

This is a base mold and under high pressure this is pressed and then the heater is on, this is basically these are the heaters there will be heat. So at high temperature this thermoplastic matrix they melt and mix up with the, penetrate inside the reinforcement structure. So it is a very expensive because mold cost is very high. Heating up and cooling down of the machine is time consuming. As I have mentioned molds are expensive but the system is very simple.

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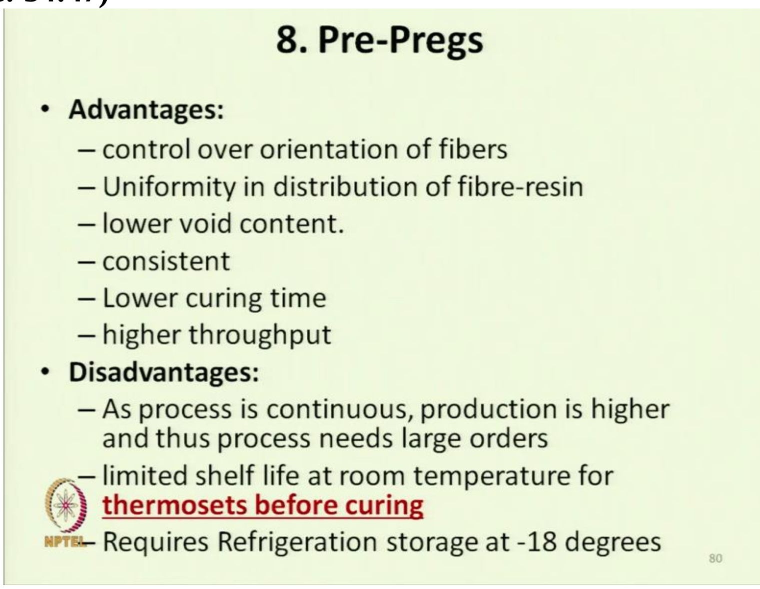

Next process is the Pre-Pregs manufacturing method in the Pre-Pregs the reinforcing fibres are impregnated inside the resin that mainly thermoset resin and then they are rolled but before rolling from both sides 2 layers of the separating films are there.

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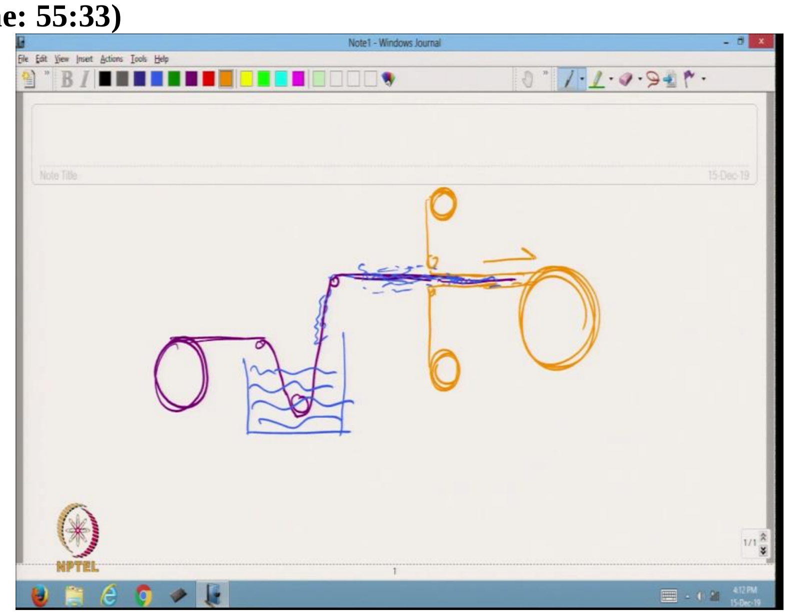

Suppose this is a reinforcing fibre or we can take the fabric as well. Now this reinforcing material is passed through resin. So they are they are getting impregnated with the resin. So this is the Pre-Pregs and this Pre-Pregs we have to maintain we have to this resin impregnated fabric and this Pre-Pregs we have to form a role but we cannot form role because they will get the next layer will stick to the previous layer for that the system here is that the separating film role, is a separating film.

From both the side there will be 2 separating films. So these films then and here in between there will be Pre-Pregs, this is Pre-Pregs and then we can form role of this a forming role and this films are separating film. So here control over orientation of fibres are there, which is very important. We can use filament. So continuous filament sheet we can use we can use woven fabric we can use nonwoven fabric as the reinforcing material here. Uniform distribution of fibre and resin is there because the reinforcing material is dipped into the resin.

So resin that it will be uniform, low void content, completely immersed because the reinforcing material is completely immersed inside the resin, it is consistent, low curing time, high throughput, because this is continuous process. The main disadvantages are, as the process is continuous the production will be high. So large order is required otherwise this is not suitable for the batch wise production it is a continuous production.

And at the same time if we produce large quantity with a thermoset resin, if we keep for a long time, then this will get solidifies. So we have to use this Pre-Pregs before it gets solidified and otherwise we can keep it under refrigerated condition for temperature is around - 80 degrees Celsius. So that adds to the cost. So if we keep at room temperature this Pre-Pregs will get solidified and that will not be useful.

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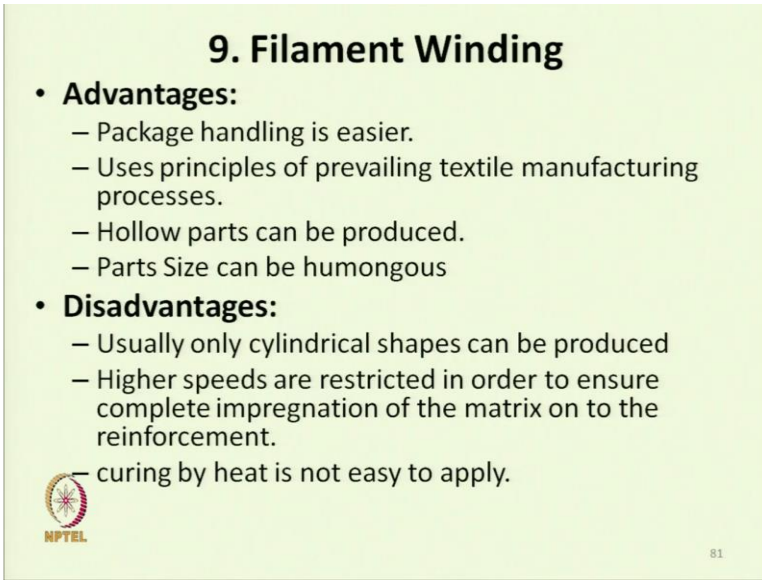

Next is the filament winding technique. It is a simple technique where the filaments are wound on the one cylindrical shaped package and before winding this filaments are passed through the resin.

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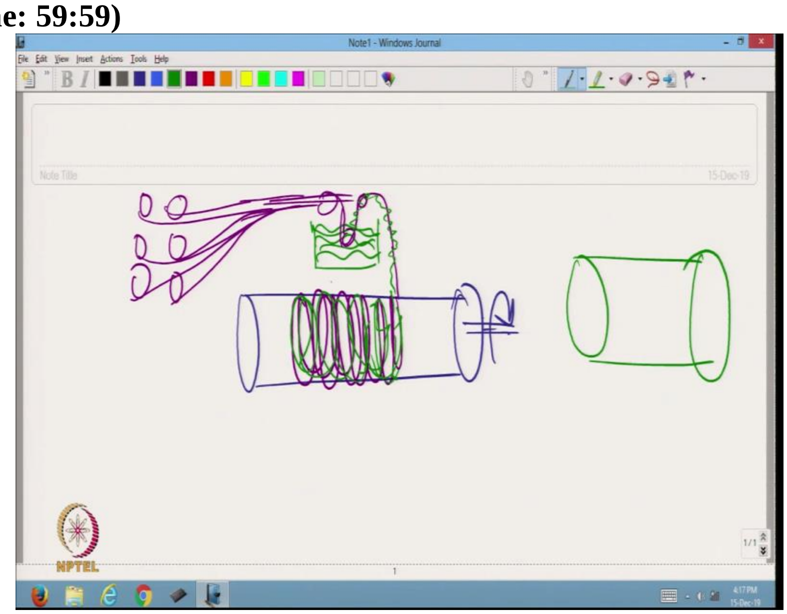

This is the cylinder and which we can, which is rotates rotating cylinder. Now the packages are there, the reinforcing materials packages are there and these are the number of packages we can take. These filaments are coming and then they are processed through the, immersed through the reinforcing material. They are like it is a resin and this resin immersed. This resin immersed filaments are thin wound on the cylinder.

There is the resin immersed the filament along with the resin they are winding on this package, this cylinder and here after winding they get automatically solidifies because the resin is thermoset resin and after solidification we can take out from the package, this base cylinder. So this and this will ultimately form a cylindrical shape composite, this composite will be hollow cylindrical shape.

So if once we take out after solidification and there will be one traversing mechanism depending on our, the shape required or depending on the thickness required, we can change the traversing speed. So here the in textile manufacturing process can be used, normal winding process can be used here. Only hollow parts can be produced here, we cannot produce any other part. So main disadvantage is the only cylindrical shape can be produced here.

So high speeds is not possible because the matrix has to be that reinforcing material has to be impregnated with the matrix properly. Curing by heat is not easy to apply because from inside there will be that base cylinder on which the filaments are winding. So heat application is not that easy. So curing time will be very high.

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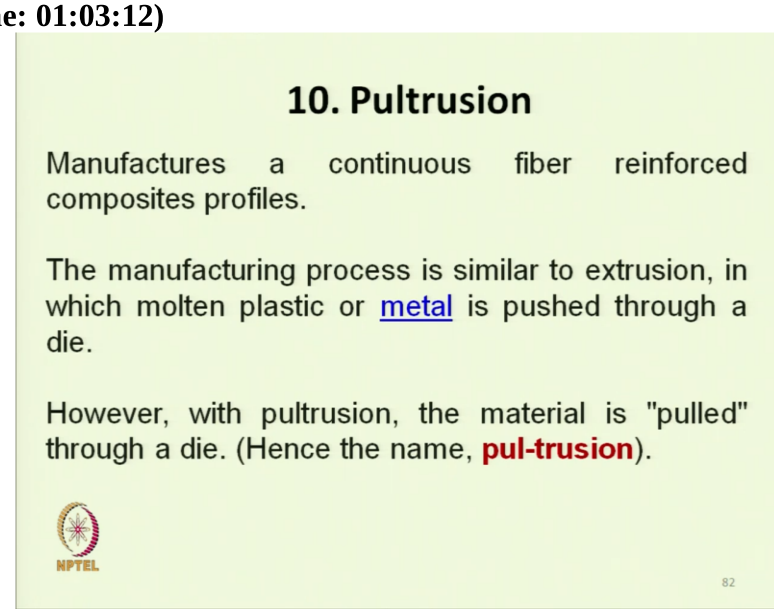

Next method of manufacturing, which is simple one, which is known as pultrusion. Here in this case only continuous filaments can be produced. So continuous filament as reinforcing composites are produced, like they are one that is the filament winding technique. The pultrusion the term came from the pull and extrusion. So here the material is pulled through the die, that the resin impregnated filaments are pulled through die to form the composite. The shape of the or cross section of the composite is controlled by the shape of die. First the there will be large number of filament packages.

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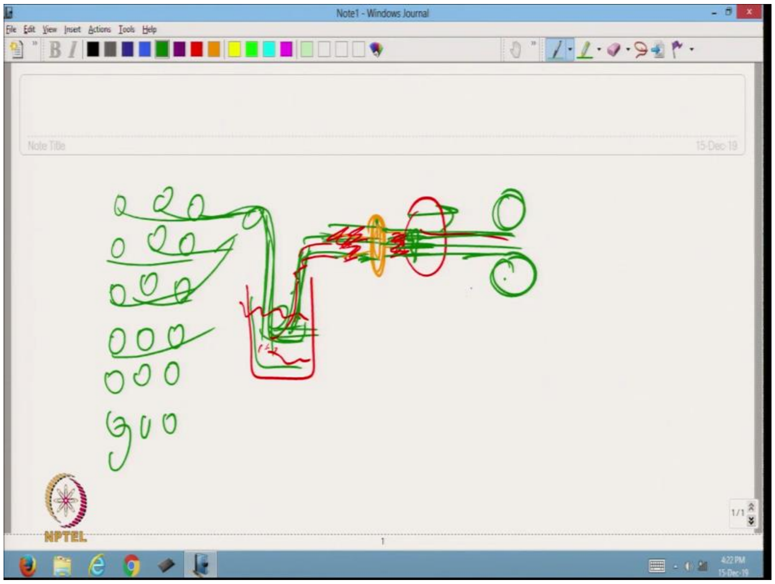

So these are the filaments depending on the requirement, so this filaments are then taken together so to form our thick tow, then they are immersed into the resin. The resins are there here and then this thick filament immersed with resin, there will be one die, this is the die shape, they will be pulled through this. So this is the die shape and this filaments will then be pulled through this die to form a required shape of composite.

So this is reinforcing material, shown in red. So we will get the composite but here we need one pulling arrangement. So maybe roller pulling or maybe other type pulling, we have to pull the reinforcing material through the die. So continuous fibre reinforced composite is produced here. So the manufacturing process is similar to extrusion in which molten plastic or metal is pushed through the die but here the reinforcing fibre, filament, along with the resin will be pulled through the die.

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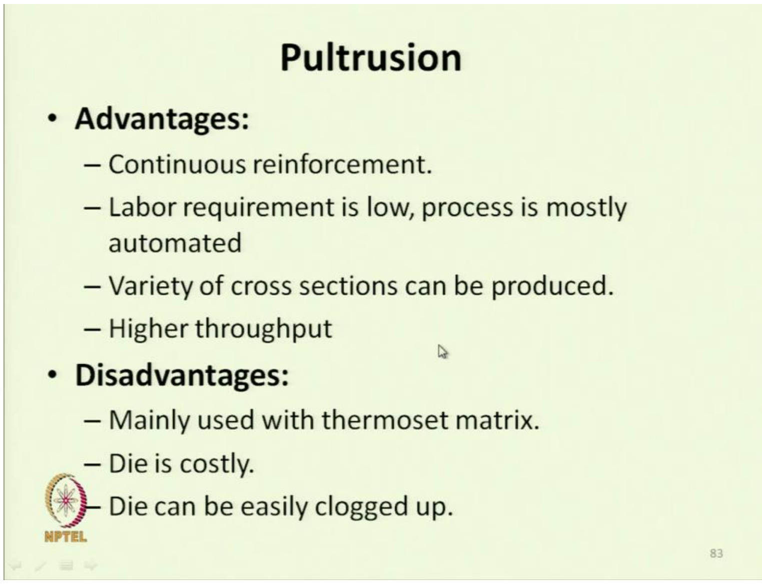

So the main advantages are the continuous reinforcement, the labor requirement is low because the moving parts are less. The process is mostly automated variety of cross sections can be produced depending on the shape of the die, high throughput, the productivity is high. The main disadvantage is that here mainly thermoset matrix can be used as I have already mentioned, die cost is very high and another point is that die can be easily clogged. Because the composite the matrix thermo set matrix deposition may be there in the die, so it can be clogged easily so we must take care of cleaning it frequently.

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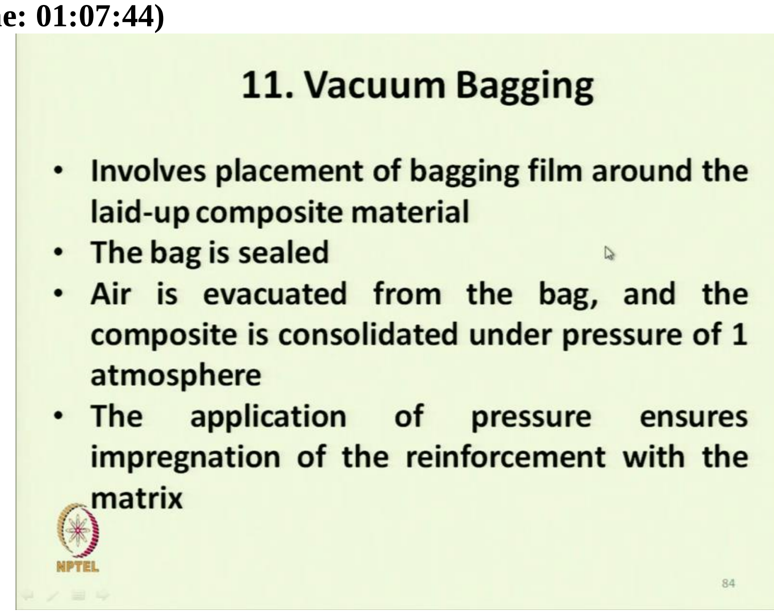

And the last method is the vacuum bagging method. In this system we do not use any external pressure for compaction on the other way we create vacuum. So that the atmospheric pressure, with the help of atmospheric pressure the impregnation and the compaction takes place. So here the impervious bags are placed. So that the films are laid on the composite material and the air is evacuated.

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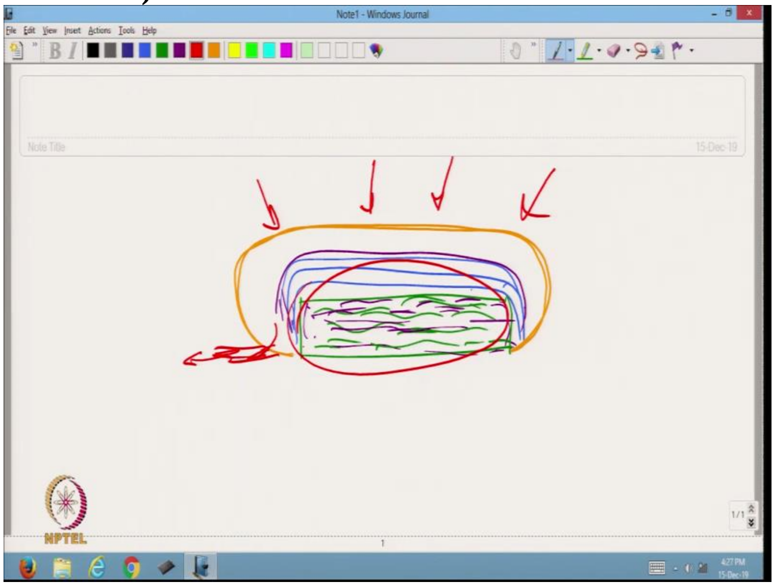

So suppose this is laminate of reinforcing material and we have placed the resin, also must be in the resin, now in this laminate what we do we are placing different layers. The layers are the bleeder layer, this is the bleeder layer which will absorb excess resin, then releasing films are there. There will be releasing film. So different layers are put on, they have their different functions.

Now at the uppermost side there will be a bag, a sheet material and this is placed in such a way there will be a gap through which we can take out the air. So this is air is taken out. So as air is taken out this will get compacted due to the atmospheric pressure and the composite will get compacted, compressed, and finally whatever wides are there the air bubbles will come out and composite formation will complete.

So air is evacuated from the bag and the composite is consolidated under pressure of one atmosphere, because it is a atmospheric pressure is required. The application of pressure ensures impregnation of reinforcement with the matrix. So there will be uniform pressure because the total air is evacuated. So uniform pressure will be applied throughout the composite.

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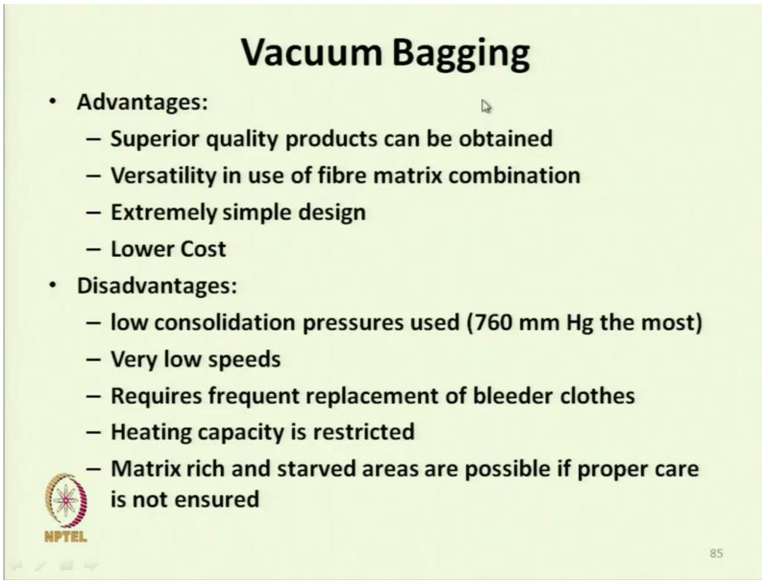

So main advantages are the superior quality product can be obtained, versatility in use of fibre matrix combinations but here we can use only the reinforce that is thermoset matrix but different types of fibres can be used. It is very simple. One can easily design this type of manufacturing method easily, it is a low cost. Main disadvantage here the pressure we have to depend on the atmospheric pressure more than that we cannot insets.

So very low speed because we have to form the total system for particular shape of composite. It is not continuous, requires frequent replacement of bleeder cloth because this will get saturated with the resin, heating capacity is restricted due to different layers the heating is not easy. So matrix rich and matrix starved areas are possible if proper care is not taken. Because we are not adding any extra matrix material.

We are only here it is a compression system at low pressure compression system. That is why chances are matrix rich and matrix starved areas are there. So we must ensure proper impregnation of reinforcing material with the matrix material. So these are all about the manufacturing methods of composites. In next class we will discuss the textile structures in advanced composite, mainly prepreg formation and preform formation, where will see how the thermoplastic matrix are used in composite manufacturing. Till then thank you.