Manufacturing of Composites
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Lecture - 08
Composites Manufacturing Process

So, a welcome to lecture number 8, this lecture is more focused towards composite manufacturing process. In the last lecture we went into a concept called design for manufacturing where in which we kept manufacturing as one of theme and then we went back and tweaked our design process designing of a component and then trying to reduce the number of parts making all the assembly in one direction and all the suggestions were made. Now, with that idea let us try to move into manufacturing of composite processes.

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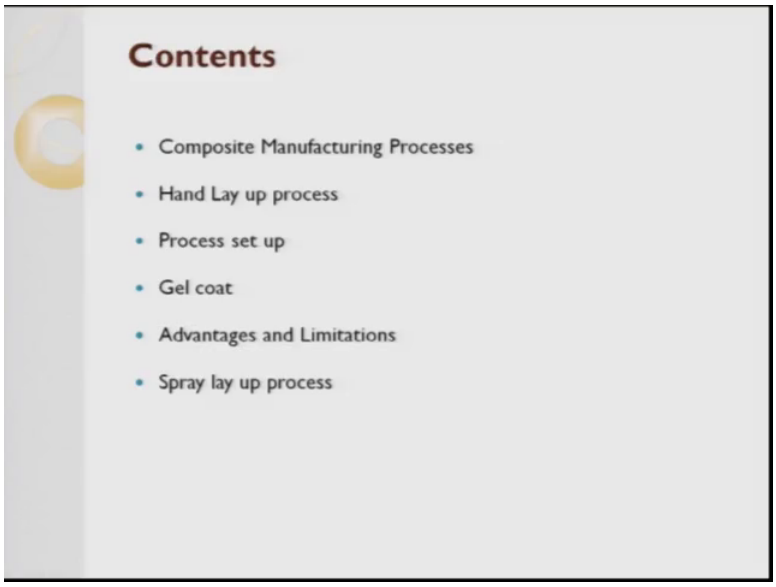

In this lecture we will try to see some classification of manufacturing of process of composite process, then we will see 2 major processes, one is Hand Lay up, the other one is Spray lay up process.

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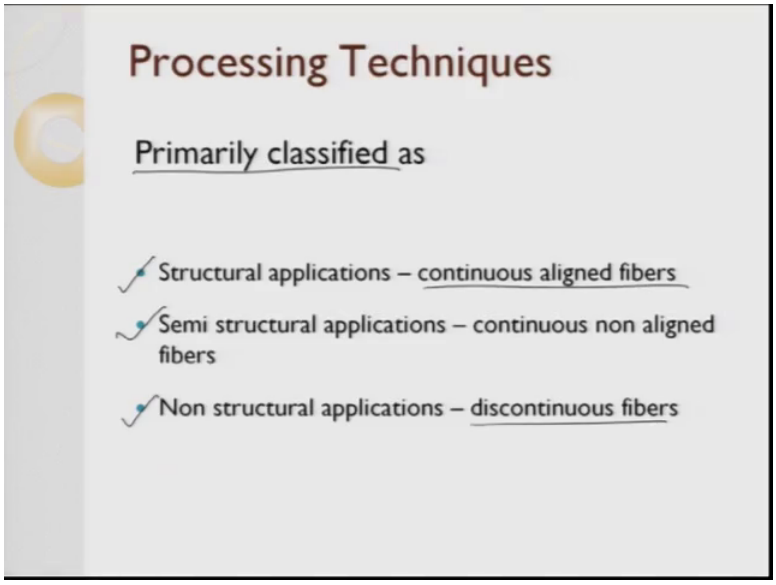

When you are looking into manufacturing process is classified primarily into 3 types, one is called as parts for Structural application, parts for Semi structural application, and part for Non structural application. Non structural application I always use to refer it as secondary structural applications, non structural applications means they do not trake a heavy loads they just give a covering, protecting, a coating or a box closure. Here predominantly we always go for discontinuous fiber, discontinuous fibers can be like you take a long finer cut it into several small pieces and then stack them.

In some in a in non aligned fashion or in an aligned fashion to just fill the space, when I talk about structural applications the fibers are aligned in the loading direction. So, this will try to give you a major lead to decide which process to choose such that you can meet out the customer requirements.

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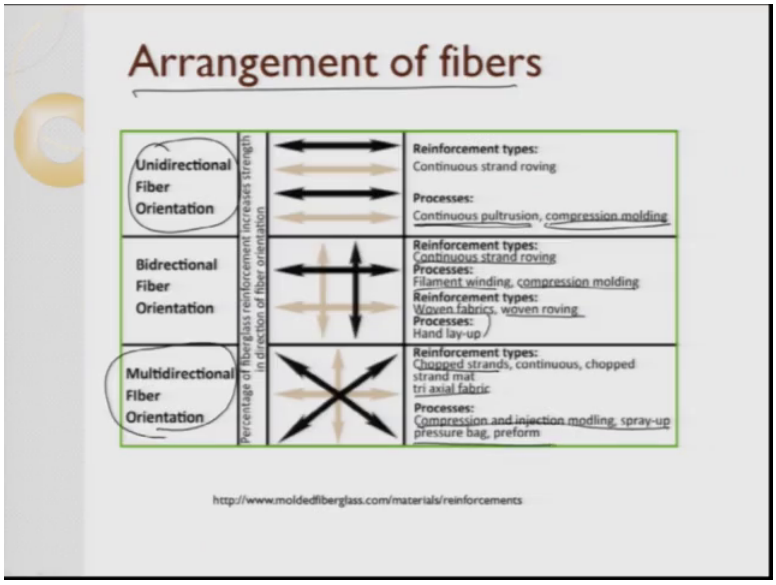

So, just a recap of arrangement of fiber and, you can have unidirectional fiber orientation, this unidirectional fiber orientation is predominantly used for taking the loads. If you look at it there are processes as of now you just get exposed to these processes names and later in the presentation you will go through all these processes when you have a the load taking composite for structural applications you will have unidirectional fibers oriented in the direction of loading.

This will lead to 2 processes called as continuous protrusion process or compression molding process, when you have bidirectional orientation the reinforcements are continuous strand roving you can have filament winding process or compressive molding process. Here we use woven fabric or woven roving and the process predominantly used for this are hand layup process, today we will see what is hand layup process.

You can also have multi directional fiber orientation so; that means, to say the fiber are oriented at several directions, this the reinforcement type can be chopped strand mat, continuous chopped strand and chopped strand mats and then you can also have tri axial fib fabrics to get more idea about this, we have already discussed in the fiber reinforcement forms all these orientations. So, here what I am trying to insist is you look at what is the orientation you have, then you can see different processes involved for making a polymer matrix composite.

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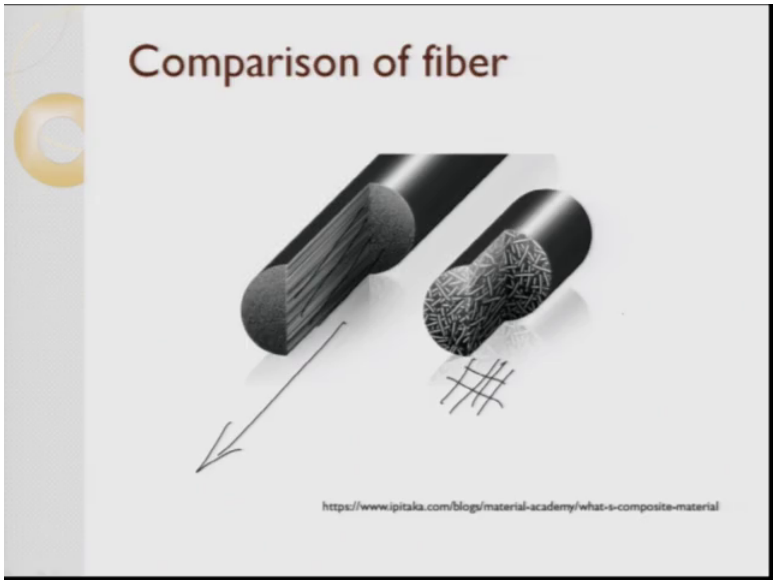

For more understanding and visual for from the visualization point of view you can see this is a continuous fiber oriented along the pipe, this is a chopped strand. The continuous fiber is broken into several small fibers short fibers if you look at it this does not follow any uniform pattern it is just cut a wovened a fiber is cut into several small pieces and they are all mixed and blend inside the polymer and it is excluded here. This figure is only to give you a comparison between continuous and chopped strand mats which are cut into pieces and then mixed with the polymer. Now, you can easily understand along the loading direction, what will be the load taken by the fiber matrix along the load direction what will be the load taken by the fiber and matrix. So, here the fiber cannot take the major load, it is going to be more towards secondary structural applications.

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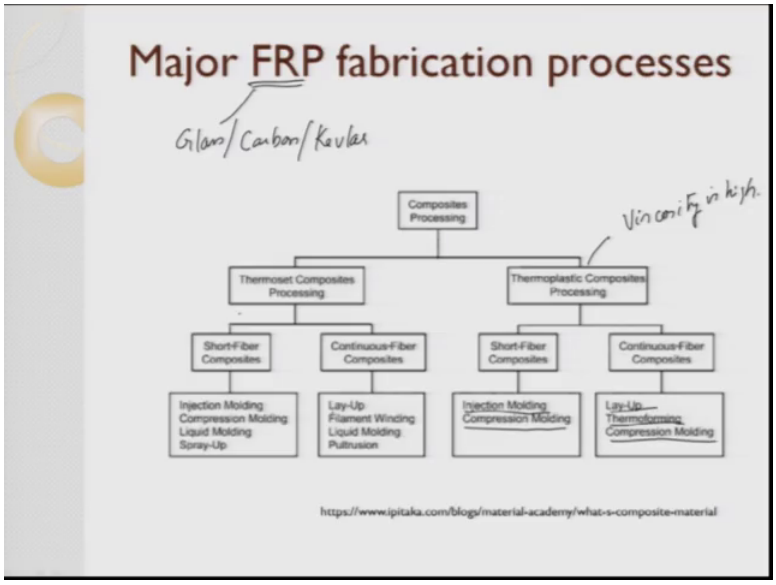

If you see the classification of FRP; that means, to say fiber reinforced plastic and here we can use either, Glass, Carbon, Kavlar for our application. They are divided into Thermosets composite based upon the matrix, Thermoplastic composites, then it can be short strand short fiber composite, continuous fiber composite and here in short fiber composite, you have injection molding process, compression molding process, liquid molding process and spray up molding process. When you talk about continuous fiber composites you have layup process, filament winding process, liquid molding process and pultrusion process. So, when you talk about thermoplastic the difference between thermoset and thermoplastic is here the thermoplastic the viscosity is very high, when the viscosity is high; it has to be injection molded.

You see predominantly it will be injection molded or compression molding, where we use pressure to give a shape to it, you can also have layup thermoforming process and compression molding process, these are some of the processes which are under the thermoplastic composite fabrication.

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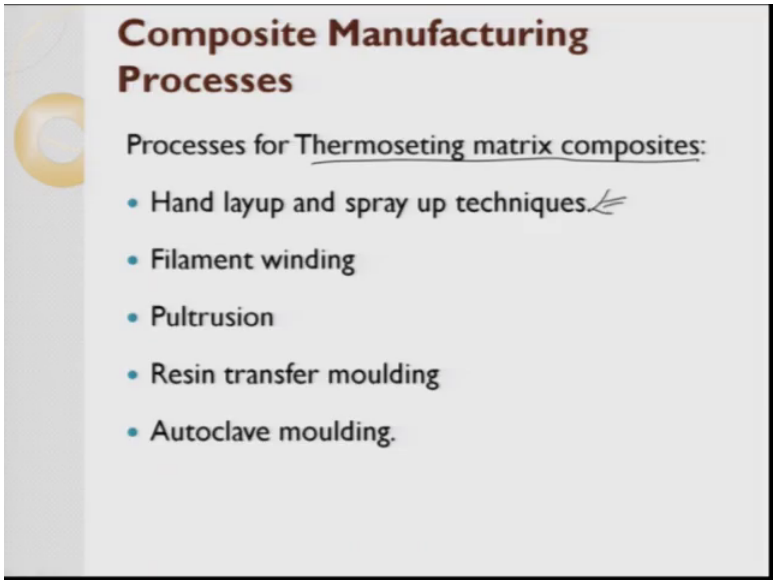

So, to have more about thermoset, first our focus is more towards thermosetting process, thermo set setting process matrix composite. We have a hand layup process, spray up technique process, filament winding process, pultrusion process, resin transfer molding and autoclave. These are some of the processes which we will try to cover in this lecture series, today's focus is more towards hand layup and spray up techniques.

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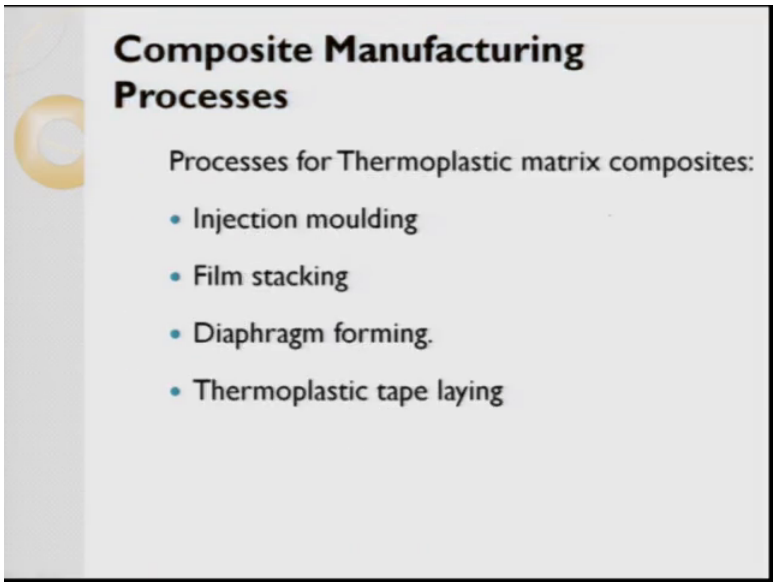

When you talk about thermosetting polymer, thermoplastic polymer, we will go through injection molding, film stacking, diaphragm forming and thermoplastic tape laying

processes.

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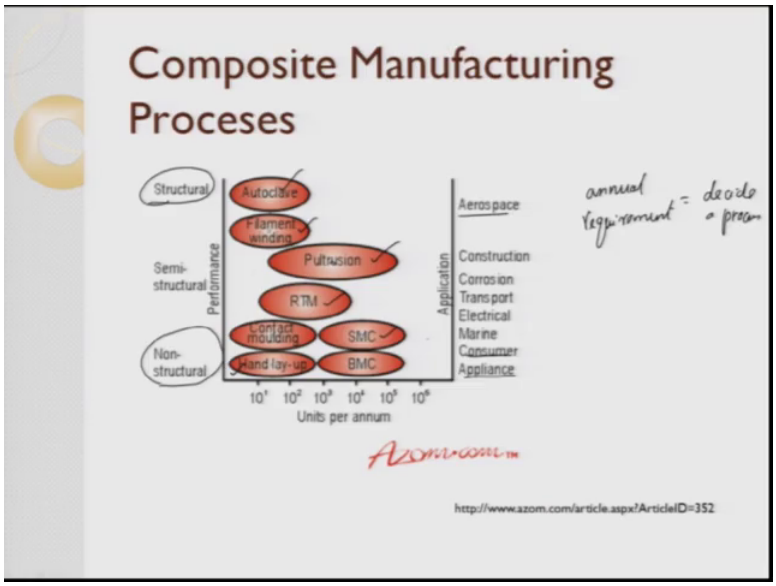

When you have to decide the process you should also keep in mind what should be the annual quantum of what is the annual requirement of a particular product because this requirement annual requirement will help you to decide a process, why is this very important because the right process will give a high quality output, the right process will also make my costing economical.

First we have to understand what is a product and what will be the annual requirement of the product, if you see here I have classified aerospace, I have consumer appliance, I have classified everything. So, you can see for consumer appliance it will be predominantly non structural composites are required, when you have looking for aerospace we also look always look for structural applications. Here these are the processes which are involved for making it, if the quantum is very low we go for hand layup process, if quantum is slightly higher we go for mold.

We also go for resin transfer molding we go for pultrusion process pultrusion is nothing, but pulling plus extrusion pultrusion we also do filament winding process, but if you want to do filament winding process the performance will be very high, but the quantum cannot

be very large. Then autoclave process predominantly for aerospace applications we use an autoclave for producing high performance components, based upon the annual requirement also is one of the factor you decide which process to choose.

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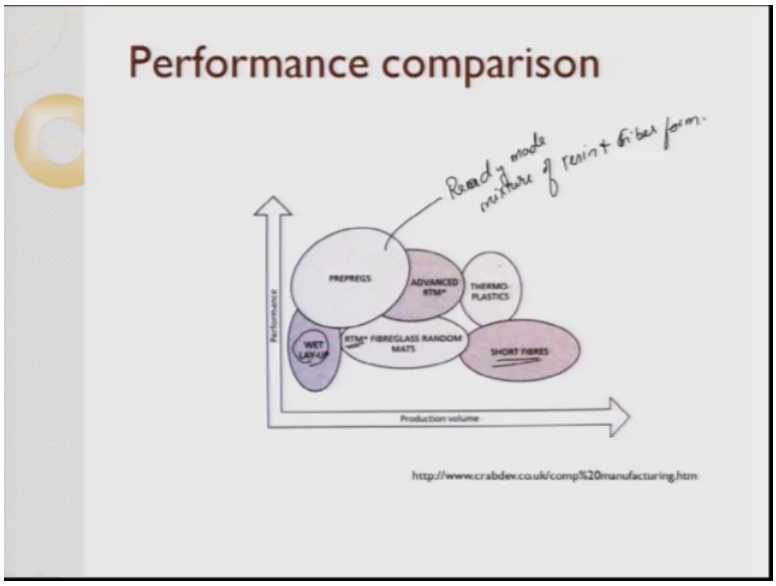

So here are again the volume versus performance, here we have put wet layup process and then we have put resin transfer molding, short fibers, short fibers when the production volume is as for short fibers, thermoplastic composite, advanced RTM, resin transfer molding and we also have something called as prepregs.

Prepregs are nothing, but readymadely mixed, it is a readymade mixture of resin and glass fiber or fiber, form it is readymadely available something like a dove or something like a lamine is there. So, very much of resin is already there they have a top and bottom thin plastic covering, that it does not get cured, moment you want it to cure it. So, what did you do remove the top and bottom layer plastic thin sheet and then stack them depending upon your orientation keeping the final outcome required and then you apply pressure and heat, you make a composite out of it.

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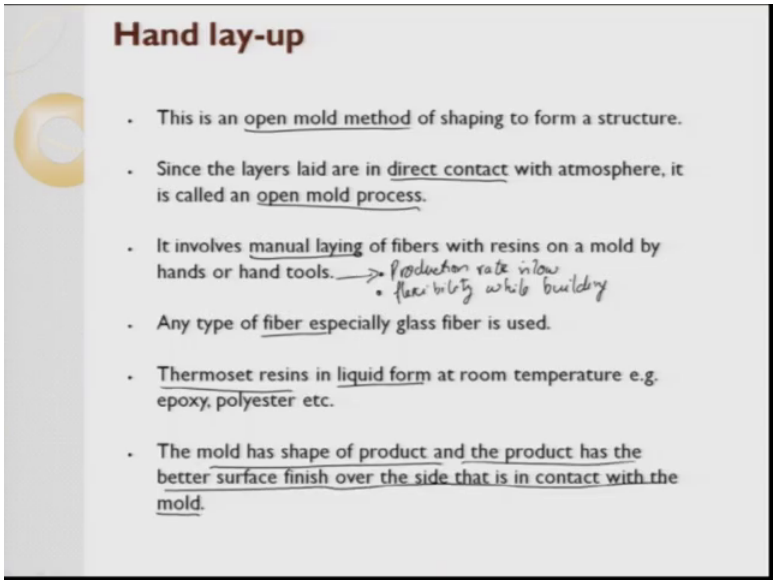

Let us look into hand layup process before getting into hand layup process I would like to tell you one more small point from the manufacturing side which will help us to decide which process to choose take any product when you take any product first you should look for what are all the functional parts and what are all non functional parts. That means, to say functional means the part where and which there is certain function expected and I am more worried about their dimension accuracy finish everything and a non functional part is a pa is a part or a non functional surface is a surface where and which I am least bothered about the dimensional accuracy and the finish.

For example, you take this component I need a smooth surface I need a hole, but I am least bothered about dimension of the hole, I am least bothered about the internal finish of the hole, I am worried about the external finish of this product. Now, this is a functional surface this internal surface not such a important parameter for me. Those internal surfaces are called as non functional surface these are called as functional surface, wherever I need to maintain a dimension and I need to maintain a smoothness.

Based upon this functional and nonfunctional surface you will also decide to choose whether to go for open molding process or for a closed molding process. Open molding process means you will have one bottom to give the shape and you will not bother about the top surface for example, a lid which is used in a in a container we are only worried about the top surface bottom surface we are not so much worried about.

So, bottom surface of the lid is called as non functional surface for example, you take a boat we are more worried about the boat outer surface rather than internal surface internal surface we can always cover it with the top wood or some other plank, that it does not matter much. That is also one leads statement for deciding the process whether you need a what are all the functional surface in the product or in the part and which process to choose for that. Hand layup is one process which is in open mold process, where and which the one surface we are more focused towards only one surface where you want to have a smooth surface finish.

Hand layup is an open mold method for shaping to give a form to a structure, since the layers are laid in a direct contact with the atmosphere it is called as open mold process, predominantly open mold process is manual process. So, here the fibers are manually laid moment the fibers are manually laid, what the production rate is low and second thing is, but the advantage is it gives me lot of flexibility while building a component while building.

For example, I can try to put an integral part inside I can try to if at all I make a mistake I have a possibility of tooting it and since I always used my hand the most flexible and controllable gripper ever made is our hand wrist. I have a lot of flexibility to move my hand and try to get the required form for it, any type of fiber can be used generally what we use is glass fiber carbon fiber can be also used kavlar fiber can also be used. So, here it we of the matrix will always be thermoset and this matrix will be in the liquid form suppose if it is in the solid form we heat it to a temperature convert into liquid or there are straight available of the shelf liquid form thermosets.

We take that resin and add the ingredients such that I get the required output the mold has a shape of the product and the product has a better surface finish over the side that is in contact with the mold that is what I said functional surface. So, only one surface will have a very good surface finish and it tries to take the shape, the other side the opposite side of the mold surface or the product which is not in contact will never have a good surface finish, but you can if you are in if you want you can also get it done.

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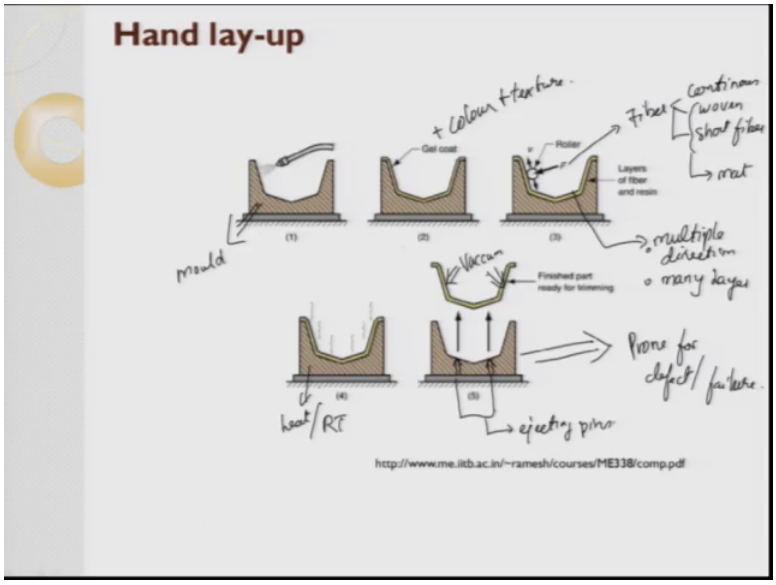

If you see that these are the processes, here the first process is you try to make this is a mold this is a mold. In a mold what you do is you try to put a releasing agent you try to put a releasing agent, the releasing agent is basically to make sure the product does not stick with respect to the dye or the mold and then this. That the mold can be re used for several for making several products, first you try to do a degreasing or.

First what you do is you just give a small greasy coating such that it does not stick even before doing greasing you do first degreasing to remove all the impurities on the surface wash it, clean it with acetone and now the mold is ready. So, you can have a flat mold or you can have a confined mold that is depending upon the requirement. Then you try to the greasing agents, that it helps in rebel removing, then you give a gel coating to it, gel coating make sure it the make sure that the surface the composite which is in contact with the dye will always have a smooth surface finish.

In the gel coating you can also add color and you can also add texture to your requirement, then what you do is on this gel coating you try to place the fiber. So, what is the fiber, the fiber can be it can be continuous, it can be wovened, it can be a short fiber, all these things the woven and short fibers these are in the category of mat. So, you can keep a mat and then what do you do is you place the mat exactly on top of the gel coating and then try to use a roller, and try to press the roller against the gel coating.

That you are doubly making sure that there is no gap between the product and the gel

coating then what do you do is you try to apply when you do the rolling you can you also try to apply the resin into it or your first roll the glass fiber alone and then you try to apply resin such that you do you have a proper contact between the gel fiber and a matrix then you have finished one layer. So, one layer and then if you want to generate lot of thickness you have multiple layers and these multiple here the fibers can be laid in multiple directions or it can be many layers can be many layers can be done on top.

So, that you get the nece required thickness, once you get the required thickness then what do we do is we allow them to cure. The when you try to use the matrix and when you try to push the matrix inside the fiber you always should to do it before the fiber gets into a solid state; that means, to say during the gelation before just before that you have to finish the entire operation. So, moment you finish it then you allow then you can either apply heat can be applied or we can do it at room temperature allow it to cure.

The un cured resin by addition of hardener is allowed to cure, once it is cure then you can release the part outside the dye. Then what you do is you can also use ejecting pins these are ejecting pins, this ejecting pins what they do is they try to release the component and if you are making a small component it is easy to put ejecting pins and remove, suppose if you are doing a very large structure for example, something like hull of a boat or you are trying to do a bus front frame.

Then it is a very large part, here what we do is apart we also try to apply vacuum on the other side, here we apply vacuum to have a proper hold on the other side of the component and then all we apply an ejecting pin or again we apply a vacuum through the bottom. So, that it is getting released out because it is a very large component, very large surface area you have to be very cautious and this is a step with it is always proven for defect or failure. This is a very critical step all the 4 steps are straight forward, but the fifth step when you are trying to release out you have to be very very careful.

This is what it is you can have a positive or a negative mold then you have a first what do you have is you put a gel coating and then if you want to have a color finishing you can try.

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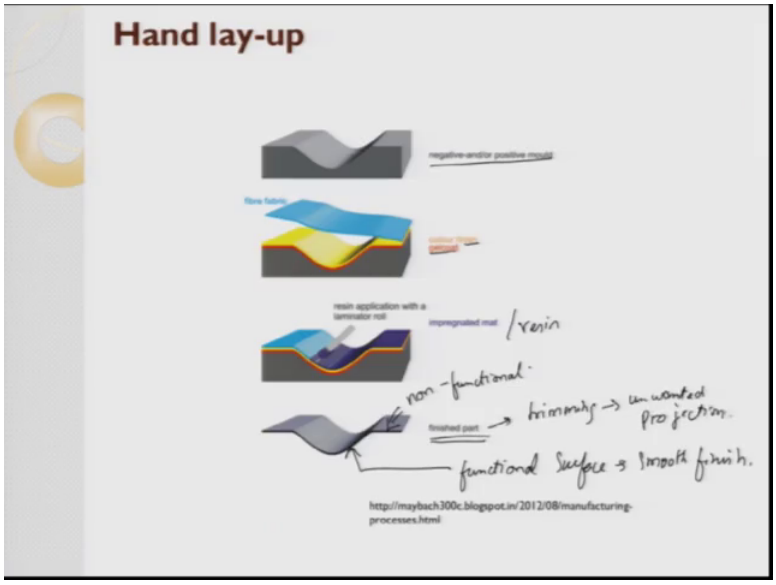

If you want to add textures you can do and then first what do you put is a glass fabric a glass fiber or a carbon fiber fabric you just put after placing the fabric then what do you do is you try to put resin. Resin is getting move the resin is poured on top of the fabric, you can use a brush or you can use a roller or whatever you want you can use. So, you just put the resin on top of this and then you allow it to cure, moment you realize out this becomes your finished part.

This surface is non functional and this surface is functional surface, you always worry about a smooth finish. Of course, with composites you cannot make micron accuracy, we always have a liberal tolerance maybe plus or minus 1 millimeter tolerance we allow because the polymer shrinks the fiber also sometimes gets slightly oriented here and there and then. We make sure and I have missed one point for discussion, here if these projections are not part of your part then there be always use operation called trimming.

The trimming is used to remove the unwanted projections which are there and why do we need these projections because these projections help during manufacturing. So, once the op the part is released then we do a trimming operation to get the end product, same way here after the finished product is done then we go for a trimming operation to remove all the unwanted projections are removed.

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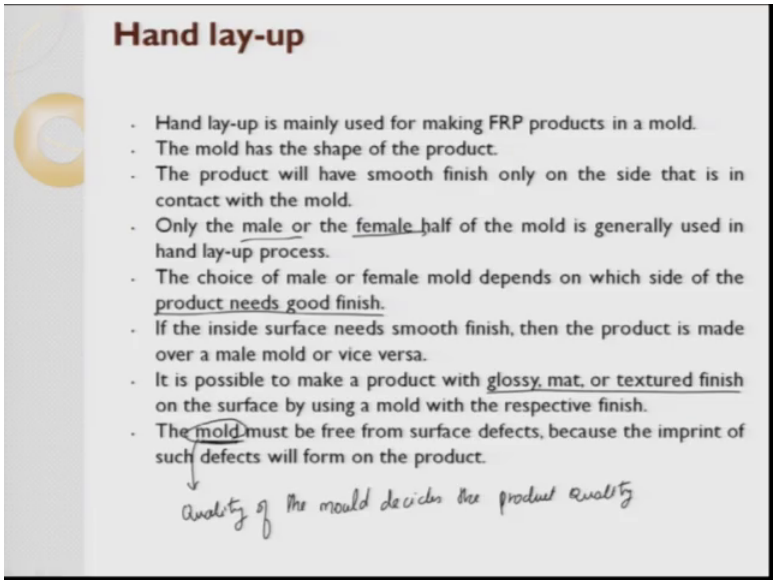

The sequence whatever we have seen on the schematic diagram hand layup is mainly used for making FRP products in a mold, the mold has the shape of the product, the product with will have a smooth finish only on one side, which is in contact with the mold. Only the male or the female half of the mold is generally used for, please understand this is what I said positive and negative male female.

So, male for the hand layup the choice of male or the female depends on which side of the product you need to have a good finish, first you have to decide the functional surface and then decide which side you have to keep, the how do you place the component in the inside, in the inside surface need smooth surface finish, then the product is made over a male mold or it is made on a female mold. This point you have to decide, how do you decide as I told earlier it is possible to make a product with a glossy mat or a textured finish, this see finally, what happens product is more impressive if you make it glossy the final finish texturing is very much talked about today because structuring is big feel improvised a feel for while using the component.

Texturing can be done in many ways right on the surface by using mold with the respective finish the mold must be free from surface defects this is very very important, the mold quality of the mold dictates or decides the product quality, if you have a poor mold whatever precaution you take while processing you will never be able to get a good surface finish or you will never be able to get a quality product. So, the mold must be free from surface defects because the imprint of such defects will form on the product, if you

have any small projection this will try to get imposed on top of the component and apart from that the quality when I said the mold strength, the mold repeatability, the collapsibility all these things are very very important.

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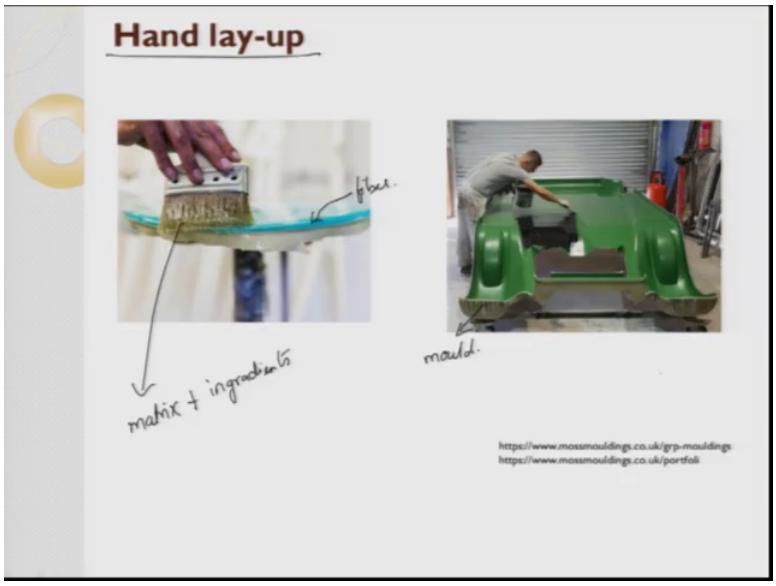

As I told you earlier, what we have made we have this is a component which is made, you can see here the fiber is placed and then the matrix is getting added. Since we are making out in hand layup process we use a brush where and which the brush has the matrix. So, here the matrix will be you will add ingredients, here it will be matrix plus whatever ingredients you wanted to add will be mixed like hardener, u v, absorber all these things will be added and it will be made in a liquid form, then it is taken from a bowl or some place and then it is just laid out.

This is a mold and on this mold they try to keep the fiber and first they do a gel coating this is a gel coating he does then they keep a glass fiber and then they keep a matrix coating, such large structures can be made and small parts also can be made.

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This is a typical example I have worked in developing this boat when I was in my college, this is a complete boat this is approximately it is not the same boat which I have developed this I have taken it from a reference, but the boat what I developed was around about 12 metres long which is used for fishing application. So, here if you see the top surface is we are not worried about surface finish, the bottom surface we it is very smooth we get it and here is a mold this is a mold.

This you can have on this supporting structure inside you will have a wooden mold made or wooden pattern made. So, then on top of it you try to do it, these are the projections which are because of the fiber, they are all trimmed before giving to the customer. The first layer of the mold is a gel coating before gel coating you have to do a degreasing then you have to put a greasing see for example, whenever we do a cake cooking we always put a butter sheet.

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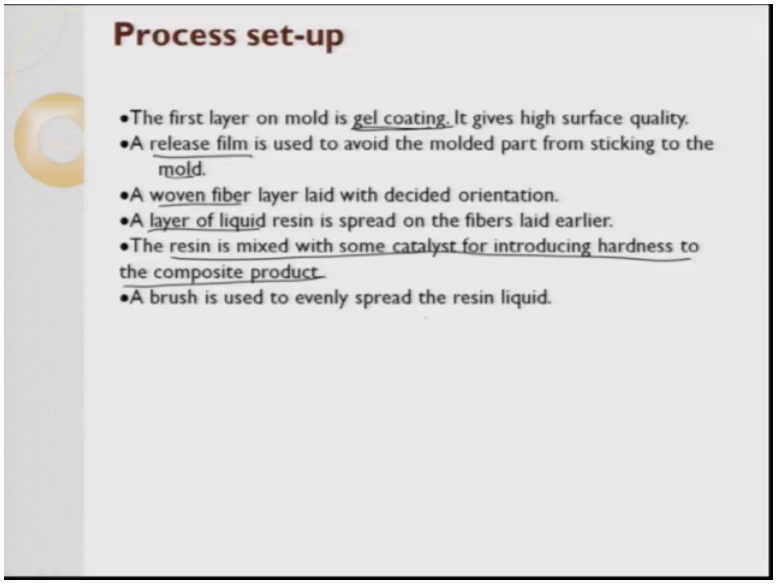

This better sheets prime responsibilities to make sure that the cake does not stick on to the basin, in the same way here we try to do a grease coating and then we try to do a gel coating. The gel coating gives you a very good surface finish a release film is used to avoid the mold from getting stuck, then we try to use a woven fabric whatever we I say discussed earlier. Then we form several layers it is not one layer there are several layers depending upon the thickness the mix the resin is mixed with some catalyst to a to introduce the hardness to the composite it is like cooking. So, depending upon the taste that depending upon the performance whatever you want the component can be ingredients can be added to it a brush is used to spread the resin.

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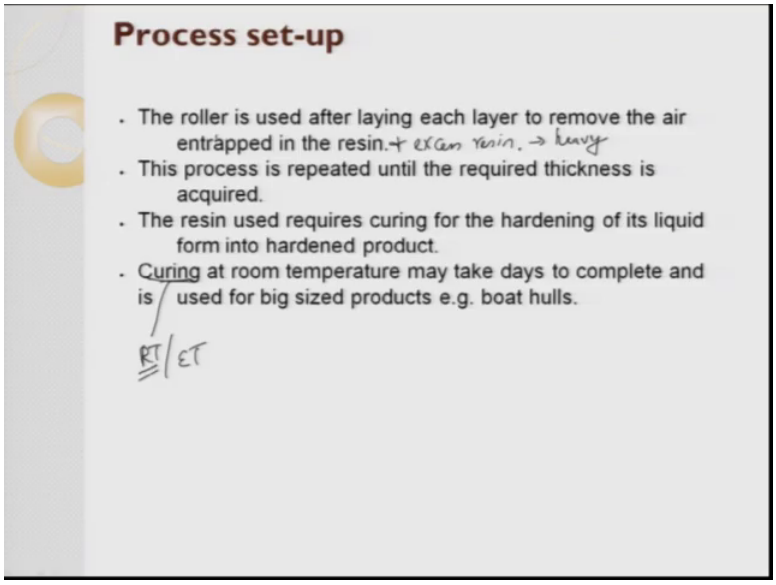

The roller is used after laying each layer to remove the air trapped in the resin and it also tried to remove the excess resin. So, that you do not get see generally what happens excess rich resin means you will have a certain pockets there will be more resin there, when the resin is added more it becomes the part becomes heavy. They will always make sure that to the air gap is removed, that you get a better performance and the excess resin is removed such that the weight is reduced, the process is repeated until you get the required thickness the resin used the requires curing for the hardening of it is liquid to form into hardened products so, that is what I said all the ingredients the curing at room temperature.

The curing can happen both at RT as well as ET elevated temperature depending upon your requirement when it is a large size product it is always done at room temperature only, and here it is you can use epoxy resin and you can use polyester resin depending upon your requirement.

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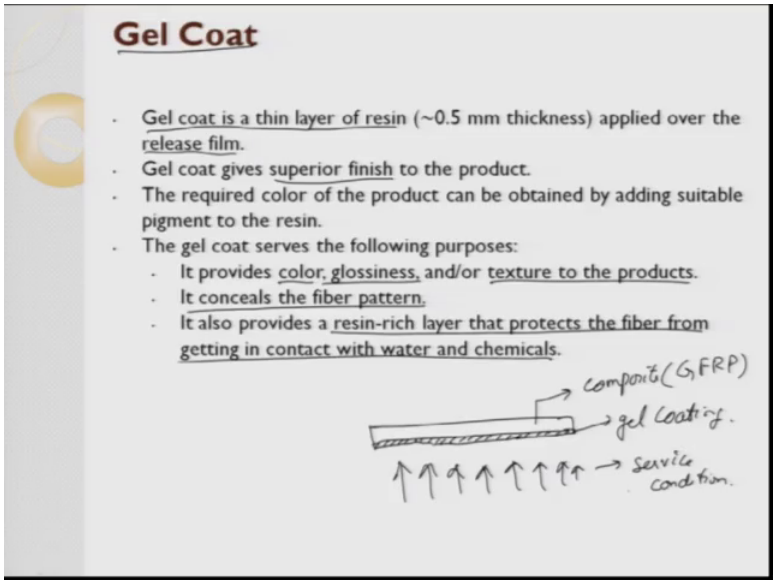

The gel coating; gel coating is a thin layer of resin applied over release film, the gel coating is the superior finish the importance function of this gel coat is only to give a superior surface finish. The gel coat serves the following purpose it provides color, glossiness and texturing of the product, it conceals the fiber pattern, it also provides a resin rich layer that protects the fiber from getting in contact with water and chemical. That means, to say I make the glass fiber and then I have a very small layer of gel coating this will try to protect from the from the service conditions, this is a service condition. So, you this is nothing but gel coating, and this is a composite and we are discussing about GFRP, this is how it is.

This is what we have said it also provides a resin rich layer that protects the fiber from getting in contact with water or chemicals this is a service condition service condition can be water and other water humidity and then chemical etchingness.

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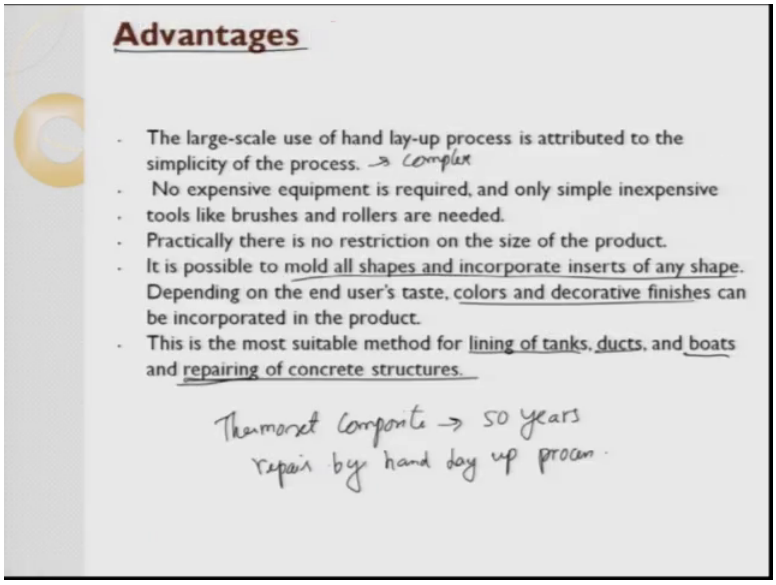

So, what are the major advantages are it can make a small part it can make a very large part very large part where and which it is complex in nature, large scale product which is complex in nature also can be made. It is a very non expensive process because there is no equipments which is required all you need is only a pattern then all the other things are brush and rollers are very trivial items.

Practically there is no restrictions on the size of the product that is the biggest advantage of this big structures very big structures where and which it does not have for structural applications very big structures only if giving form it can be used it is possible to mold all shapes and incorporate inserts of any shape. This is what I said is the flexibility of the process, if you want in between 4 or 5 layers you want to keep a metal strip and reinforce the composite once again depending upon your requirements or if you want to put a mesh or if I want to put smart sensors to monitor what is going on.

For example in marine applications the submarines are they have they are all the shell of the submarine is made out of the composites and they wanted to do monitoring of the process what is a heat getting generated very close to the motor, they try to embed all these sensors. This is possible by this process depending upon the end users taste, color the decorative finishes can be done, this is the most suitable method for lining of tanks, ducts, boats and repair of concrete. This process can also be used for repairing, see what has happened is the thermoset thermoset composites which came into the market before 50 years now slowly the matrix is got deteriorated. So, moment the matrix is deteriorated

the reinforcement is now getting exposed to service conditions. If you want to repair those parts, then we use hand layup repair by hand layup is very common, repair by hand layup process is very very common.

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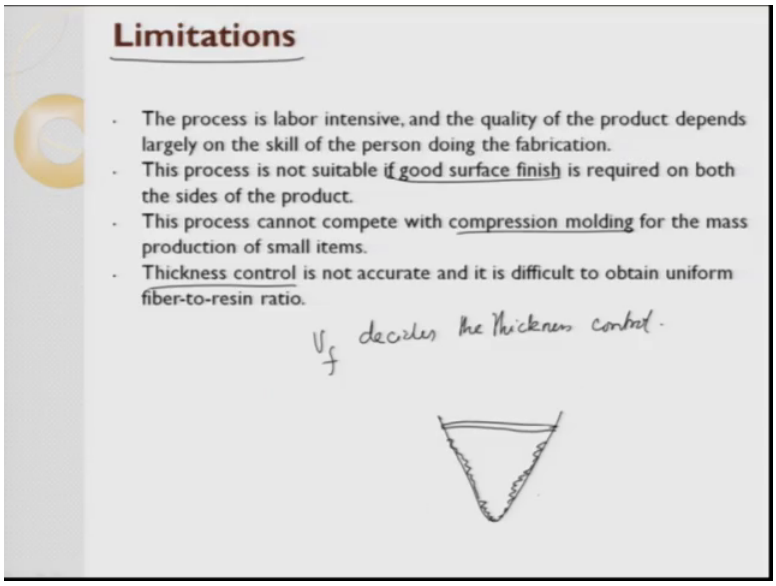

There is a limitation first thing is the process is labor intensive and the quality of the product predominantly depends upon the skill of a person and while doing this process there is lot of toxic gases are also getting released. It is little hazardous for the operator or the for the labor who is involved in this process and if you make very large structures releasing of a large structure really need skill and this has to be planned while making the mold itself. The process is not suitable if good surface finish is required on both sides that mean, to say if you want both side surface finish.

You need to have a female dye and a male dye and then it becomes a close mold process, but here it is a open mold process the process cannot compete with compression molding for mass production of small items. This process is only for large and complex geometry the thickness control cannot be very accurate it depends upon the resin to fiber ratio so that means, to say the volume fraction decides the thickness control. That is why is said non functional surface dimensionally will be very liberal we will set 3 millimeter tolerances for me, for 2 milli meter tolerances for me. If you see as such also in a boat the internal you have you the internal surface here the internal surface you do not need to have very

good surface finish or a dimensional tolerance, but yes, outside you need to have the proper profiling and other things this tries to take care of your drag.

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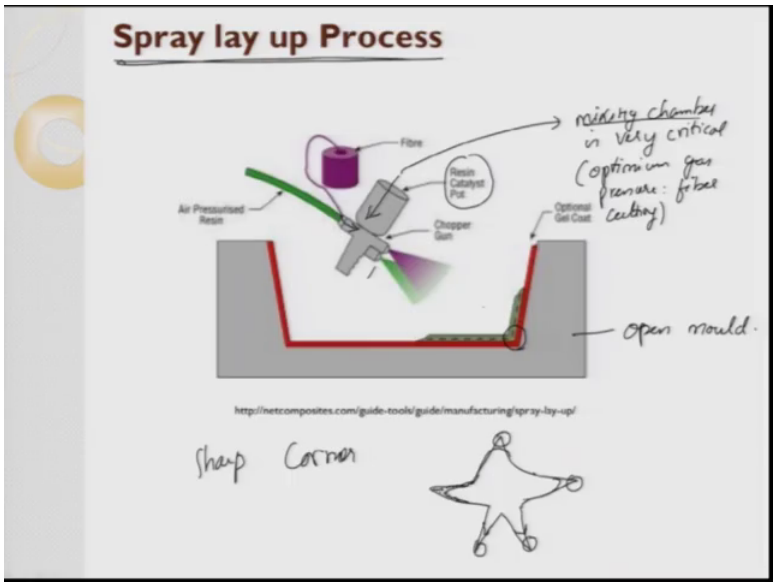

The next process of discussion is going to be spray lay up process, spray lay up process is almost the same like that of your hand lay up process, but the only thing here is we will try to use a long fiber right a long fiber and this long fiber is allowed to pass through a nozzle where and which it is chopped and then it is spread. It is chopped and then it is same, you have the resin which is mixed along with the catalyst comes through this hopper and then the fiber comes through here and it is getting chopped, this 2 gets mixed.

There is a mixing chamber this mixing chamber design is very very critical is very critical why because there has to be a optimum, gas pressure, verses fiber cutting. So, fiber cutting, this 2 gets mixed here and then once it is getting mixed then what you do is we try to spread, it gets mixed and then you try to spread. There are 2 ways of doing it can be done inside the mixing chamber, or it can be done outside the mixing chamber people generally try to do it inside the mixing chamber, that you get a controlled product.

Here the process is the same it is a open mold you have a open mold this open mold is given a gel coating as I told this gel coating decides this gel coating is acts in between the

product and the mold this gel coating will exist in the final product. Then what do we do is then we tried to spray the part, what is the advantage here where ever you had a sharp corner for example, a star these are all sharp corners. So, in sharp corners trying to push the glass fiber at extreme edges at these edges is very very difficult.

You will always try to get if you use a hand lay up process you will get the radiusing in order to avoid this radiusing what we do is we try to use this spray lay up process. Spray lay up process wherever there is a intricate part, the intricate geometry this process the air is at high pressure. This polymer gets mixed with air, then they try to go and occupy the sharp corners to get the required product rest all is the same it is open molding process, here one side you get a good finish the other side you get the unfinished or semi finished part.

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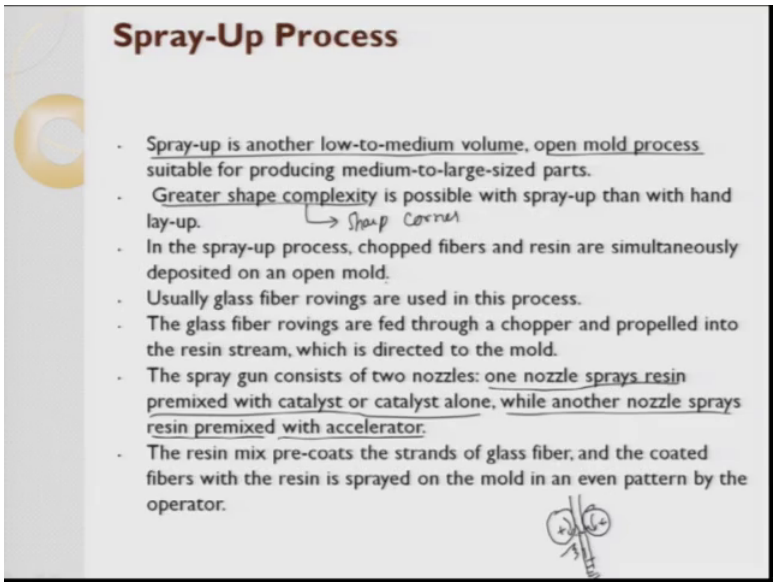

Here the spray is another low to medium volume and a open mold process here the production is higher than that of the hand lay up process. So, greater complexity in terms of sharp corners sharp corners can be made using this process in the spray laying process a chopped fiber and resin are simultaneously deposited on the open mold. Usually glass fiber rovings are used in the process, the glass fiber roving are fed through a chopper so that means, to say you will have 2 wheels fiber comes in between them and then what you do is you try to have something like a chopper which passes through it tries to chop and

then try to make several small fragments of the glass fiber.

The glass fiber roving are fed through a chopper and propelled into the resin stream which is directed towards the mold. So, I said mixing can happen both inside a mixing chamber and then it can spray or you can only just cut and move forward resin comes and gets added in between. So, the spray can consist of 2 nozzles 1 nozzle sprays resin premixed with the catalyst or the catalyst alone while the other nozzle sprays the resin premixed with the accelerator, you see now I have put talked about 2 terms one is called as an accelerator catalyst.

Accelerator and catalyst are predominantly used for enhancing the curing process. So, the resin mix pre coats pre coats the strand of the glass fiber and the coated fiber with a resin is sprayed on to the mold in an even pattern by the operator. So, basically what you do is the operator tries to take a gun and he goes around and the sharp corners and fills it up and here also what happens is he uniformly tries to fill it up if he does not uniformly do it then at certain patches you will have rich fiber reinforcement and rich resin mix.

So, it becomes very difficult and the biggest challenge here is the coating has to the coating; that means, to say the wet ability between the fiber and the matrix has to be done proper. The interface has to be proper otherwise the quality of the product is not good, the resin mix pre coats the strands of the glass fiber and the coated fiber with the resin is sprayed on the mold and in an even pattern by the operators.

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It is also a skilled process depending upon the operator if you look at it look at this at dome this is a man, it should be almost his size or slightly larger. This dome is been completely made out of composite, it is light in weight and it is used for applications. So, you can see here the operator goes around holding the nozzle, this is a nozzle, you can see here a nozzle the nozzle consists of 2 the 1 is for resin, the another is for fabric.

Here you can also have combinations are it is you put a you put all these fab this spray coating in the first region and then you can also try to have hand lay ups. So, hybrid process hybrid processes are followed today so; that means, to say hand layup and spray layup are mixed also to get the required output required thickness right. So, you can always have a hand layup and are this is process hybrid process are followed hand layup and spray layup are mixed to get the required output.

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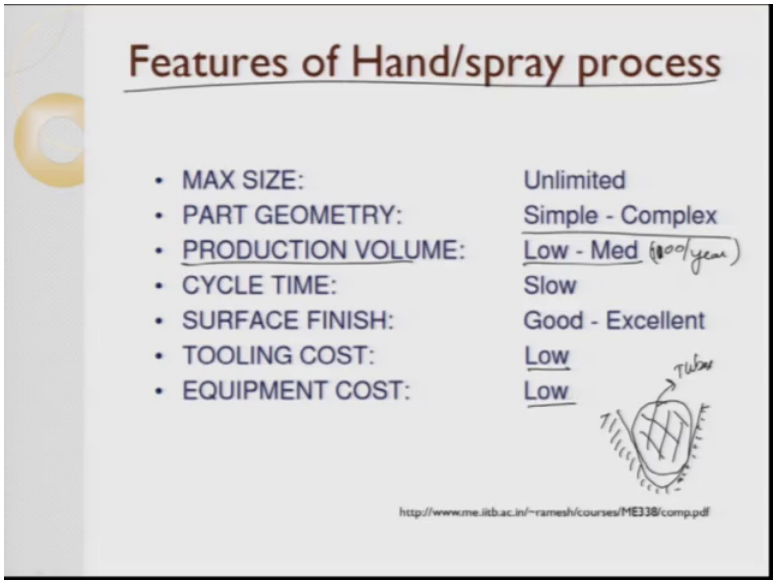

If you look at the features salient features or if you look at the importance if you want to understand which process to choose, here size you these 2 process size is not a restriction at all, you can make very large part very small parts people do not do it because it is very difficult to do small parts and then get removed and other things. It is used for very large size part geometry can be very can be very simple to complex for example, the shell which is which I have shown you as an example is a simple structure boat when you look it is slightly complex you can also have aerospace components. The production volume can be always low to medium; that means, to say we are not expecting more than 100 per year or 1000 per year, this is the numbers typically we are looking at it the cycle time is very slow it takes sometimes.

If you have a very large component it takes several days to form right and if you have very large component and using a roller is not a good idea. So, what generally people do is on the this assuming this is a hull since I worked on it I have got exposed. e always use to put here tubes pressurized with air. So, that this tries to, but against the fiber and this will try to, but against the mold to get the required smooth output surface finish can move from good to excellent tooling cost is very low tooling equipment cost is also extremely low. This process is most welcome for low part volume production with complex geometry, we are done with today's lecture.

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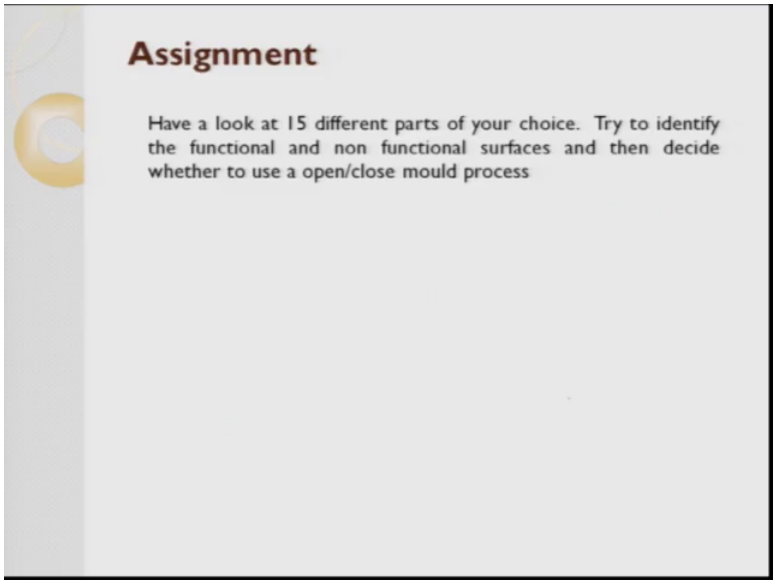

I would like to give you an assignment, you try to have a look at 15 different parts of your choice let it be a glass let it be made out of sorry it can the part can be made out of ceramic polymer it can be made out of metal choose 15 different parts and try to identify which are all the functional surface and nonfunctional surface, moment you identify functional and nonfunctional surface.

Now you go to the next step and decide whether to go for open molding process or a closed molding process. Open molding process you will use the male part or the female part male side or the female side for producing it only one side will be predominantly used for making when it is closed we have something like a male and female put together maintain a small thickness we try to make an output. So, with this we have finished the first 2 basic processes of thermosetting glass fiber reinforced, plastic composites, open molding and closed molding process.

Thank you.