Processing of Non-Metals
Prof. Dr. Inderdeep Singh
Department of Mechanical & Industrial Engineering
Indian Institute of Technology, Roorkee

Module - 5
Polymer Matrix Composites: Processing
Lecture - 9
Pre-Pregging and Sheet Molding Compounds

A warm welcome to all of you in this lecture of pre-pregging and sheet molding compounds, we have been discussing the various aspects of processing of polymeric matrix composites for the last few lectures. We have seen what are the polymeric matrix composites compound materials, what are the different types of composite materials and where do polymeric matrix composite materials fall in the broad spectrum of polymeric matrix composite in the broad spectrum of composite materials?

We have seen that there are different types of processes which can be used for processing of p m c parts or polymeric matrix composite parts. Now, what are these processes, is there are number of processes which can be classified as the open mold processes, closed mold processes and there are other type of processes which is used as such as (( )) and filament.

In our past lectures we have seen that there are few processes which are open mold category there are few processes which are closed mold category, but each of this process has got certain advantages but, there are certain limitations also moreover there is a fixed application or a specific application spectrum for each of these processes, one of the common points to note in all the process is that we have covered let me first outline the process that we have covered the process is hand layer process, spray layer process, filament winding paltruzen compression molding.

So, these are some of the processes which we have already covered in our series of lecture zone processing of polymeric matrix composites in all this processes if you remember, we have a reinforcement and a matrix that we are combining together to make a composite product. So, we have two important ingredients that we are blending together that we are mixing together or that we are bringing together using one or the other forms of energy or one or the other techniques to make a composite product but, the today's lecture will focus on a slightly on different aspect of composite materials or

processing of composite materials we are going to make prepregs or the sheet molding compounds which will act has a raw material for subsequent processing into the final product.

So, we are now modifying our raw material and we this particular raw material and then finally, we used to converting into a final product if you remember in our lecture on injection molding of polymeric matrix composites we have seen that the raw material is pre blended with the fibers the polymer pallets are pre blended the fibers are incorporated into the pallets before the actual injection molding process. So, this is also the principle is same here also the fibers would be pre impregnated with the resin and these will be stored in a uncured state before been transported to a place where they will actually molded into the final compound or the final product.

This is an simple example can be given of the bread or the roasted bread which is uncured or semi beaked bread as we call in India the paratas sometime the paratas are made in a semi beaked stage or a semi processed stage and as soon as the order is received in a restaurant or on a dhabha the pratas are finally, cured on additional oil is applied on the paratas and then they are converted into the final form or has have form.

Similarly, the prepregs and the s m c that is a sheet molding compounds are also the raw materials in which the fibers have been pre impregnated and with the resins and these particular pre impregnated fibers which have the resin in the uncured state are stored under specific conditions and then these are taken out raped over the final mold of the product and then finally, they are fully cured with the application of pressure and with the application of heat the pressure may applied in the form of consolidation roller or the vacuum may also sometimes be used to apply the pressure.

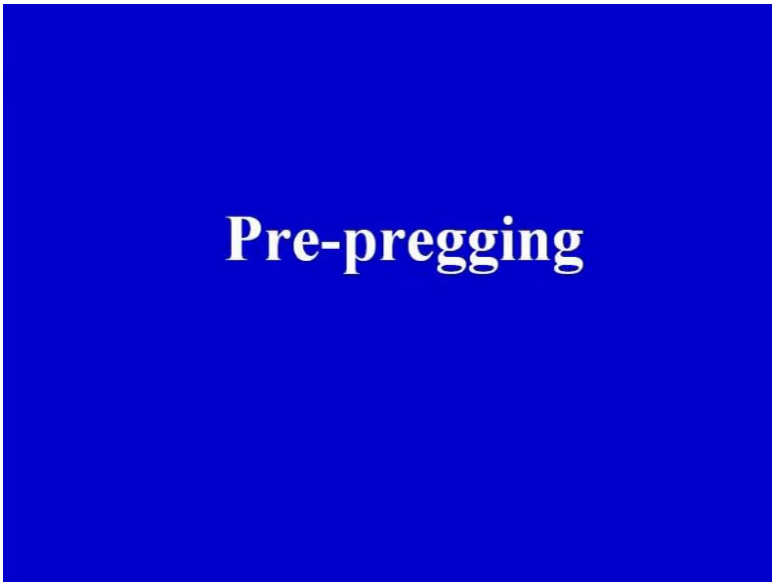
So, basically today's lecture would be focusing on processing or can say preparing the raw material for further or subsequent processing of the polymeric matrix composites we will try to understand how the sheet molding compound and the prepregs are prepared they are further subsequently used to prepare the final product. So, once again to summaries that what is the difference between the processes that we already covered and the two processes that we are trying going to cover today, the major difference lies in the application the previous process is have been used to directly to make a composite product by combining the reinforcement and the matrix or in other words we can say by

combining the fiber and the polymer we were getting the final output which was in the form of a composite product or a polymeric matrix composite product, but in today's lecture we will be seeing two different processes in which the raw material for subsequent processing is being prepared.

So, this raw material is blending the process is process of blending the two constituents together taking them to a slightly higher level and a lower level than the final product or the final processing. Suppose we have to reach at this level and these are the raw materials this process will take us to a slightly to higher level than the basic raw material, but certainly lower than the final product. So, this is slightly we can say in other words treatment of the raw materials to make them ready to be processed into the final product.

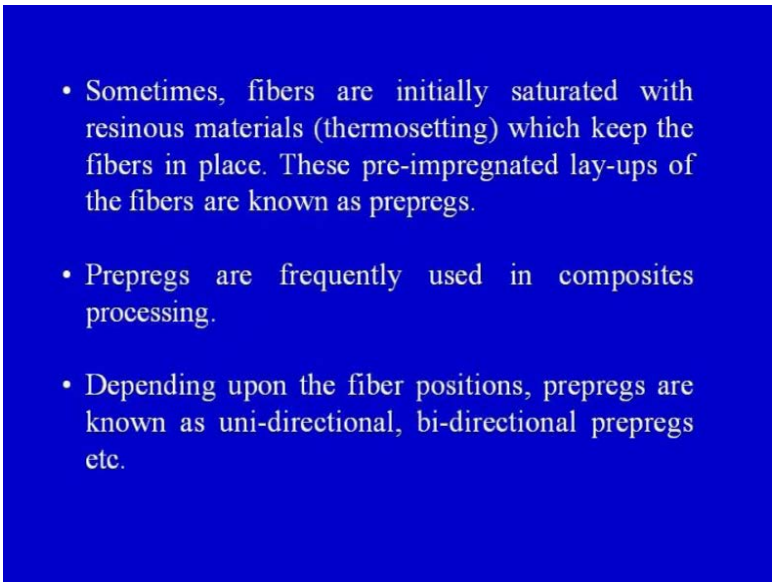
So, let us now start our discussion I have given a brief summary of what we are going to discuss today we going to treat the fibers with the resin and we going to make the prepregs and the s m c which would be further be used for final processing to give them the desired shapes.

(Refer Slide Time: 06:56)



What is pre-pregging? Pre-pregging basically is the fibers are initially saturated with resinous material. Now, the two constituents of the composite material are the fibers and the resins. The fibers or the polymers which are in the form of the resins.

(Refer Slide Time: 07:17)



Fibers are initially saturated with resinous material which is usually a thermosetting resin which keeps the fibers in place. So, suppose I have these four fibers or these five fibers, I will saturate with the resin. I will apply the resin and semi cure this resin to make it in the form of a tape and this is my raw material or subsequent processing. So, the first point you can see the fibers are initially saturated with resinous materials that is the matrix material or it is a type of polymer which keep the fibers in place that is will stop or hinder the movement of the fibers independently it will make a tape of the fibers these pre impregnated lay ups or these prepregs of the fibers are known as the prepregs.

This pre impregnated tapes or lay ups are called the prepregs, prepregs are frequently used in composites processing now I have semi cured raw material available with me it is in the form of a tape now suppose I want to make a tube what I need to do I will have a mandrill on that mandrill I will wrap one prepreg on top of it I will wrap another prepreg another prepreg depending upon the thickness of the tube required I will wrap the prepregs around the mandrill and the inner diameter would be definitely equal to the diameter of the mandrill and finally, I will cure this in a farness or I will supply heat increase the temperature of this assembly and the final curing of the prepregs would take place and I will get a tube and finally, the mandrill can be taken out.

So, this is a similar process as of the filament winding in filament winding also the fibers were coming from the fiber grills and they were getting impregnated in the resin bath and

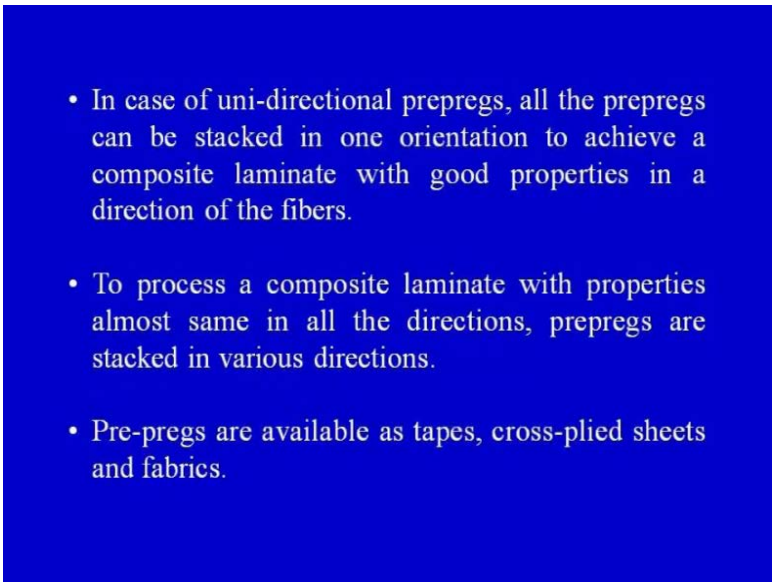
finally, they were been wound over the mandrill we could have easily we can easily control the winding pattern on the filament wound product.

So, what is the difference between then the filament winding and the process just I have explained of making access metric tube in case of filament winding the fibers were coming and they were getting impregnated during the process only but, here in the pre using the prepregs, what we are doing the raw material is already ready. We are just bringing the raw material in the form of prepregs and then we are winding this already semi cured material or semi cured prepreg tape on top of the mandrill and finally, doing the final curing. So, we have better control over prepregs as compared to the filament winding process.

But, there are some limitations of the prepregs also that we will see in the subsequent slide, but, first and foremost we need to understand that there is a difference between the between mixing of the fiber and the resin during the process and mixing the fiber and resin one step earlier and then bringing this tape which is having a unsaturated you can say resinous material which is finally, being wound over the mold of the final product and the shape has been generated.

So, the prepregs are frequently used in the composite processing because the control becomes almost or better or it becomes easier depending upon the fiber positions prepregs are also known as uni-directional or bi-directional preggs. So, uni-direction bi-directional these words already we have seen in our previous lectures uni-directional means all the fibers are oriented in one direction and bi-directional means that we have fibers in both the directions. So, we have. So, we can have fibers in all in one direction or we can have fibers in both the directions. So, the prepregs can be uni-directional prepregs or bi directional prepregs or woven fabrics and mats can also be used to make the prepregs but, one important point note here is that most of the time the fibrous reinforcement would be continuous in a nature.

(Refer Slide Time: 11:27)

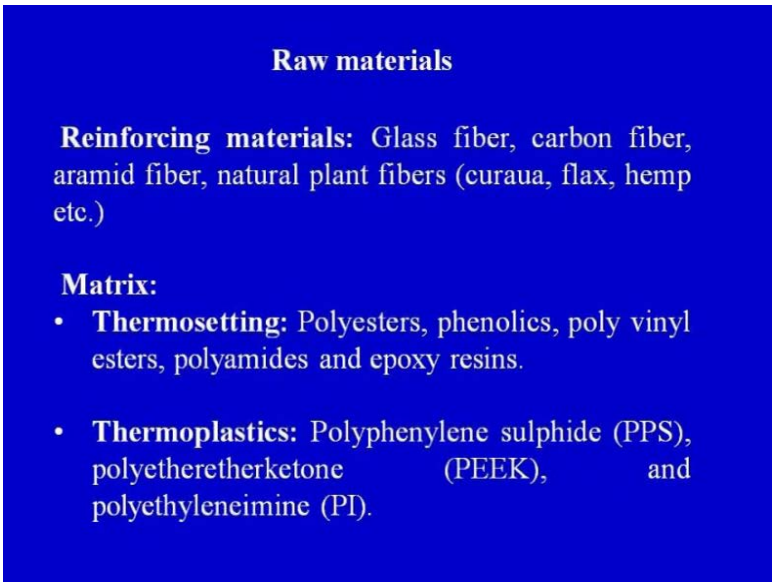


In case of uni-directional prepregs, all the prepregs can be stacked in one orientation to achieve a composite laminate with good properties in a direction of the fibers. Now, suppose 1 prepreg tape is having all the fibers in 1 direction, on top of this when I put another layer or another prepreg which is having all the fibers, in that particular direction only and all four or six layers having fibers in one direction only the properties would be very good in the direction of the fiber.

So, we can have directional properties using the pre-pregs. To, process a composite laminate with properties almost same in all the directions the pre-pregs can be stacked in different directions now we have the choice to place the prepregs before the final product is made. So, we can place the prepregs having fibers all in one direction or we can place the prepregs in different direction depending upon the final requirements of the product which would be finally, made after the curing has taken place.

So, we have better control over the properties that is also possible in some of the processes were we are mixing the fiber and the resin during the process itself, but we have a better control in case of pre-pregs. Pre-pregs are available as tapes cross plied sheets and fabrics. So, this is the types of the prepregs which are available with us. So, till now we have seen that now we are modifying the raw material to suit to our requirement.

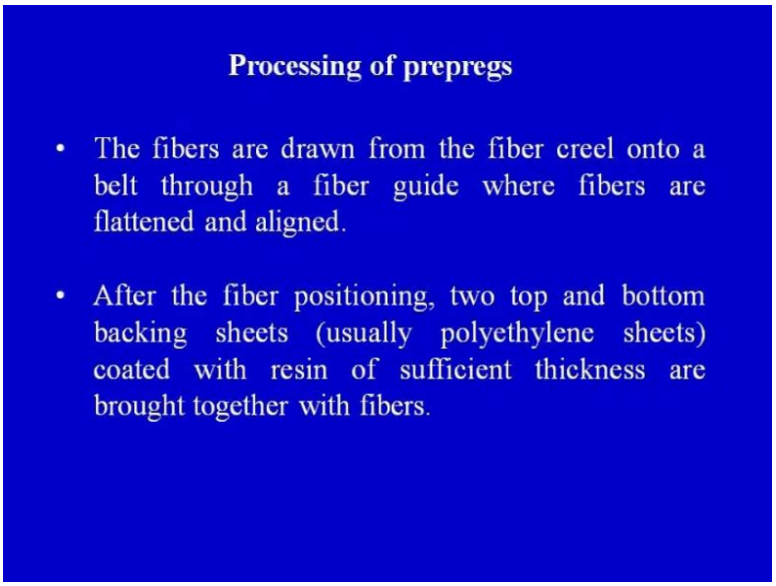
(Refer Slide Time: 13:03)



Now, what are the raw materials which are used for pre-pregging. Reinforcement materials can be glass fiber, carbon fiber, aramid fiber or sometime the natural plant fibers can also be used like flax hemp etc. So, different types of reinforcement materials can be used, different types of fibers that can be used for making the pre-pregs is given on the screen, you can have a look. We can use glass fiber, carbon fiber, aramid fiber or sometimes the natural plant fibers can also be used as the reinforcement material for matrix. We can use thermosetting matrix polyesters phenolic or polymides, sometimes we may think of using the thermoplastics like the polyethylene sulphide or polyetheretherketone peek and polyethylene mine pi.

So, different types of fibers can be impregnated with different types of polymers in order to make the pre-pegs and these pre-pegs would finally, be wound over or depending over the requirement layer over oven on top of the other and final curing would take place. In order to convert these raw materials into the final product. So, the reinforcement and the matrix or we can say different types of matrix and different types of reinforcement are possible in case of the pre-pegs.

(Refer Slide Time: 14:26)



Now, processing of prepregs the fibers are drawn from the fiber creel, the fibers are wound over the creel, we have different fiber creels onto a belt through a fiber guide. Now, we have as if you remember the process we have already is seen that is a filament winding process. In filament winding process, what was there in filament winding process there were fiber creels having the fibers now the fibers have been pulled and they were taken through a pre former to give them a particular direction then, these fibers were getting wet in the resin bath before being wound over the rotating mandrel.

So, here also the fibers are drawn from the fiber creel they are the fibers are available in the wound over the creel and then they are taken to a belt through a fiber guide. So, all the fibers are coming from the different creels, they are given a particular direction. They pass through the hole like structure which we can call has a fiber guide and all the fibers than come out of the fiber guide and they are you can say guided towards the belt or the belt is continuously moving.

So, a fiber guide where the fibers are flattened and lined and they are (( )) pushed towards the rotating or moving belt after the fiber positioning to top and bottom backing sheets usually you may be using polyethylene sheets in case of top and the bottom sheets these are coated with the resin or resin is the polymer which we are going to impregnate the fiber.

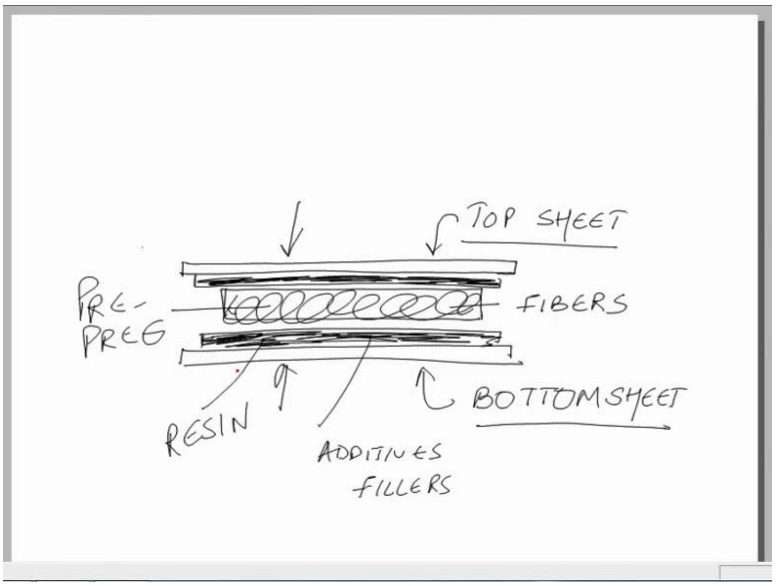
Fibers are been impregnated with the resin which is present on the polyethylene or any other thin film sheets. So, after the fiber position the fiber positioning has been done the fibers have come from the creels they have been formed or flattened or they been given the shape with the help of the fiber guide and once they take up particular shape the resin has to be impregnated.

So, now the how the resin will be impregnated all these fibers suppose are in this particular direction now there will be two sheets the top sheet and a bottom sheet the top sheet will have a resin layer inside and the bottom sheet will also have a resin layer inside the top sheet will be placed on top of this flattened fibers and the bottom sheet would be placed at the bottom of this flattened fibers.

So, after the fiber positioning two top and bottom backing sheets now backing sheets can usually made of polyethylene or there can be other materials which can be used for these backup sheets thin film have to be used thin plastic film has to be used has the backing sheets and backing sheet is now carrying the resinous material with which we going to impregnate the fibers.

So, these sheets are coated with resin of sufficient thickness and are brought together with the fillers. So, if some filler additives have to be added those will be there Impregnate already as a part of the resin which is going to impregnate the fiber. So, all additives would be added to the resin only. So, we have now we can say different layer we have first a flattened fiber and then flattened fibers are a bundle of fibers then we have a bottom sheet and we have a top sheet

(Refer Slide Time: 17:52)



So, just to explain the basic point just I would like to draw a simple diagram on your screen you can see. Suppose this is the layer of the fibers this is there are different fibers which have been flattened here on top of this we will place a sheet a thin plastic sheet here we can see we have a thin plastic sheet.

So, these are the fibers which have been flattened and this is the top sheet and this is the bottom sheet and in between these sheets we have the resinous material and now, the pressure would be applied from both the side and this resinous material will enter to the fiber and we will get a pre-peg this would be a pre-peg once the resin has impregnated the fibers. So, whatever additives have to be added those will be added into the resinous material or the resin sheet.

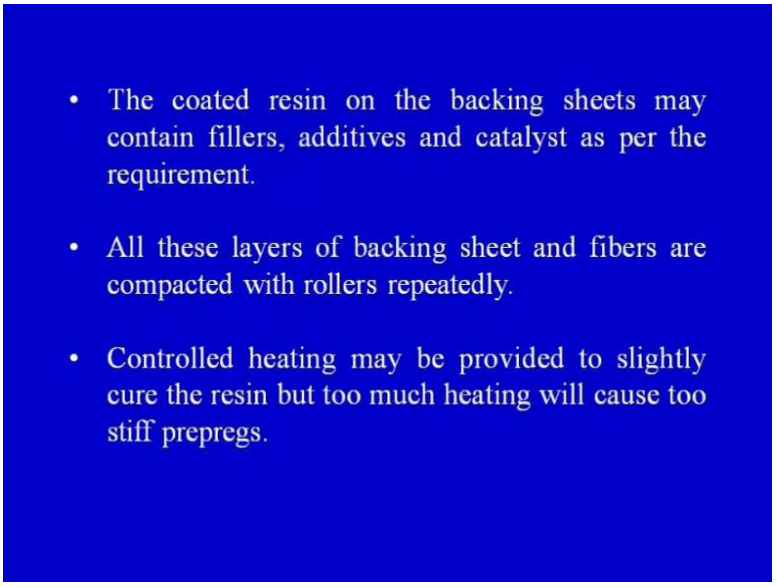
So, we have a top sheet and we have a bottom sheet and the top and the bottom sheets these are plastic or we have seen in the any thin film can be used as we have seen on the slides that the polyethylene can be one material can be used for taking up these sheets then we have the fiber where the fibers have to be impregnated with the resinous material. So, this dark portion represents the resin. So, when we will apply pressure as well as slide increase in the temperature this particular resin would go and impregnate the fiber and then the final product that we will get would be a pre-peg.

So, now we will continue our discussion on the different aspects of the pre-pegs. So, fibers again I am repeating the fibers are drawn from the fiber creel onto a belt through a

fiber guide where fibers are flattened and aligned. So, we now have a sheet of the fiber or a lined fiber in one particular direction.

After the fiber positioning as the diagram I have shown, when the fibers have been positioned in place two top and bottom backing sheets usually, polyethylene sheets coated with resin of sufficient thickness are brought together with the fibers.

(Refer Slide Time: 20:55)



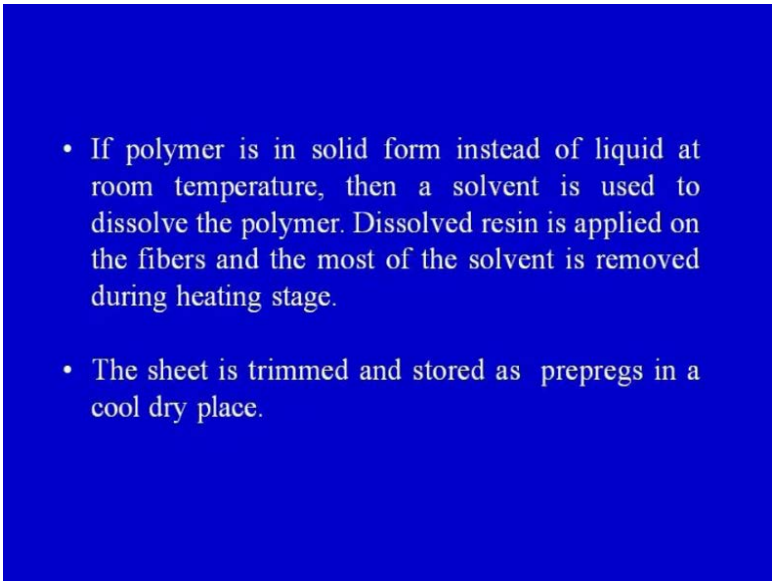
The coated resin on the backing sheets may contain fillers additives and catalyst as per the requirement which I have already drawn in the diagram that this resinous material may be having additional ingredients such as additives fillers or the catalyst. All these layers of backing sheet and fibers are compacted with rollers repeatedly as I have, shown the pressure is applied on this assembly of the flattened fiber sheet and the resinous material and finally, the backing sheets of the any other plastic or for that matter we can use a polyethylene sheets also.

Controlled heating may be provided to slightly cure the resin, but, too much heating will cause too stiff pre-pegs. So, we have to apply two important parameters here that is, the first parameter is compaction which can be achieved with help of rulers and we have to apply slight temperature also. So, if we apply very high temperature full curing of the resinous material may take place and we may get a fully solid prep rag or a very stiff prep rag which may not which becomes unusable for subsequent applications.

So, basically again am I emphasizing that the pre segment sheet molding composites that we are discussing today have to be use for subsequent application, they have to be given the desired shape call into the requirement at the later stage what we have doing, we are blending to the raw material we are bringing to a level which is closer to the final form of the product. So, we do not want to give the shape here only if we have give to the shape at this particular stage only than we will use only the hand layup process here we are manipulating the raw material in such a way. So, we have a better control over the shape of the product suppose we have a very complicated shape which cannot make by the hand layup process there we can use the pre-pegs for making the final product. So, this process is different from hand layup spray layup and all of the process is that we have seen.

So, here two important points are note are by the pleasure and we have to supply a certain amount of heed for semi curing or we can say slide curing of the refiners are the we can say polymeric material if the polymeric is in solved form now sometimes polymer may be in the solved form which is layer which is available in the form of layer on the thin plastic sheet which is being used as a bottom sheet and the top sheet.

(Refer Slide Time: 23:36)



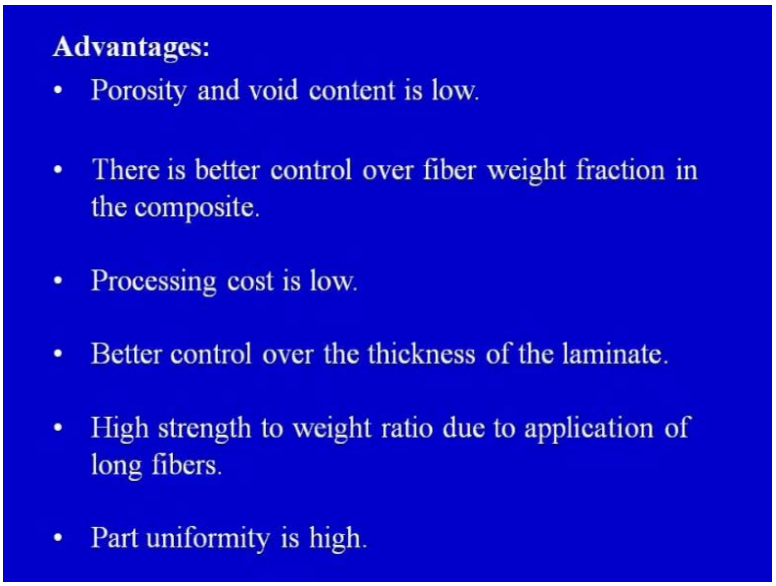
So, the polymer is not in we can say in semi solid sheet it is the fully solid sheet, then what we need to do if a polymer is in a solid state instead of liquid at room temperature, then a solvent is used to dissolved the polymer. So, we have to bring it to state where it

can impregnate the fibers dissolved resin is a plied on the fibers and the most of the solvent removed during the heating stage now the resin which was here in the solid stage. We have a added we can say solvent the solvent have resulted in the dissolution of the resin now this dissolved resin now it impregnating the fibers and then the impregnation process is complete the solvent is removed during the heating stage.

So, an important point to note here is that the polymer we are use in may be in liquid stage in semi liquid stage or in a solid stage. So, even if the resin if the polymer is an solid state we can use a solvent in order to dissolve this resin and final finally, this resin would be finally, form of pre pegging the sheet is trimmed and stored as prepregs in a cool dry place.

So, once the semi curing resin as the taken place and we have get a tape or we have get in the perform of tape which may be un-directional or bi- directional this particular tape than it trim from the corner and it stored in a cool dry place. So, sometime there is specific storage requirement for the prepregs and it may require very low temperature to the 2 minus of 18 degree, 2 minus 50 degree and those that temperature as to be maintain and this storage temperature would depend upon the type of the polymer that we have used for impregnating the fibers.

(Refer Slide Time: 25:26)



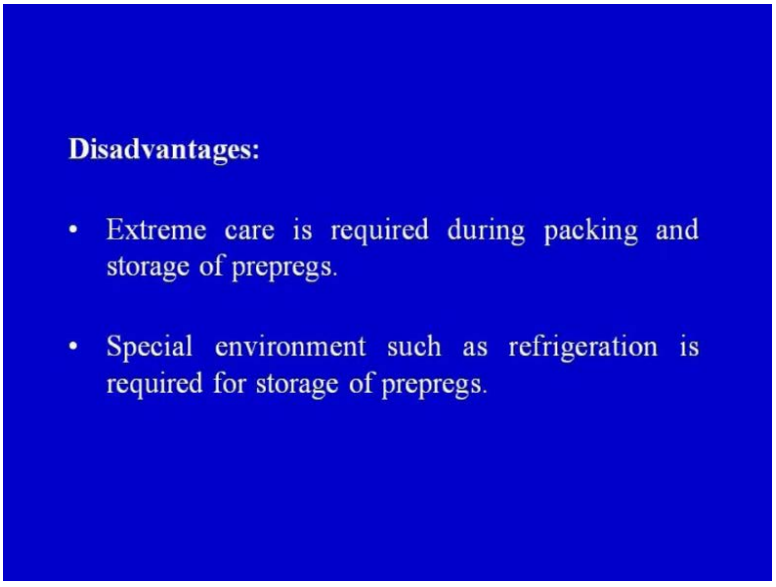
Now, what are the advantages of pregging? So, major advantages are porosity and void content is low, there is better control over fiber weight fraction in the composite,

processing cost is low, better control over the thickness of the laminate, high strength to weight ratio due to application of long fibers and part uniformity is high.

So, on your screen you can see different advantages which are possible when we use the prepregs for making the final composite product. So, porosity and void content is low because we are doing the consolidation process the rollers are being used to consolidate the different layers of the raw material that we are using in case of pregging fiber weight fraction because we can never metered amount of the fiber and we have metered amount of the resin that.

So, we can very easily exercise control over the fiber volume fraction and why fiber volume fraction fiber weight fraction is important because it dictates the final mechanical properties of the products that we are going to make out of these pre-peggs. Cost is low. It is not a sophisticated process and then better control over the thickness of the laminate can be achieved. We now know that we want to make a 4 millimeter thick laminate and we can easily control the thickness of single pre-pegg and we can see how many layers of the prepregs would be required to make a composite laminate high strength to weight ratio why because there are more fibers whenever the fiber weight fraction or the fiber volume fraction would be higher would have better strength to weight ratio part uniformity is also high.

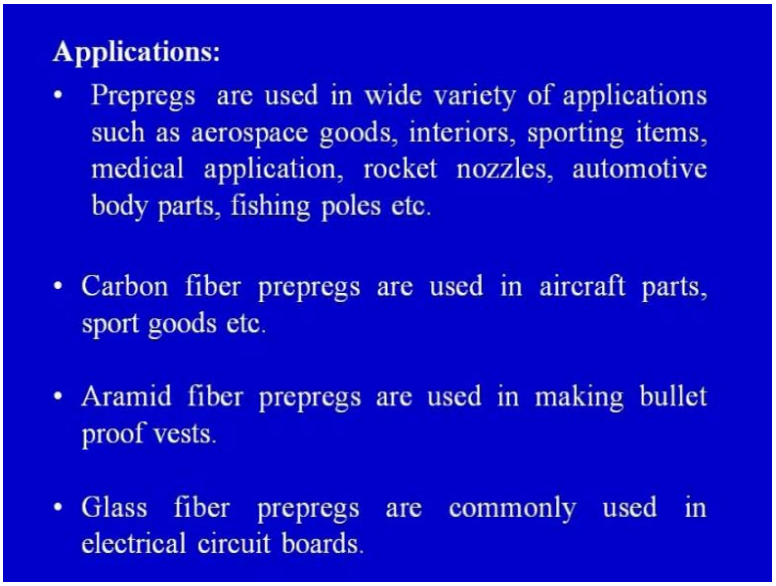
(Refer Slide Time: 27:10)



Now, what are the disadvantages of pre-pregging, there are some certain disadvantages like extreme care is required during packing and storage of prepregs which I have already highlighted, that there are certain storage requirements which have to be met otherwise at room temperature only the final curing may take place and the prepregs may become stiffer and may become unusable for the final processing for the different parts or different complex geometries for which we have developed the prepregs.

So, we extreme care, have to be exercised for storage of the prepegs and sometimes very low temperatures are required for certain polymers when we have to store them, special environment such as refrigeration is required for storage of prepregs that I have already highlighted.

(Refer Slide Time: 28:03)



And now, what are the applications of the prepreggs? So, pre-pegs are used in wide variety of applications such as aerospace components or goods interiors supporting items, sporting items like different equipment that we use for sports, medical application, rocket nozzles, automotive body parts and fishing poles.

So, different types of applications are there for these prepreggs. So, once the raw material in the form of prepregs is ready, depending upon the final shape of the product we can cut the prepregs put the pre-peggs on the mold on which we want to make the final product or the final desired geometry that we want to make and finally, take them to a farness or take them to a chamber where we manipulate the temperature at slightly

elevated temperature full curing of prepregs would take place and they would become fully solid and finally, the mold can be removed and we can get the final products out of the pre-peggs.

And we have seen in this particular slide, that there is large number of applications of these prepregs depending upon the shape, depending upon the complexity of the shape we can design and develop a mold and on top of mold we can wrap this prepregs and finally, cure this prepregs to get the desired product.

And now, there are few examples which are given in this slide you can see carbon fiber prepregs are used in aircraft parts sport goods etc. Sometimes pyramid fiber prepregs are used in making bullet proof vests glass fiber prepregs are commonly used in electrical circuit boards. So, different types of applications are there are depending upon the type of fiber in the prepregs depending upon the polymer in the prepregs.

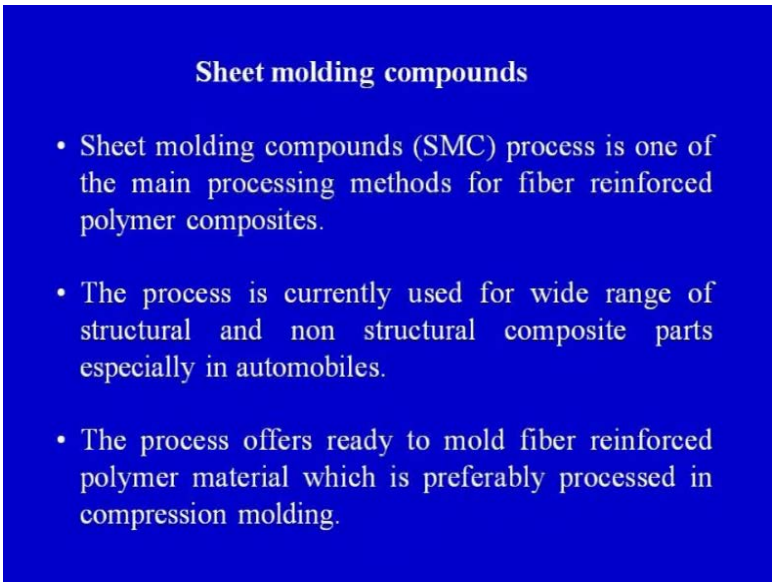
We can have different types of applications. So, we can have a layered structure of continuous fibers in case of the. So, we have seen that what is the process of pre pregging how it is different from the other process which we have already discussed such as hand layup product spray layup process filament winding paltrusion compression molding injection molding all this process is we have already discussed in the series of lecture zone processing of the polymeric matrix composites, but, this prepregs and sheet molding compound process is different from those processes because in those processes we are (( )) in those processes we are mixing the fibrous reinforcement and the matrix together during the process itself here we are mixing them at an earlier stage and then we are using the prepregs in order to convert it into a final product.

(Refer Slide Time: 30:46)

Now, coming on to the other type of the compounds which are used for finally, making composite product that is the sheet molding compound. So, the basic difference between the pre-pregging and sheet molding compound lies in the types of the fibers that we are using in case of sheet molding compound we would be using chopped fibers or shot fibers where as in case of prepregs we may generally sometimes we may use chopped fibers on top of the uni-directional long fiber tapes or the oven mates in order to give a specific type of texture on the surface of the prepregs or finally, on the surface of the final product.

So, sometimes we may have a layer of a continuous fiber which may be uni-directional or oven and we may spray chopped fibers on top of it while making the prepregs. So, we will have short fibers on top of the layer of the uni-directional or oven mates or a, oven fiber, but in case of sheet molding compounds in most of the cases our focus would be on using the short fibers. So, we will now see. What is a sheet molding compound? We will try to understand the sheet molding compounds with the help of a diagram.

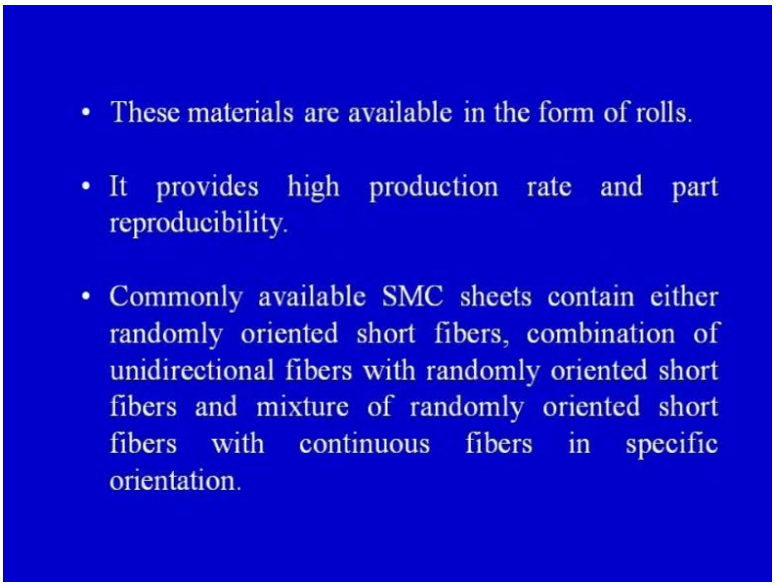
(Refer Slide Time: 31:57)



The sheet molding compounds or s m c as are they better known is one of the main processing methods for fiber reinforced polymer composites. So, the sheet molding compound acts as raw material for making the final product of the fiber reinforce plastic or the polymeric matrix composite. The process is currently used for wide range of structural and non structural applications especially in automobile industry the process offers ready to mold fiber reinforced polymer material which is preferably processed in compression molding. So, basically in sheet molding compound process we are making a raw material which would be subsequently used for other processes and sheet molding compounds are basically used as the raw material in case of the compression molding process.

So, we will have sheet molding compound, if you remember the basic principle of the compression molding process we have a two plate mold in which we have a top plate and bottom plate two important parameters are controlled that is the pressure as well as the temperature. So, we have a pressure control and we have temperature control and the raw material is placed usually in the bottom half of the mold and the top half of the mold is used to apply pressure on the mold or the compound which is put inside the top and the bottom half of the mold or the raw material which have been placed in between the two mold halves so that, raw material that we are putting inside the mold cavity is basically, are sheet molding compound.

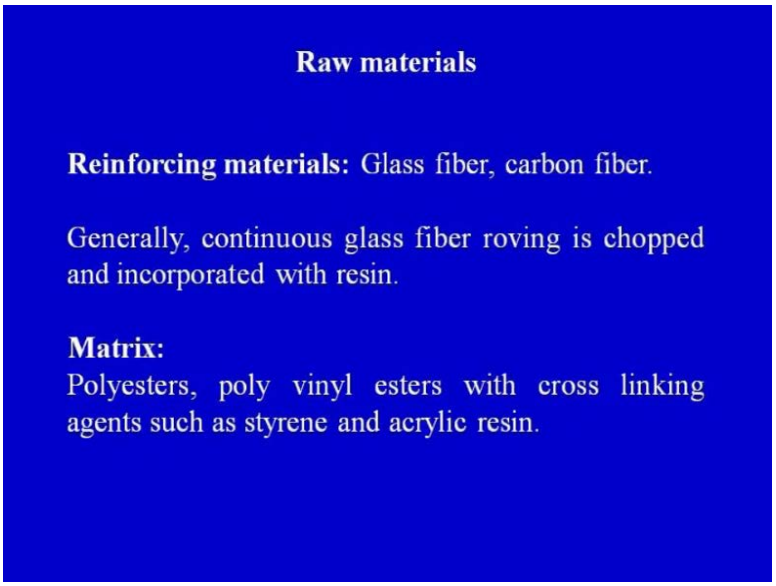
(Refer Slide Time: 33:39)



So, how the sheet molding compound is made? That we are going to see now in the subsequent slides. These materials are available in the form of rolls. So, we can have a sheet molding compound in the form of a roll the roll can be taken it can desired dimension can be cut it can be placed as raw material in the compression molding machine and finally, when the pressure would be applied and the temperature would be their this particular compound sheet molding compound will deform and take the shape of the mold cavity and we will get a final product in which we will have the fibers have the polymer and it would be a composite product.

So, here also the fibers and the resin are impregnated the resin is impregnated on. to the fiber than the (( )) and we can have a tape or a continuous tape in which we have short fibers and the un cured resin it provides high production rate and part reproducibility.So, this another you can say characteristics of sheet molding compounds commonly available s m c sheets contain either randomly oriented short fibers. Combination of uni-directional fibers with randomly oriented short fibers and mixture of randomly oriented short fibers with continuous fibers in specific orientation. So, here also sometimes may be using combination of fiber also for in most of the cases sheet molding compounds would be basically focusing on the short fibers reinforcement.

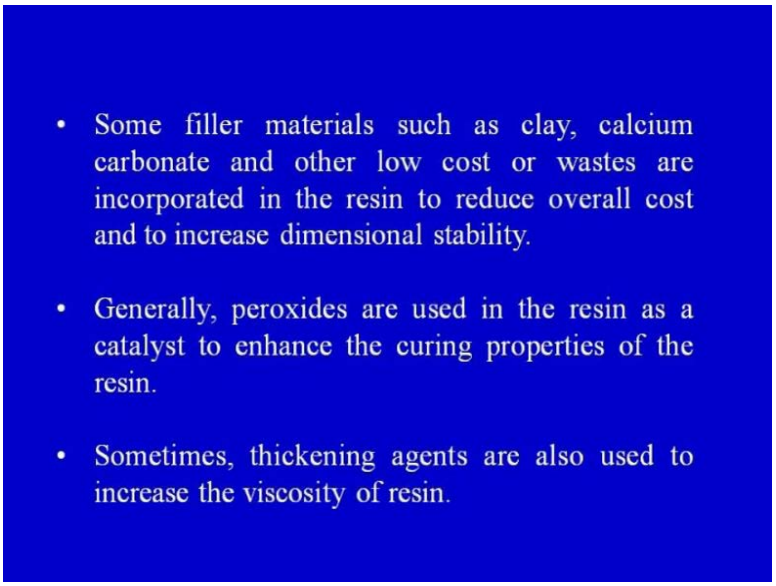
(Refer Slide Time: 35:08)



Now, what are the raw material that we are going to sheet molding compound the basic reinforcing, reinforcing material is the reinforcement materials are the glass fiber or the carbon fiber. Generally continuous glass fiber roving is chopped and incorporated with resin. Again the emphasis on short fiber roving only or roving contain the long fiber they are chopped in to small, small fiber than the short fiber these short fibers are used as the raw material for making a sheet molding compound.

So, we will try to understand this with the help of diagram and generally again I am emphasizing that short fiber reinforcement is one of the basic characteristic of the sheet molding compound. So, the metric material or the polyester can be used poly vinyl esters can be used and with cross linking agents such as styrene and acrylic resin.

(Refer Slide Time: 36:02)



So, different types of metric material can be used for making the sheet molding compounds, some filler materials such as clay calcium carbonate and other low cost or waste are incorporated in the resin to reduce overall cost and to increase dimensional stability of the sheet molding compound.

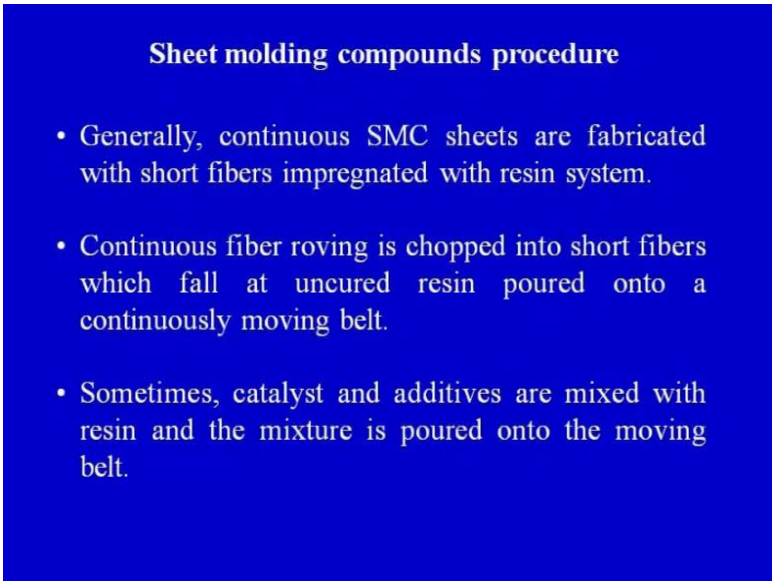
So, basically additional fillers which were used in prepregs also and also be used in the sheet molding compounds also. In this particular case, what are the types of fillers we are putting? Different types of filler can be used, some of the examples are clay or calcium carbonate and some time the waste material can also used in the form on the fillers to the metrics or the resin the resin would be mixed with the fillers and then this resin would be used to impregnate the fibers and what are the purposes is and why this fillers are being added in order to improve the dimensional stability and reduce the overall cost of the sheet molding compound. Generally peroxides are used in the resin as a catalyst to enhance the curing properties of the resin.

So, the peroxide can be audit into the resin in order to improve its curing characteristics, sometimes thickening agents are also used to increase the viscosity of the resin as we have discussed in previous lectures also. Whenever we have a polymer, the viscosity of the polymer is very very important which we have already seen in our series of lecture. In another module, processing of plastics they are the polymer melt, viscosity is one of the important characteristic. If the polymer will not have adequate viscosity very high

viscosity and very low viscosity both are not desirable, we that desirable characteristic that we should have an optimal viscosity.

So, sometimes we have certain agents in order to manipulate of the viscosity of polymer. So, in this particular point you seen in your screen you can see sometime thinking agents are also used to increase the viscosity of the resin we have to manipulate the viscosity of the polymer or resin in order to to make a very good quality.

(Refer Slide Time: 38:04)

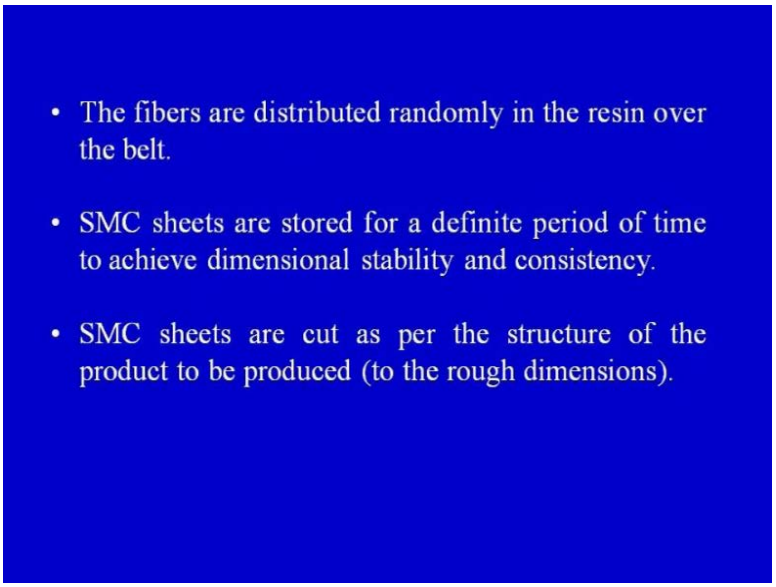


Sheet molding compound, sheet molding compounds procedure. How was sheet compound molding procedure? Generally, continuous s m c sheet are fabric with short fibers impregnated with resin system again the word short fiber is coming in to picture. So, in case of sheet molding compound majorly the focus would be on short fibers continuous fiber roving is chopped into short fiber the roving is the fiber coming in form of roving or cut it into small, small fibers chopped in to short fiber which fall at uncured resin poured on to continuously moving belt. So, there is a belt which is moving continuously and there is a packing sheet or we can say back up sheet which can be of any material any plastic material and top of there resin is there, now on this resin chopped fibers would be falling and when this chopped fibers are falling the fibers and the resin system is there in place on top of these another plastic sheets is put and then this particular assembling is finally, consolidated with the help of rollers.

So, again I am a trying to repeat the things again we have back up sheets on top of it we have the resin then chopped fibers are falling on this resin the resin is uncured resin the another top sheet is put on this particular resin and fiber system and this total assembly is then consolidated inside the rollers that we will see with the help of diagram where we will revise these important points.

So, sometimes catalyst and additives are mixed with resin and the mixture is poured into the moving belt. So, the continuous fiber coming from the rolling is chopped into the short fibers in the short fibers are used as a reinforcement material in sheet molding compound.

(Refer Slide Time: 39:51)

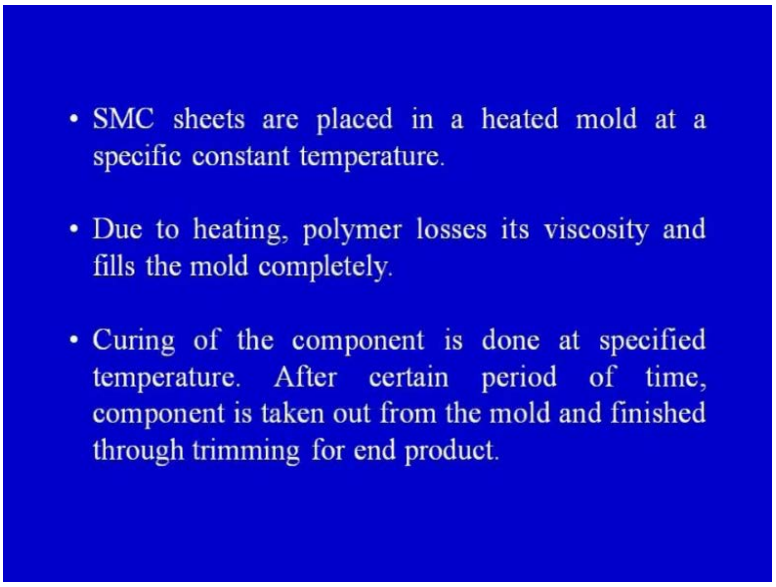


The fibers distributed randomly in the resin over the belt. So, will have randomly oriented sheet in sheet molding compound s m c sheets are stored for a definite period of time to achieve dimensional stability and consistency. So, once the sheet has been made before actually is use is these will be kept for some time, may be for a few hours depending upon the type of the polymer which has been used to make sheet molding compound it has to be stored that it becomes dimensionally stabled and it become consistent in thickness and other properties.

So, s m c sheets are cut as per the structure of the product to produced may be we have a complicated geometric now we have to put the s m c compound over this particular

geometry we will cut the sheet according to the dimension and then wrap this sheet on top of that mold.

(Refer Slide Time: 40:51)



And finally, cure the resin in order to sold if composite a final product, SMC sheets are placed in a heated mold at a specific constant temperature. So that, I have already highlight it that the SMC sheets would be cut in to the desire dimension and then it would be owned over or pasted over the mould of final product and this mold and SMC assembly would be put in a heated mold. we are we will have heat or we will have a temperature control and were the final curing of the SMC compound would take place due to heating polymer losses its velocity and fills the mold completely curing of the atmosphere curing of the component is done at specified temperature after certain period of time component is taken out from the mold and finished through trimming for end product.

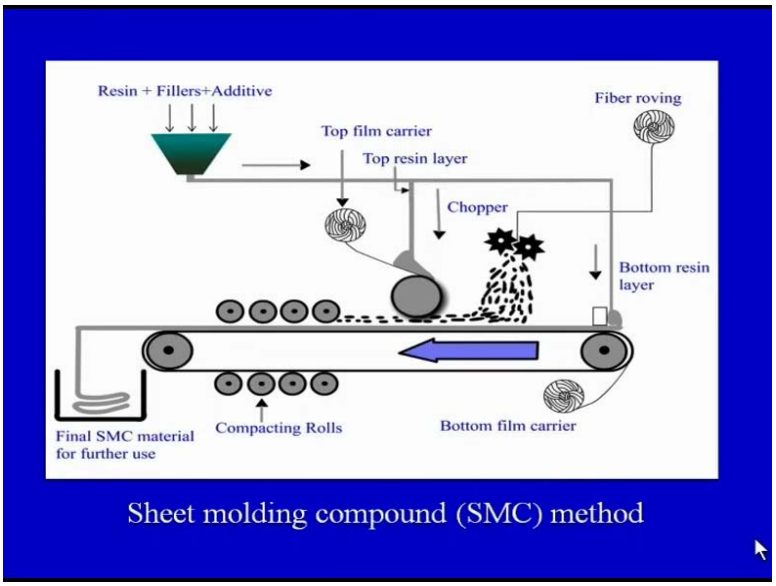
Basically, the process is same how we are getting the final product in case of pre-peging similarly, in case of sheet molding compound the finally, product would be got once these SMC compounder s m s sheets are ready once there SMC sheets are ready, then we are going to use the SMC sheet we would be taking them out from there storage places and we would raping them over the mold, Placing them mold depending upon the requirement.

And finally, we would become solid in them applying the pressure and applying the temperature and the resin would fill the mold cavity and we will get the desired shape as I have already discuses that sheet molding compounds are basically used as a raw material in typical compressing molding machine which we have already discussed the basic principle of completion molding machine.

So, in compression molding machine the SMC sheet would be placed a pressure would be applied temperature would be increase at increased temperature the resin would start to flow and when this resin would flow it would fill the mold cavity depending up on the shape of the cavity fibers are already in place we then finally, would be getting the final product. So, there are different types of uses of the pre prepregs and the sheet molding compound as one of the specific application of the sheet molding compound is in the completion molding set up.

So, in case of prepregs we already seen those would be owned are this would pasted over the mold and a pressure and a temperature may be applied in the form of consolidation this assembly would put in a heated mould the temperature can be increased when the temperature increases the curing of the prepregs are taken place and finally, the solidification of the product would take place in case of sheet molding compounds these compounds may be take inside the mold cavity pressure may be applied temperature is increased when the pressure is applied temperature is higher the sheet molding compound would take the shape of the mold cavity and we will get the final product.

(Refer Slide Time: 43:52)



Now, here you see how do make a sheet molding compound on your screen we have a very simplistic re presentation of a process which we used for generating a sheet molding compound. We can see fiber rowing on top, this is the fiber roving from here we will get the fiber, this is a fiber it will not be a single fiber that can be you can say a bundle of fiber which are used then, there are chopper here.

We see this is a chopper, these are the 2 chopper fibers are coming from here and getting chopped here. We can see a continuous fiber is coming from the roving and it is getting chopped at these particular stage and these chopped fibers then are falling on through a moving belt. This is a moving belt on your screen, this is rotating, this is the moving belt and then we have a bottom film carrier. A bottom film will move from here and on this film, the resin would be placed.

We can see this is the resin system, in the resin system we have the resin we have the filler and any other additives that have to be added in the resin. This is the resin mixture or we can say a polymeric, polymeric resin this resin is coming through this channel and it is coming on top of the bottom fill, another bottom this is the bottom fill carrier.

Here we have a bottom plastic fill that is coming here and on top of this film this particular resin is coming from this place to this place only the resin is getting pasted on the bottom film and here the chop fibers are falling on this resin, the resin would definitely be are liquid resin, here the chopper fibers are falling on the resin and this

particular mixture of resin and the fibers is moving in forward direction and here we have a top film carrier here and here the top film is coming in another top film is getting bound over the assembly over the resin and the fibers.

So, the mixture of the resin and the fibers is getting encapsulate between the bottom film and the top film. So, we have a film on topper fit the resin is coming at it is moving continuously chopped fibers are falling over the resin and finally, the resin and the fibers are being again encapsulated with the top plastic film.

So, what do we have a bottom film on topper fit we have a resin layer on topper fit we have the fibers which chopped fiber and top of the fiber and resin mixture we have another plastic film. So, this assembly are this 4 layers either in between the mixture of the resin and the fiber it would be a mixture some we cannot say it would be a independent that bottom would be resin and top would be fiber it is not like that when the fibers would fall the mixing resin and the fiber will take place fibers would get intragrint it in the resin.

So, we have not have three layers we have a bottom film we have a mixture of the resin and the chopped fiber short fiber and we have another film there that is the top film bottom film mixture of the resin and the chopped fibers and the top film. So, this three layer than finally, would be can solider by the roller these are the rollers on your screen these are the compacting or consideration roller this roller would press this assembly of different layers and finally, we would be getting the final sheet molding material for further use.

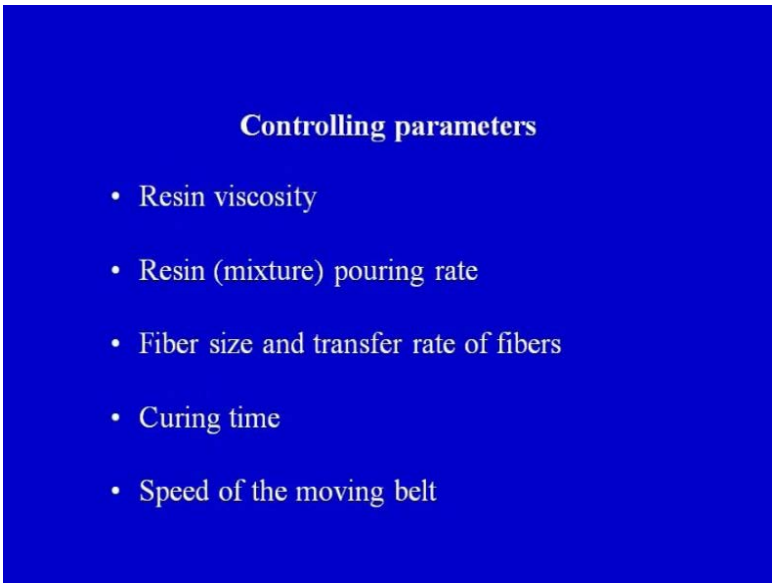
So, this is a raw material which would be further using for making the composite product. So, this would finally, can be used we have already seen it can be use as a raw material and can be placed an corporation molding machine where we can apply a pleasure maintain the temperature and we can get the final formed shape of the final product that we want through the final shape would definitely would depend upon shape of the mold cavity.

So, this particular diagram play in how a sheet molding compound can be made which would further act as the raw material to finally, make a composite product which would have randomly entitled fibers. So, again very briefly I would explain this process again we have a bottom film coming here the resin coming from resin tank the fibers

continuous fibers are coming from fiber rolling they are getting chopped here at the bottom we have a bottom film top of the bottom film.

We have a resin in the resin the fibers are getting added here from the chopped of the short fibers are getting added with the resin and this particular junction we have a top film which is coming. So, we have a bottom film we have the resin and the mixture we have a top of film at this particular combination is getting a solid dated pleasure is being a plied in the comp active for the consideration roller with the and finally, we are getting the sheet compound and this sheet molding compound would act as a raw material for other process is deforming the sheet molding compound into the final composite product.

(Refer Slide Time: 49:23)

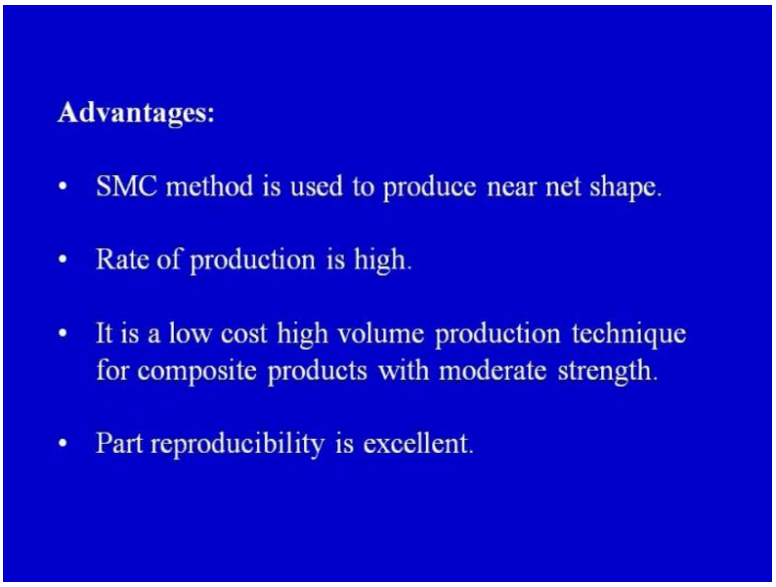


Now, what are the important controlling parameters in case of a s m c, the resin viscosity as we have a discuss earlier here also very very important and we need to have a optimal resin viscosity, resin pouring rate, the rate at which the resin is coming on top of the bottom film that is very important in bracket. We have seen mixture the resin is mixed with the additives and the fillers therefore, the resin mixture pouring rate is also very very important fiber size and transfer rate of the fiber is very important. If the fiber transfer rate is very very high it will be the chopped fiber, a huge quantity of chopped fiber is filling to the resin all the fibers man not get impregnated are there may be (()) of the fibers at one particular place which my act as the failure side when assuming

compound would be converted into a final product in using any of the further process techniques such as the completion molding.

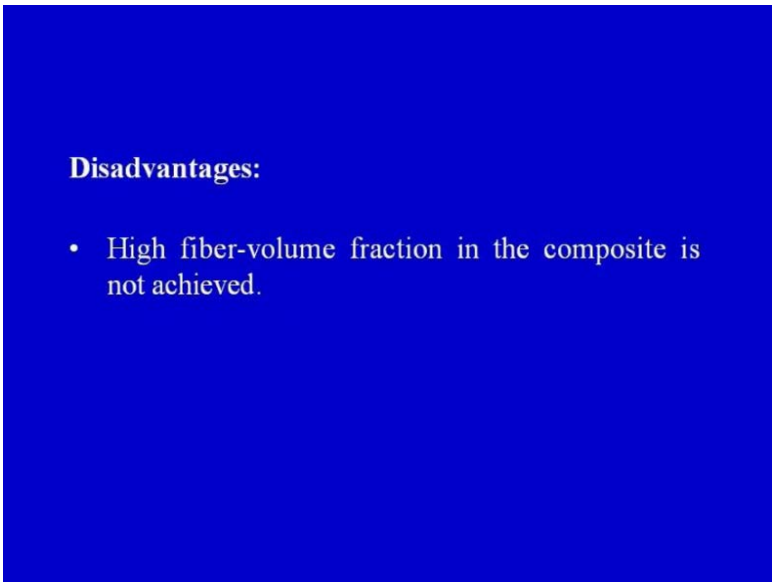
So, we do not want a globalization of the fibers at one particular place. So, we need to control or monitor the fiber monitor rate on top of the of the resin film the curing time is also equally important we should not over cure the resin and speed of the moving belt is also important because speed of the moving belt would dictate the thickness of sheet molding compound.

(Refer Slide Time: 50:44)



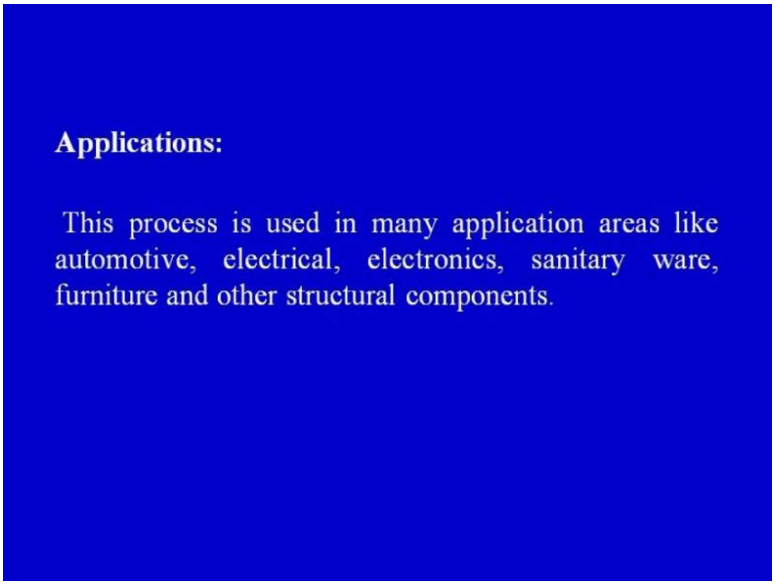
Now, what are the advantages of s m c? s m c method is used to produce the near net shape. So, s m c compounds can be use to making near net product the rate of production because it can be a continues product it is a low cost high volume production technique for composite products with moderate strength now again I want to emphasize here the term moderate strength because here we are using short fiber reinforcement we are using chopped fiber has the reinforcement material in case of s m c and whenever chopped fibers randomly oriented in the matrices would be used the strength would be comparatively less as compare to a continues fiber reinforcement in the form of mats or the fabrics, wherever we have mats and woven mat are fabric as the reinforcement material the strength of the composite product would be higher as in case of s m c. We are focusing on short fiber or chopped fiber we are strength would be moderate. Part reproducibility is excellent of s m c.

(Refer Slide Time: 51:48)



Now, this is the disadvantages of these sheet molding compound the high fiber volume fraction in the composite is not achieved with the fiber volume friction that we achieved in a sheet molding compound is relatively less to pre-peging why because, we are using short fiber reinforcement.

(Refer Slide Time: 52:06)



Now what are the applications of the sheet molding compounds, this process is used in many application areas like automotive, electrical, electronics, sanitary ware, furniture and other structural components. So, there are large varieties of applications of the sheet

molding compounds in making the automotive parts or in electronic industry sometimes insanitary.

So, an application are huge application are enormous and the sheet molding compounds are used as a raw materials for getting the final product. So, one of the process is which uses sheet molding compound as the raw material is a cooperation molding process. So, summarizing what we are covering in today's lecturing we have seen 2 important processes that is preparing and sheet molding compounds.

So, these two are we can say important raw materials which are finally, used to convert in to a final composite product and we have also tried to understand that how pre-peging and the sheet molding compounds are different from the product that we are produced using other processes. For polymeric metric composites such as the hand layup process spry up fill amid (( )) injection molding, all these process combine the fiber and the metrics in the process itself. We are in the pre-peging sheet molding, we are using them as the raw material. We are using the sheet molding components and the pre pegging as a raw material which would further be used in any of the processes and one of the process that used the sheet molding component has the raw material is the compression molding process.

So, here suppose we have the raw materials at this stage, we are bringing the raw materials, combining the two raw materials together and slightly increasing their process ability and finally, these are the sheet metal compound and pre-peging compound. Finally, they would be cure we will get the final product. So, we are manipulating the raw materials to make them more we can say controllable while we are processing in the final stage. So, these we can say bring us to the end of this particular lecture, in our subsequent lecture we will see other processes for processing polymeric matrices composites.

Thank you.