Processing of Polymers and Polymer Composites

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Lecture - 26
Sheet Molding

[FL] friends, welcome to session number 26, in our course on processing of polymers and polymer composites. Just you have a review of what we are covered in the previous sessions. We are currently focusing our attention on polymer composites and the various processing techniques that are used for processing of polymer based composites. We have seen that the major classification can be based on the mold, and we can see that we can have open mold processes and we can have closed mold processes. And if you remember just you revise once again in closed mold, we have seen compression molding, injection molding in open mold, we have seen hand layup, spray layup processes.

Moreover, we have seen other processes also; such as autoclave molding resin, transfer molding. And we have seen in the previous session another commercial process, which is used; that is pultrusion. So, the pultrusion process is used for long uniform cross section products, and the length of the product is not a limitation in case of pultrusion process. So, broadly there are two most commonly used commercial processes; that are filament winding and the resin transfer molding, as well as the pultrusion process. These three processes are most widely used in industry and the processes are fairly automated. Processes on the manual side we have a hand layup and spray layup processes, which are also widely used for making the large size products.

So, I think the learners must appreciate that the wide variety of processes are being used for processing of polymer composites, because of the reason that the application spectrum of these materials has increased most rapidly in the last 20 to 30 years, and because of the specific areas of application, there are specific processes that are used for processing of polymer composites. Currently we will be focusing on two important raw material. We can say it is not raw material; it is just advanced stage of raw material that is used for a raw material for processing of the parts.

So, we will see that how this raw material can be used for the processing of the products. So, today we are going to cover sheet molding compound. So, usually it is called as SMC

and sheet molding is a process in which we prepare a raw material, which is further processed, maybe in the compression molding process or maybe sometimes in the autoclaving process. Also we have already seen these two processes. We already know; what is compression molding process, we know that what is autoclave molding process, but here we will see that the raw material that is used in compression molding and in autoclave molding, how that raw material is prepared

So, the basic process is called sheet molding process, and let us see what is sheet molding with the help of the presentation SMC. As I have already told you SMC sheet molding compounds are very common materials that are used for molding of composite parts.

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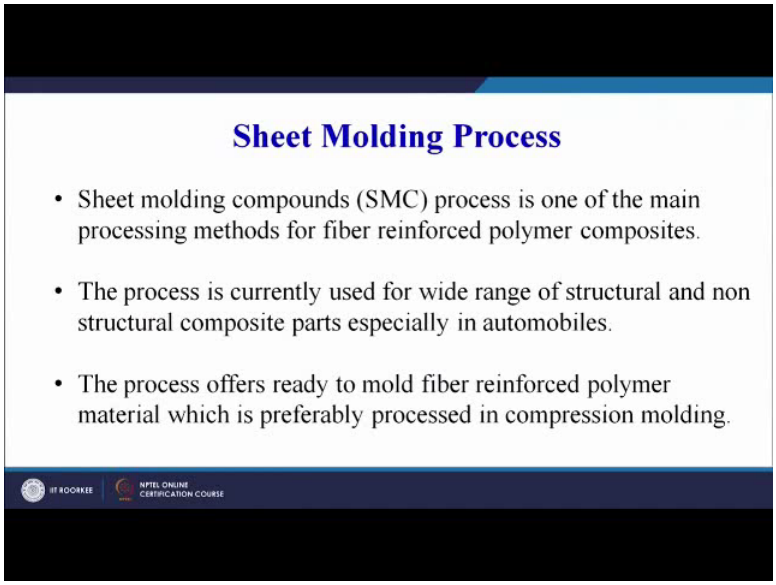

So, sheet molding compounds is one of the main processing methods for fiber reinforced polymer composites. So, it is half cooked, half-baked material which is fully cured to make a composite product.

So, it is a combination of the fiber and the polymer, but in a half cooked stage. Half cooked stage means that we have cured them, but partially we have not cured them fully. Partially means that little bit of strengthening has happened. Little bit of maybe solidification has happened, but it is not the complete solidification. So, final curing will give us the final product. So, here the sheet molding compound is one of the raw materials that will be further process to make a composite part.

So, the process is currently used for wide range of structural and nonstructural composite parts, specially in automobiles. So, in context of automobiles, this question would be much relevant. Sometime this may be asked that how; what is the full form of SMC. So, you can very easily answer, it is sheet molding compound. Now what is the SMC? You must be able to answer that it is a combination of a polymer and a fiber, in which the fibers are short fibers; where it is used. It is used as a raw material for autoclave process or a compression molding process. How it is made. There is a process mechanism that we will be, and trying to understand today with the help of a diagram and a video.

So, the point is that, it is in an important compound which is used for manufacturing of products or composite products and composite also, which type of composite fiber reinforced plastic products or a polymer based composite product. The process offers ready to mold. Now important point to not ready to mold. So, the process offers ready to mold fiber reinforced material, which is preferably processed in compression molding.

So, it acts as a raw material. The sheet molding compound acts as a raw material for the compression molding process, and I believe that all of you may be knowing about the compression molding process, which we have already covered, both for polymers as well as for polymer based composites, the sheet molding process.

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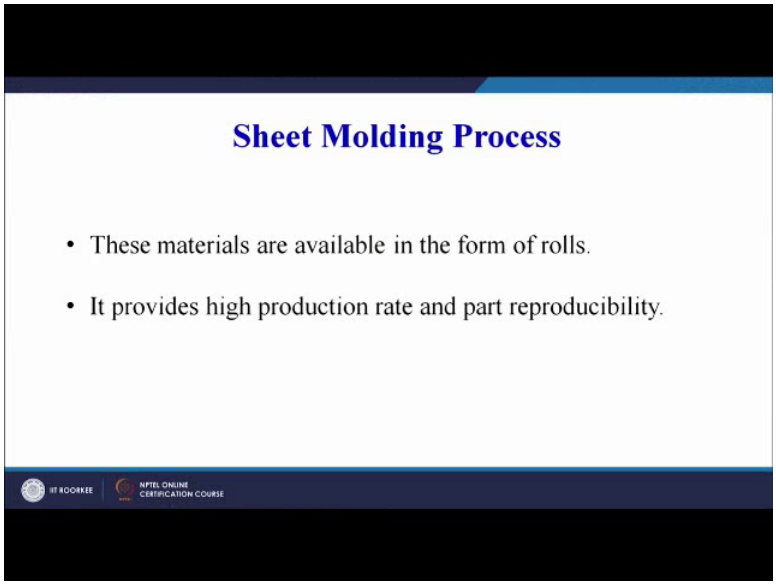

These materials; that is sheet molding compounds are available in the form of rolls. It provides high production rate and part reproducibility.

So, high production rate means that process is automatic automated, and we can very easily process the large volume of material in a very small duration of time, because of the continuity of the process, or because of the continuous nature of the process we can get a high volume production. In case of SMCs and the part reproducibility is also very good.

Now, what are the raw materials that can be used for sheet molding compounds. So, generally we are a, processes are well developed for synthetic fibers; such as glass fiber and carbon fiber, and generally the fiber will be in chopped form; that is a short fiber form. So, generally continuous glass fiber roving is chopped and incorporated with resin which acts as the matrix. So, fibers, there will be in short form. So, it will be a short fiber reinforced composite material, what will be the matrix. So, polyesters polyvinyl esters with cross linking agents; such as styrene and acrylic resin.

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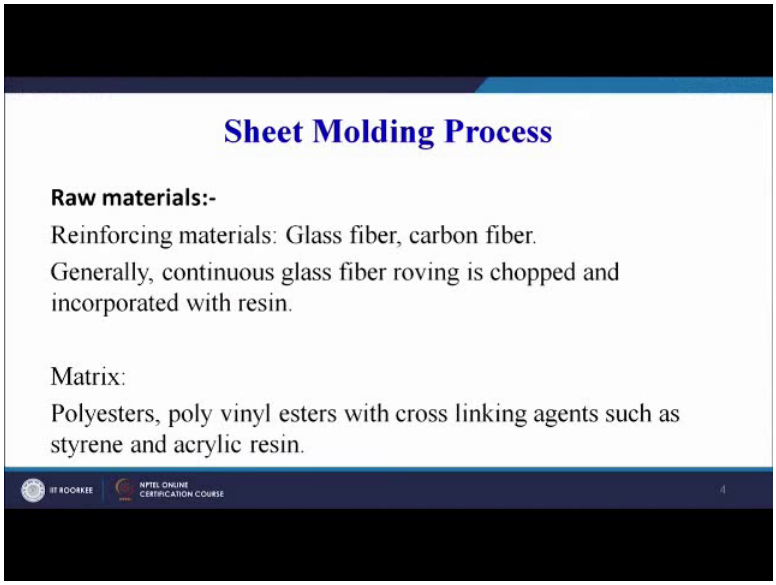

Now, why the cross linking agents have to be added in our other processes. We have seen the material is either in case of thermosetting materials, either a thermoset and a hardener or a catalyst, but here we are adding additional cross linking agent. The catalyst and the harder also provides the cross linking or the catalyst action during the polymerization or thermosetting resin, but here why we are adding additional cross linking agents, because we want to clear it partially, we do not want to cure it fully, that is one reason. Another reason is a time response in which the cross linking has to take place; that is also very

important, because the material when it is getting rolled in the final roll form, it should have attained sufficient degree of stiffness.

So, that it is rolled properly, and the cross linking must have started and initiated during the process itself, it make the finish, maybe slightly after the rolling process is over, but start and initiation, at least some degree of cross linking must happen during the process only. Therefore, we add additional cross linking agents to the thermosetting type of polymers.

So, the matrix is also kind of specialized in case of sheet molding compounds, and the polymer that we are using has to be added with additional cross linking agents. Whereas the fibers, the specialty is that they have to be short fiber or chopped fibers, which will be used as the reinforcing agents. Now the process, let us try. We have seen in the raw material; what is the specialty, additional cross linking agents are added, fibers are short fiber, chopped fibers. Now how the process takes place.

Now, for every process we have to see that how the fibers and the polymers will be combined together to make a compound. So, here we will see that; how was sheet molding compound is made, or what is the sheet molding process.

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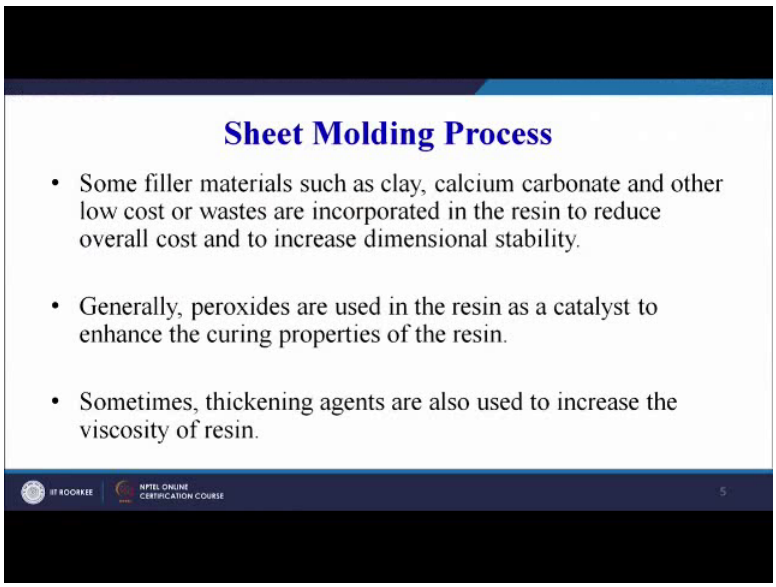

So, some filler materials; such as clay calcium carbonate and other low cost or wastes are incorporate in the resin, to reduce the overall cost and increase the dimensional stability.

So, that is another advantage, the cost parameter has been addressed here, that sometimes we add clay or calcium carbonate. May be some other low cost fillers also in order to reduce the cost, as well as they import or improve the dimensional stability of the sheet molding compound. Generally peroxides are used in the resin as the catalyst to enhance the curing properties of the resin. As in the previous slide also we have seen that the curing process is very important in case of making or processing of a sheet molding compound; why, because in the cycle product, development cycle or the process development cycle, we have to ensure that the curing process completes within that time domain only

Otherwise when you will start making composite materials, you will see that the very first video that we have seen in case of composites in the hand layup process. You might have seen and you will remember that fibers were cut with a scissor, and then this mat of fiber was placed on a very thin plastic film, and then we have applied the resin through a cup, and then we have consolidated it with the roller, then another layer of fiber mat was put, then another layer after applying the resin, step by step by step we have build up a laminate. And finally, we are closed the mold and we are kept it for curing.

So, the curing process may take 6 hours to 8 hours, maybe sometimes 24 hours to complete, and after curing we will get our solid product, because the polymerization process may have been completed. Although we have added the hardener and the catalyst in the epoxy or in the thermosetting resin

So, the curing cycle is sometimes very long, but here the partial curing is happening, and that has to be done within that time window only. Time window means, within that time interval only. And therefore, the curing we have to ensure that the partial curing, may take place or must take place within that time window only. And therefore, again and again the same point is coming into picture, that the additional ingredients constituents are added to the resin. So, that we are able to ensure that curing takes place quickly.

Sometimes thickening agents are also used to increase the viscosity of the resin. So, that is also very important. Generally continuous SMC, sorry these days SMS has become very common.

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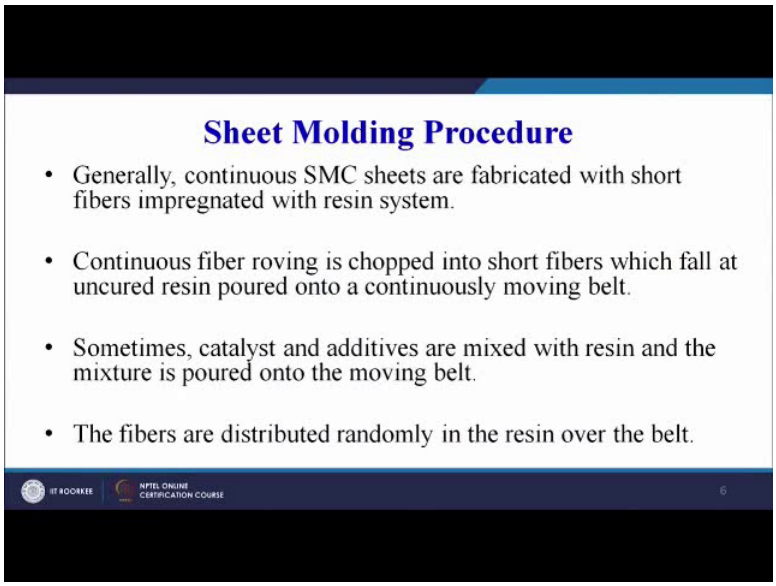

So, maybe continuous SMC sheets are fabricated with short fibers impregnated with resin system. So, here we will not have long fibers or woven mat form of fiber. We will have shot chopped fibers, which will be used as the reinforcing agents for the thermosetting type of polymers.

So, sheets are fabricated with short fibers impregnating the resin system. Continuous fiber roving is chopped into short fibers which fall at the uncured resin, poured onto the continuously moving belt. So, this we will try to understand with the help of a schematic diagram. We have a continuously moving belt, and on top of that we have a carrier film carrier, carrier film.

So, this carrier film we will put both our ingredients. Now what are our ingredients here; the first ingredient is a resin, the other ingredient is a short fiber, both this will fall on the continuously moving belt, which is having a carrier film. Then both of them will fall on the carrier film, it will move forward, and because of the heat that is supplied, or because of the harder and the other ingredients that we have added to the polymer, be the polymerization process will start. And after moving to a particular distance, but top side of the SMC compound will also be covered with the another carrier film.

So, on top and bottom we will have a carrier film. In between we will be having our SMC or sheet molding compound which is nothing, but a combination of the resin and the short fibers that we have introduced on to the carrier belt. So, the continuous fiber

roving is chopped into short fibers, which fall on the uncured resin, poured onto continuously moving belt.

Sometimes catalyst and additives are mixed with the resin and mixture is poured onto the moving belt. So, both our constituency we have to drop on the moving belt. The fibers are distributed randomly in the resin over the belt, because there short fiber be will not get any particular orientation of the fiber. They will be randomly oriented within the resin or the matrix system.

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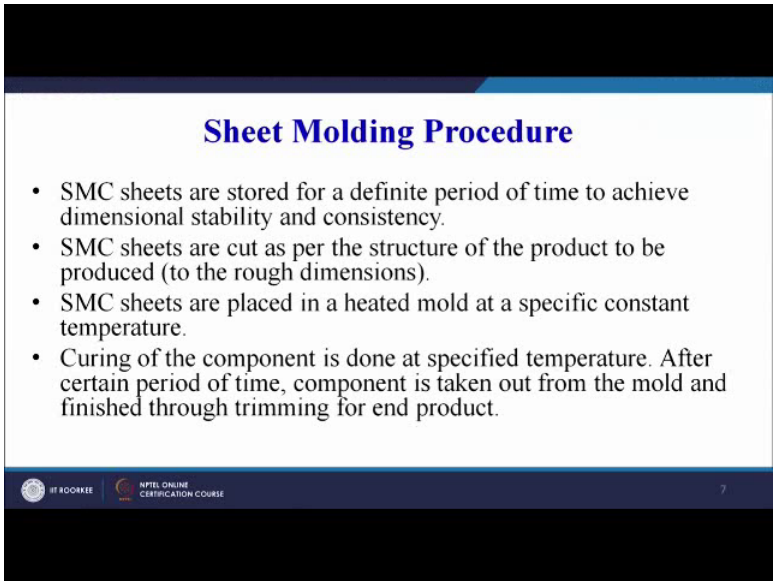

SMC sheets are stored for a definite period of time to achieve dimensional stability and consistency. I have already highlighted this point, that during the process, the curing process must start initiate and particular degree of curing must be completed. Then we will keep them, we will store them for the final curing process to happen. And after final curing, we will ensure that we have achieved particular dimensional stability and consistency. So, the curing process may take longer time, but within that time frame, during the process also, partial curing must happen during the process.

So, SMC sheets are cut as per the structure of the product, maybe to the rough dimensions, because later on we have to trim the part finally,. So, SMC sheets are cut as per the structure of the product to be produce. SMC sheet are placed in a heated mold at a specific constant temperature; now why heated mold, because we have to ensure the final curing of the resin system which has been incorporated into the short fiber.

So, SMC sheets are placed in a heated mold at a specific constant temperature. So, that we have to see, that what is the thermal cycle to which we are going, to which we are going to subject our SMC compound. So, the curing of the component is done at a specified temperature. After certain period of time, component is taken out from the mold and finished through trimming for the end product.

So, basically this particular three four points are emphasizing, the another process which we have already covered. So, in this particular sheet molding compound process, what we have to do. We have to club the fibers and the resin system together, and finally, the output of the sheet molding compound process would be a roll of the SMC. And that roll will then be used as a raw material, this cutting of the raw material as per the product, then placing the different layers, stacking up of the different layers in the mold, heating of the mold under temperature and pressure. All these falls under the subsequent process which we can call as the compression molding and if you are applying, maybe vacuum bagging also, we are a putting this inside a autoclave, we are maintaining a temperature and pressure inside the autoclave. Then we can sometimes call it as an autoclave molding process also.

So, the sheet molding compound will act as a raw material for the subsequent processes. So, the last three points on your screen are just giving the secondary or the next level of processing of the SMC. Today our topic is to see, that how the SMC is produced, and that we can understand with the help of this diagram; that is there on your screen. This is the schematic from Google images.

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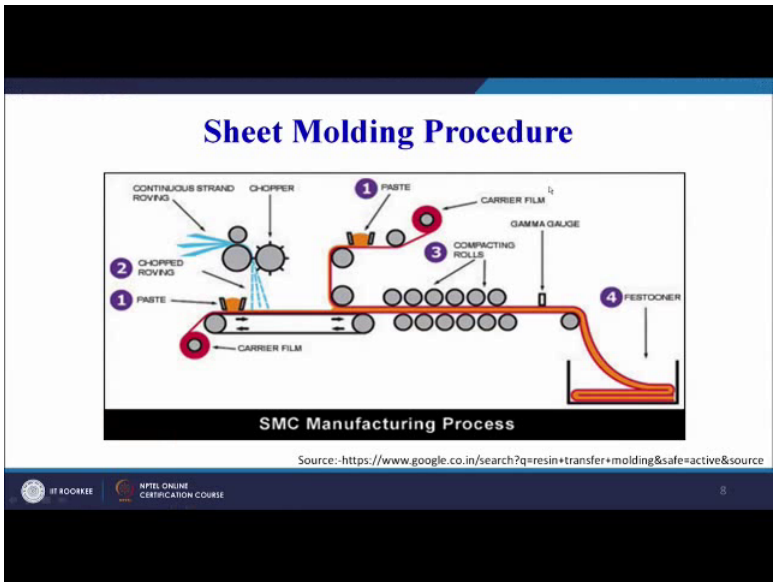

So, you can see sheet molding procedure. Let us first see this is a moving belt, which I was talking about. This is a moving belt continuously rotating. This is a red color is the carrier film, on which our both the constituents; the resin and the short fibers will fall.

So, it will carry; therefore, the name carrier film. It will carry both our compounds. So, one is the resin, this is the resin, and here we can see chopped fibers, continuous strand roving there may be crease air from where the rovings are mounted the fiber is coming, and it is getting chopped here. There is the chopper here, short fibers falling on to the carrier film, and where we have the resin system; that is coming, and it is moving forward. And then after moving to a particular distance, there is another carrier film; that is coming here, inside again we have the paste or the resin system, and then it moves forward these are the compacting rolls which will apply pressure.

So, that we get a uniform thickness of our SMC. So, these are the compacting rolls which are being applied. Then there is a gauge which can check the thickness of our product, that we are producing that the sheet molding compound. And finally, they are stored here. There can be a roll also, where they can be rolled in the form of a roll. So, basically the two ingredients are this resin system, or they are calling in the diagram as paste. So, we have a resin system and a fiber and we are combining them together, in the form of a tape or a roll.

So, the important things that we have to control here is, this speed of this belt, the amount of resin that we are going to use, the amount of fibers that we have to use, and then we have to see thickness that we have to control, than the amount of compaction these rollers are going to place or exercise on our sheet. So, this is the basic process.

Now, let us try to understand it with the help of a video. The video is available on YouTube. So, you can have a idea here. This is a carrier film, which is coming from here.

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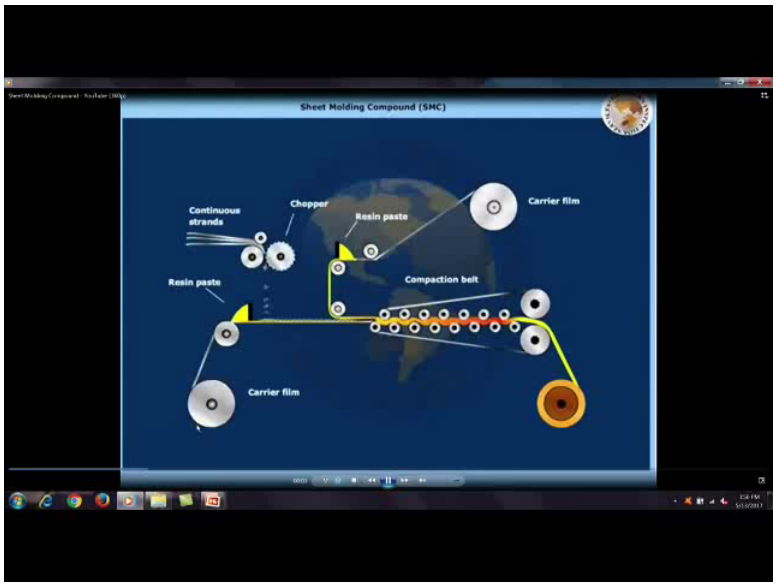

This is a resin paste, being applied, chopped fibers falling on this is moving ahead. This is another carrier film coming from here, again the resin plate or resin paste, this is coming from this side. So, the carrier film two carrier films. And before we use this product or SMC as a raw material for our subsequent processing, we will remove this carrier films and we will only be using the fiber and the polymer SMC that will be using as a raw material for a final product. And these are the compaction rollers, we can see here, and this is our final SMC compound which is getting rolled over the roller.

So, again just to begin, there is a carrier film, there is a resin and fiber falling on to the carrier film. After moving a particular distance, this carrier film will act as a bottom support for the SMC, and this carrier film will act as a top support for the SMC. So, it is on coming on the top, and the resin fiber together, sandwiched between the upper carrier film and the lower carrier film will move through the compaction belt, where it the complete SMC, along with the top and the bottom carrier film will be compacted and

finally, the compacted SMC will be rolled over the finished roller. You have seen the process I think.

Now, what are the control parameters? First thing is from the resin we have to control the viscosity that is first thing. Second thing is the resin mixture.

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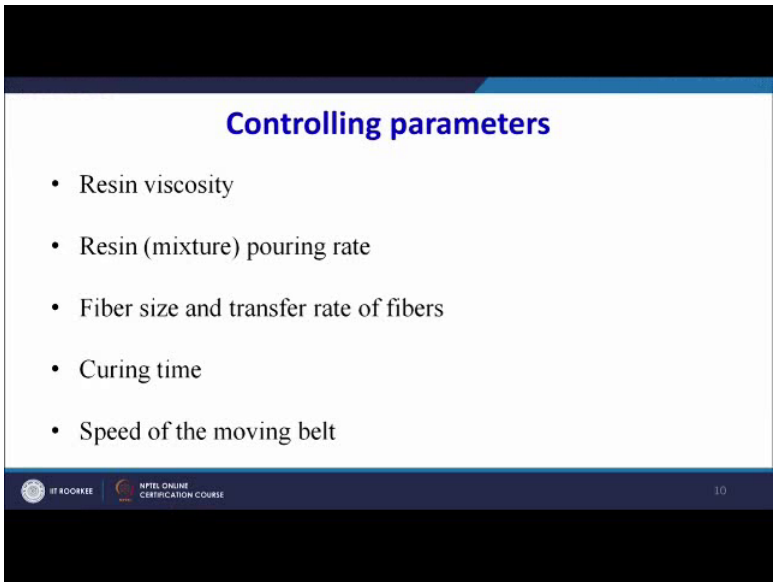

That is the pouring rate, or the resin pouring rate. Fiber size and transfer rate of, fibers we have to control curing time we have to control, and speed of the moving belt which already I have highlighted. So, regin viscosity is important, because the resin must be able to properly impregnate the fiber. So, that is therefore, the resin viscosity is important. Second is the resin pouring rate; that is also equally important if we are pouring the resin at a very fast rate, more resin less fibers product does not have the strength.

If we a very less resin, large number of, or large volume of fiber resin is not able t,o amount of resin is not able to properly impregnate the fiber, So again the product is not a poor quality, is of poor quality is not a good quality. So, the resin pouring rate is important, fiber size and transfer rate of fibers, the rate at which the fibers are being cut and are falling down on the carrier film, that is also very important. Curing time, we have laid lot of emphasis on the curing of the fibers, or curing of the SMC compound, and we have added number of ingredients in order to have a good curing cycle.

So, that is curing, time is also very very important, finally, the speed of the moving belt the speed. If it is very fast the thickness that we are planning to get for our SMC will very less, if it is very slow we may get a thicker SMC. And therefore, at the end we have a gauge to measure the thickness of our SMC compound. So, therefore, these are not the only parameters that we need to keep in mind. There will be number of other parameters which we need to govern, in order to get a good quality sheet molding compound. Why the quality of the SMC is important because it is going to be used as a raw material for our subsequent processing. And if the quality is poor the final product that we get, will not be up to the desired specifications, and therefore, the quality of the product would be poor.

So, we have to ensure judiciously optimally select, all these parameters. So, that our process is well within the control, and we get a adequate good quality, cost effective product. Otherwise quality maybe poor quality of the product may be. Now coming on to the advantages; usually we have finished all our sessions with advantages and limitations only. Now what are the advantages of SMC? SMC method is used to produce near net shape.

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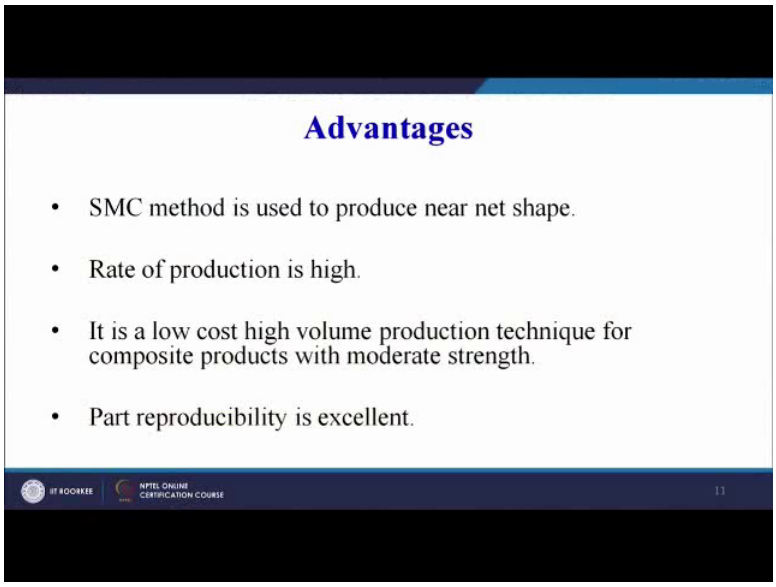

Now why, because whatever SMC product we are producing, we cut it as per the desired shape of our product, and then we stack layer by layer by layer up to a required thickness, and then we put it in a autoclave, and then we apply heat and pressure for final

curing of the product to take place. So, there is no wastage of the material in case of products being made by SMC, rate of production is high, as it is very very obvious that once you have a partially cured resin, you have to cut it, place it and then subject it to the thermal cycle the temperature and the pressure, and you will get your product quickly.

So, the curing time that is taken otherwise will be reduced, and here the curing cycle would be much quicker and faster. It is a low cost, high volume production technique, for composite products with moderate strength. Now cost is low volume high volume, because I have already told you the continuous process. So, therefore, the high volume production is bound to happen. And more over the last part moderate strength is important; why, because in this case we are using short fiber reinforcement, and usually for high strength applications we will go, for woven mat type of reinforcement.

Since we are using short fiber reinforcement in case of SMC compound, strength would be moderate. So, it will not be, we can say comparable with the reinforcement where we have continuous fiber in the form of mat. Part reproducibility is excellent why, because from the same raw material we are cutting the SMC sheets, and then they are being use for making the final product.

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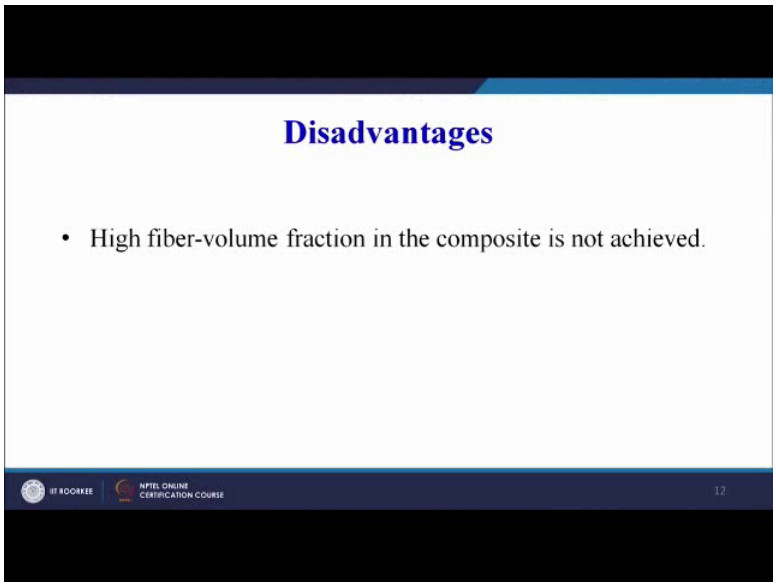

What is the disadvantage? The disadvantage is at high fiber volume fraction in the composite is not achieved.

So, we have to properly impregnate the fiber; therefore, we need to have a adequate amount of resin, and the viscosity also we have to control. So, that the resins are properly. Sorry the fibers are properly impregnated by the resin. Therefore, sometimes the high fiber volume fraction is not achievable in case of SMC compounds. So, with this we come to the end of our today's session on SMC. In the next session we will discuss prepregs, which we have already seen in one of the processes, I think it should come to your mind. I have explained the basic concept of prepregs there, if you remember in one of the animations we have seen, that the prepregs are coming the top and the bottom film are being removed, and then there cut as per the desired dimension, and there going, and being put on the mold surface, as per the design of the mold and finally, the curing or the heating is taking place. So, if you remember that process, that process was the autoclave molding process.

So, the raw material in that autoclave molding process was a prepreg and how the prepregs are made. The process is more or less similar to SMC, but these are important raw materials for, may be processing of composite based products. Therefore, we will see in one session that what are the prepregs, how they are manufactured, and what is the utility and advantages of using the prepregs. With this we come to the end of today's session.

Thank you.