Processing of Polymers and Polymer Composites

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Lecture - 21
Reaction Injection Molding (RIM)

Welcome friends. So, we are now into the second half of our course on processing of polymers and polymer composites, which is quite evident from the first screen; that is there for today's session we are into lesson number 21 in our course on processing of polymers, and polymer composites as you are well aware that; this is a 20-hour course and we have to have 40 sessions of half an hour approximately each. And we are now into the 21st session in the course. And if you remember in the last session, we have discussed as the process on your screen you can see injection molding. Today one word is added that is reaction injection molding.

So, in the previous session we have seen the intricacies on injection molding, and I think the process is absolutely clear to all of you. Today the reaction injection molding process is a slight variant of the injection molding process. The basic injection molding process as we have seen in the last session also. There is a in process cycle in which we have a mold closing, then we are filling up of the mold, then we have holding time for which the mold remains closed, cooling of the product find the opening of the mold. And finally, the ejection of the product from the mold.

But in this case the process is slightly different. We have to combine the 2 or 3 ingredients together or constituents together, and then we have to come up with the final product. In case of injection molding we have seen 3 variants in the previous session. The first variant was a pre blended pallets are available which have pre impregnated fibers already in the pallet form. So, we have a polymer pallet which has fibers inside it. And these pallets are used in the hopper and the process is done in the most simplest manner as for normal polymers.

Only thing only difference is the pallet shear are different the raw material is different, why? Because these polymers have pre blended fibers inside. So, that was one variant of introducing the fibers, the second variant was that you can mix the fiber and the polymer pallets, and directly feed them into the hopper. The third variant was specifically for

natural fibers; that you have a separate hopper for short fibers just at the end of the barrel and you can introduce the fibers into the polymer melt just before the injection of the polymer melt into the mold cavity.

So, 3 different variants of introducing the fibers was seen in the last parti last session, particularly for injection molding process. So, today our target is to understand that what are the other process variants for injection molding. And we can see we are the title we have given today is reaction injection molding. So, as all of you understand the chemical reactions. So, the reaction will be one part the 2 ingredients that are coming separately will react and then they will be pumped into the mold cavity. And mold cavity will with the exact replica or it will be the duplicate of the final product that we want to make.

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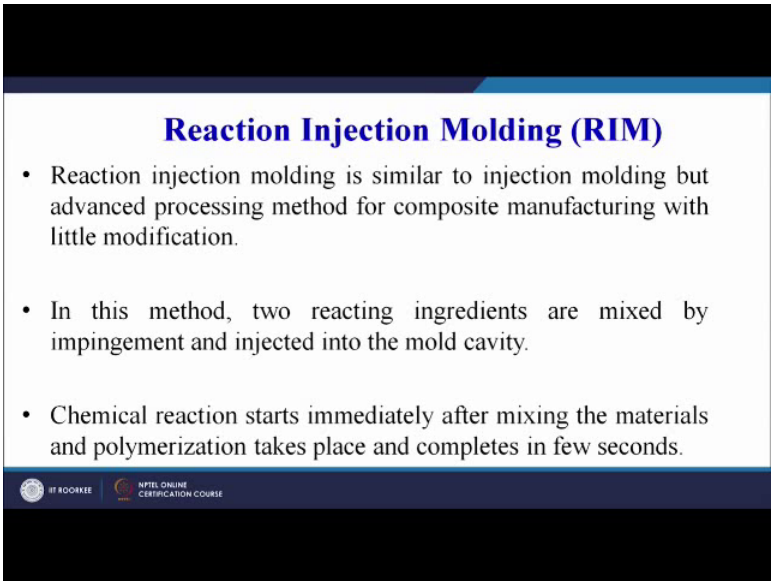

So, let us go through the presentation and try to understand the process. In reaction injection molding it is similar to the injection molding process, but advanced processing method for composite manufacturing with little modification. As I have already introduced in the beginning of today's session that how the process takes place in case of injection molding, and how the fiber is introduced into the polymer that we have understood. So, this process will also introduce another variant in which the fiber will be introduced separately into the final product.

So, this process is slightly we can say advanced or is a variant of the normal injection molding process. In this method 2 reacting ingredients are mixed by impingement and are injected into the mold cavity.

Now, I think one hint is being thrown here one hint is being shown here. And one hint has been printed in point number 2; that is 2 reacting ingredients. So, there will be 2 ingredients which will react. Now you can yourself imagine, we have seen that injection molding process can be used for both thermosetting and thermoplastic type of composites, I think I am right. In the previous session we have seen that. And most of the discussion that we did was focused on polymer melt we will apply the heat the polymer will soften, then the fibers will be introduced and the this mixer of fiber and polymer will be forced to the nozzle into the die cavity or the mold cavity. So, the polymer was available in the pallets forms, and which is a raw form of thermoplastic polymers.

So, we have seen that thermoplastics can be used for injection molding using the setup that we have covered in the previous session. But we have we were slightly silent on how the thermosetting resins will be used in case of thermo in case of injection molding process. And we have seen in our raw materials in the previous session, that both thermosetting as well as thermoplastic type of polymers can be used for injection molding. That we have already seen.

Now, let us see that how this hint is going to help us, and maybe it is possible that we will see today that this reaction injection molding maybe more suitable for thermosetting type of resins. Let us go through and try to understand. Now the chemical reaction starts immediately after mixing the materials, and polymerization takes place and completes in a few seconds. So, we have different ingredients coming from different chambers and getting mixed in a third chamber where the polymerization takes place. And finally, this mixture is pumped to the mold cavity.

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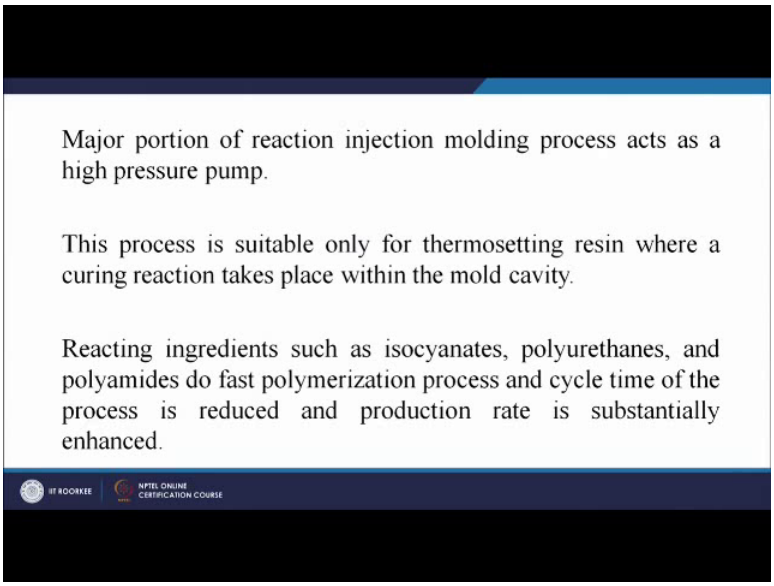

Major portion of reaction injection molding process acts as a high-pressure pump. So, I have already told that we have to pump this material into the mold cavity. This process is suitable only for thermosetting resin where are curing reaction takes place within the mold cavity. So, the hint which was dropped in the previous slide is has been confirmed here; that this process is most suitable for thermosetting type of resins.

So, the previous setup we have seen in our session number 20. As well as in a previous session when we were discussing the processing of polymers; is mostly suitable for thermoplastic type of composites. So, whenever thermosetting type of polymers will be used, we will make use of the reaction injection molding process. This process is suitable for only for thermosetting resin, where a curing reaction takes place within the mold cavity.

Reacting ingredients such as isocyanates, polyurethanes and polyamides do fast polymerization process and cycle time of the process is reduced, and production rate is substantially enhanced. If you remember in hand layup process we have seen; that it is used mostly and in most of the cases for thermosetting type of polymers only and the cycle time is quite large. Sometimes it may range for 24-hour cycle also cycle time also. But here you can see the type of raw material that we are using or the reaction ingredients which is isocyanates polyurethanes, the cycle time has been reduced or lowered. So, that is one advantage of reaction injection molding.

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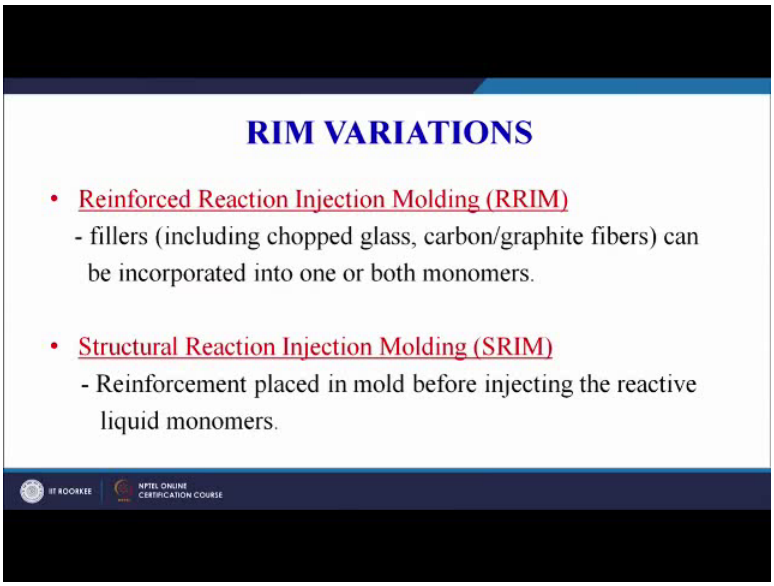

Now, reaction injection molding has further 2 variants. That is reinforced reaction injection molding RRIM, maybe you can again remember this acronym or RRIM, reinforce reaction injection molding in which the fillers including chop class carbon graphite fibers can be incorporated into one or both monomers. So, we can introduce our fibers or pre blend the fibers into the polymers or the monomers. Or the second variant is structural reaction injection molding that is SRIM. So, we have RRIM reinforced reaction injection molding, and SRIM; that is structural reaction injection molding the reinforce is placed in the or the reinforcement is placed in the mold before injecting the reactive liquid monomers into the mold cavity. And once the fiber is already there in the mold you introduce your monomers into the mold and finally, the reaction will take place, and the final composite product will solidify in the mold. The mold can be opened and the product can be taken out.

So, there are 2 variants of reaction injection moldings. Reinforced reaction injection molding, and the structural reaction injection molding.

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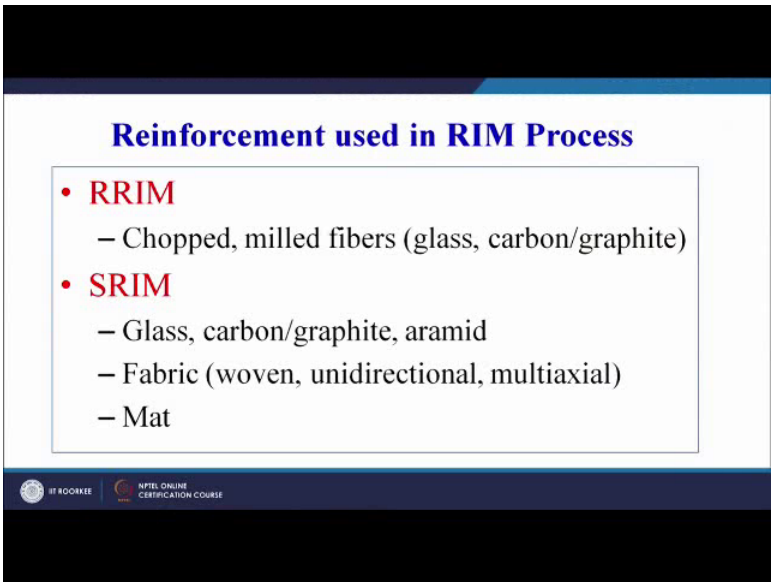

Now, let us try to understand these processes. The RRIM process as I have already told in the previous slide also. It is used for chopped or milled fibers glass carbon graphite fibers can be used as the raw material or the reinforcing agent for the thermosetting polymers.

In structural reaction injection molding we can use glass carbon same aramid fiber can be used. This fibers can be in fabric form woven or unidirectional multiaxial fibers or in the mat form; that is the mat and fabric we can just try to remember that they can be in the form of cloth. So, clothes everybody understand. So, it is in the mat form you have fibers in both the direction in the warp direction also, in the weft direction also. So, for a textile terminology point of view warp and weft is more appropriate. And from mechanical engineering point of view, we can say fibers are running in the longitudinal direction as well as in the transverse direction also.

So, we have the fibers that are there which can be preplaced into the mold cavity. The reaction components can come they can react their post into the we can say mold cavity we are the fiber is already there and finally, the they will impregnate the fiber and we will get our composite product on the curing of the polymers.

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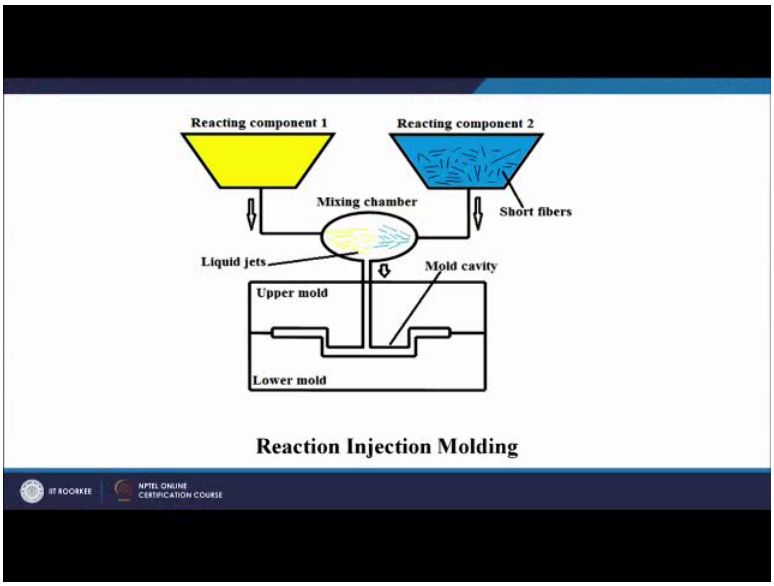

The figure is very clear on the screen. You can see there is one reaction component which is shown in yellow color. There is another reaction reacting component, which is shown in blue color and it can have short glass fibers also. You would short fiber this can be glass fiber this can be carbon fibers. Sometime this can be natural fiber also. Then there is mixing chamber in which the reacting component 1, and reacting component 2. There will be a mixer here. And then there are liquid jets here, and then you will push this material or pump this material into the mold cavity. The mold you can see is in 2 halves. The upper half of the mold and the lower half of the mold. The mold is in the closed position and it is forming a cavity, which is conforming to the shape of the final product that we want to make using these 2 reacting components.

So, we have a yellow reacting component it can be one type of a monomer, we can have another type of a monomer which already has pre blended fibers both of them are getting mixed in the mixing chamber and then pumped into the mold cavity. And we can once it has solidified we can open the mold and take out the final product. So, this is the basic concept of the reaction injection molding process.

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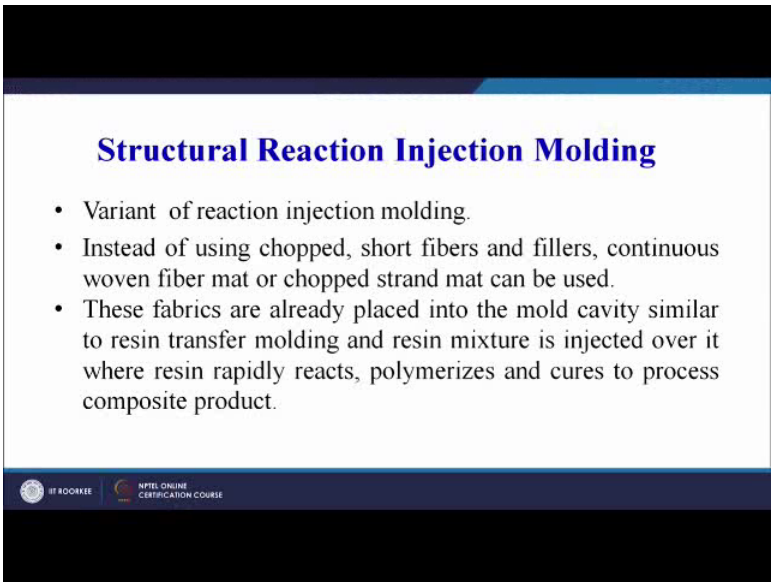

Let us see in structural reaction injection molding, what is going to happen it is a variant of reaction injection molding; as has already been explained. Now instead of using chopped short fibers and fillers as we have seen in our diagram. In the right-hand side, the blue reacting component was having short fibers. So, instead of using chopped short fibers and fillers continuous woven fiber matter chopped strand mat can be used.

So, in case of structural reaction injection molding we can have a mat form of reinforcement in which the fibers are running both in the lateral as well as in the longitudinal direction. So, these fabrics are already placed into the mold cavity. So, these are we have already seen in our previous slide also.

So, in case of structural reaction injection molding we will put our reinforcement in the mold cavity, and then we will mix the ingredients or the reaction component then push this reaction components into the mold cavity. Where the final curing of the polymer will take place and we will get a solid rigid composite product after opening the mold cavity.

So, this fabrics are already placed into the mold cavity, similar to the resin transfer molding process. Now one more process we are seeing here that is RTM and most commonly used process for making of composite products; that is a resin transfer molding. If some word is coming to your mind, I think it is good for our discussion. Transfer molding process we have already covered for polymers.

So, the similar concept, similar mechanism is there for resin transfer molding process in context of the composite materials. So, if you remember the transfer molding process for polymers, I think it will be it will be very easily clear to you that what is will what is going to be the process mechanism or process details for the resin transfer molding process.

Similarly, the structural reaction molding process or structural reaction injection molding process is also similar to the resin transform molding process. Because in that process also our reinforcement will be preplaced inside the mold, and our polymer will be transferred to the mold cavity at high pressure, and there it will react or it will may be form interface with the polymer pol between the fiber and the polymer and we will get our composite product on solidification.

So, here also structural reaction injection molding process also. The fibers in the woven mat form will be placed in the mold cavity, and the polymer will be or the reacting component or the reaction components will mix up in a chamber, and this will be pumped into the mold cavity. And there fiber already is there we have the resin also now entering into the mold cavity, and they will combined together to make a composite product.

So, the resin mixture is injected over it where resin rapidly reacts. Polymerizes and cures to process the composite products. So, fiber is already there polymer we are injecting through the chamber, and once the polymer and the fiber are there in the mold cavity, they will have very good friendship and they will develop a interface, and final product will be developed on polymerization and solidification.

Now, let us try to differentiate one I think question remains. That what is the difference between resin transfer molding, and structural reaction injection molding. So, I think that question we will try to address, when we will discuss the resin transfer molding process as applied to the composite materials or the polymer based composite materials. So, let us first try to understand the difference between the reaction injection molding, as well as the injection molding.

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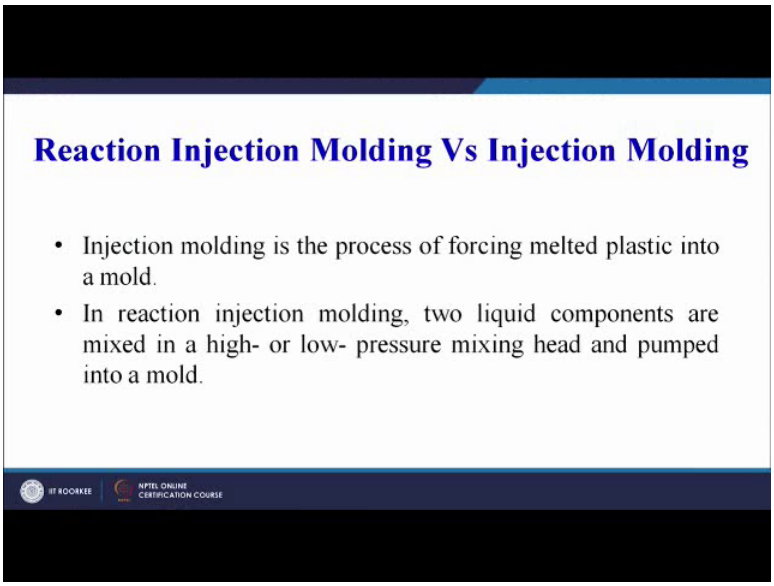

Now, injection molding is the process of forcing the molten plastic into the mold. So, that is the basic concept of injection molding. In reaction injection molding 2 liquid components are mixed in a high or low pressure mixing ahead and pumped into the mold. Now if you remember in the injection molding process if you remember the diagram, the polymer or the polymer pellets come from the hopper. They enter into the barrel the barrel is heated because of the heating arrangement all around it is periphery, and then the screw inside the barrel fields this molten of fields this polymer palette forward towards the mold cavity. And because of this length and the shearing action by the screw this polymer melts, or this polymer softens. And this soft polymer then moves forward with the screw or the rotation of the screw and it is fed through the nozzle into the mold cavity.

So, that is the basic concept of injection molding. Whereas, in reaction injection molding as we have seen today there will be 2 reacting components, there coming there getting mixed in a mixing chamber and from there they are being pumped into the mold cavity. So, here there is reaction taking place between the 2 components. Whereas, in case of injection molding there is no reaction taking place, the direct polymer that is coming from the hopper is being fed into the mold cavity through the barrel which has a got a heating arrangement. So, there is no chance of any reaction between the different constituents.

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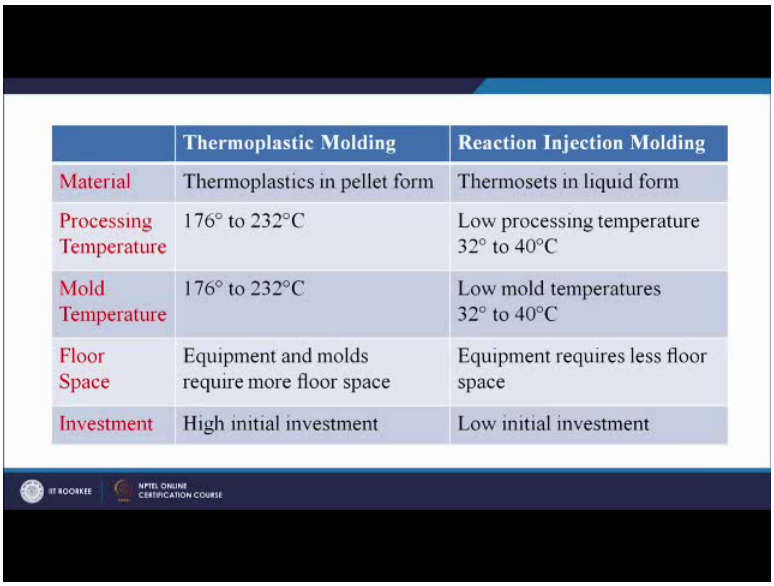

Now, let us try to understand the conventional thermoplastic molding versus the reaction injection molding. Now in thermoplastic molding we have seen the thermoplastics is in the palette form. Whereas, a thermosets is in the liquid form. So, as we have seen in the very beginning there was a hint that; this is because of the reaction between the ingredients, and the reaction usually takes place between the harder. And the polymer that is in the form of epoxy or polyester which is a thermosetting resin.

So, we have seen that yes the reaction injection molding process. Maybe more suitable for the thermosetting type of polymers. And therefore, it is clear in this differentiation also; that in thermoplastic molding thermoplastics are available in the palette form. Whereas, in reaction injection molding the thermosets are used which are available in the liquid form.

So, processing temperature range is given we cannot be 2 specific with this range, but the broad range is 176 degree to 232 degree centigrade. Whereas, in reaction injection molding the temperatures are considerably lower or the lower low processing temperature in the range of 32 degree centigrade to 40 degree centigrade. So, the mold temperature we can also see the low mold temperatures in case of reaction injection molding, floor space the equipment and molds require more floor space. Whereas, equipment requires less floor space in case of reaction injection molding process and if you have seen any standard injection molding machine it is a large size machine as

compared to the size of the product that it can process. For a very small product maybe of the size of this pointer we may have a machine, which may be as low as good as maybe 8 feet, which will occupy maybe 8 feet by 8 feet room.

So, the size requirement of the injection molding machine is larger as compared to the reaction injection molding machine. So, in a high initial investment is required for thermoplastic molding. As I have already told you that the investment because we have to properly control the process in injection molding, when we are using thermoplastics as a raw material and injection molding as the process we have to have precise control over the process. If you see in the last session we have listed on so many parameters the injection pressure the injection temperature, the clamping force the holding time and then there are other parameters like the melt viscosity.

There are parameters in the terms of heating rate the heating cycle. All these parameters need to be controlled, and when there are so many controls that we have to exercise over the process the process automatically becomes slightly expensive. Whereas, in reaction injection molding process the process is not that expensive, why? Because we are not going to control too many parameters. So, therefore, the process remains navy within the capital investment limits.

Now, what can be the advantages of this reaction injection molding. As we have seen reaction injection molding also has got further 2 variants; that one is the reinforcement reaction injection molding and the other one is the structural reaction injection molding. And after today's discussion it should be absolutely clear to all of you that; what is the difference between the structural reaction injection molding and the reinforcement reaction injection molding.

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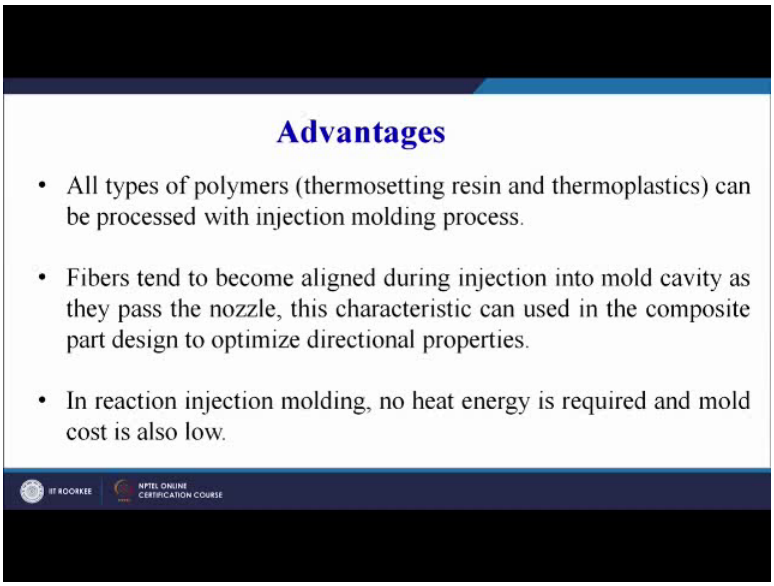

So, advantages of this process is that all types of polymers that is thermosetting as well as thermoplastic. Now I think this we need to understand that for reaction injection molding process majorly we are going to use the thermosetting, but in special circumstances we may also use the similar process for thermoplastic type of raisins also. Can be processed with the injection molding. Now injection molding in general we can say both thermoplastics and thermosets can be used. Conventional injection molding process most suitable more suitable for thermoplastics. Reaction injection molding process both it is variants that is reinforcement reaction injection molding, as well as the structural reaction injection molding more suitable for thermosetting type of polymers. Fibers tend to become aligned during the injection into the mold cavity as a pass through the nozzle. This characteristic can be used in the composite part design to optimize the directional properties.

Now, our melt mixture which has fibers also, when it moves through the nozzle and it enters into the mold cavity the fibers have a tendency to get aligned in one particular direction. And if you understand the composite from the mechanics point of view, the direction of fibers in a composite also plays a very important role. And we get properties different in different directions. So, along the direction of the fibers we will get different properties. Across the direction of the fibers we will get different properties.

So, if we can control the orientation of the fibers in our composite, we can very easily control the properties of the developed composite also. And in injection molding we have this liberty, we have disadvantage that we can control the movement of the fibers inside as we are using short fiber. Direction of fiber alignment also plays an important role and in injection molding we can with the optimal design of the nozzle the diameter the gate the runner, we can try to ensure the directionality or the direction of fiber in the final product. And that will help us to make products which have directional properties. Sometimes some people usually call it as a we can say, smart materials or maybe not the smart materials may not be the right word the right word can be functionally graded materials having specific properties in specific directions.

So, that type of advantage lies with the injection molding of composite products, in reaction injection molding no heat energy is required and mold cost is also low. Now why it in reaction injection molding? Because the polymerization takes place because of the reaction of the 2 ingredients or the 2 constituents that are coming from 2 reaction chamber, and the process is exothermic. So, the heat of the reaction helps in the curing process, and no additional heating system is required as in case of the conventional injection molding process.

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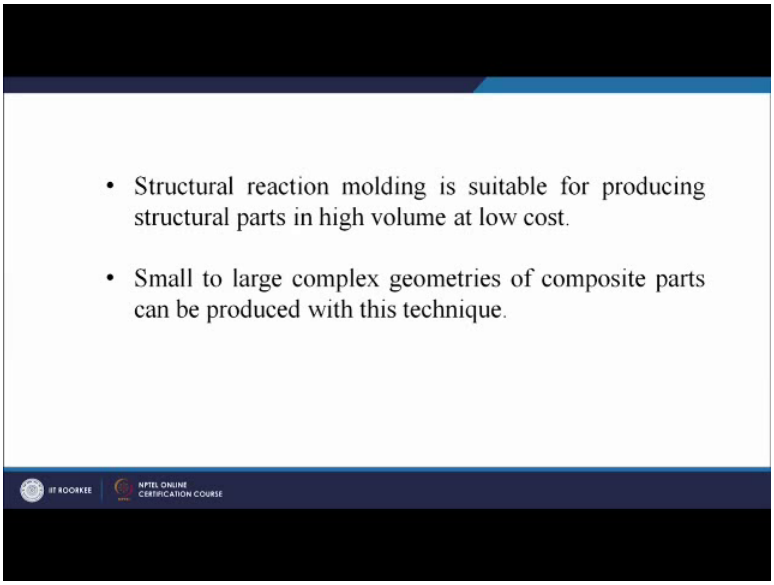

Structural reaction injection molding is suitable for producing structural parts in high volume at low cost. So, that is one of the advantage, which is specific to structural

reaction injection molding small to large complex geometries of composite parts can be produced with this technique. So, the complexity can also be achieved with the reaction injection molding process. What can be the limitations now? Mainly suitable for chopped fiber reinforcement.

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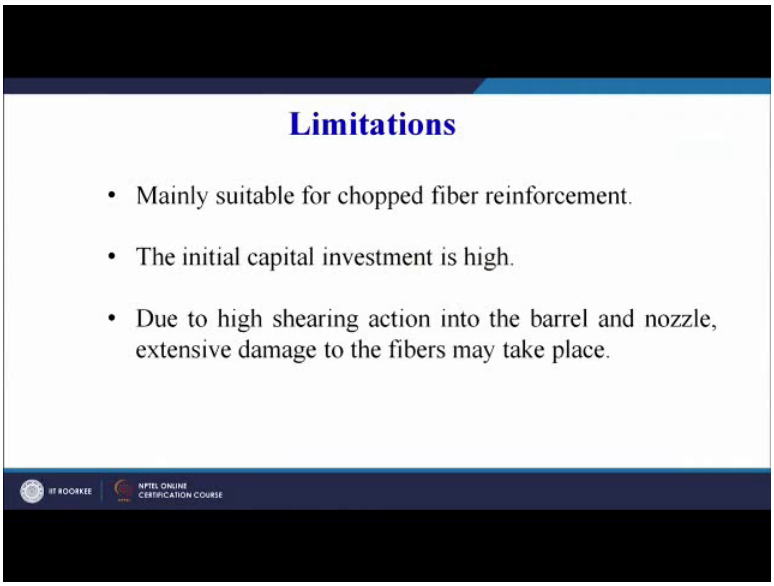

Whereas the structural reaction injection modelling can be used for woven mat type of fibrous reinforcement also. The initial capital investment is high, maybe it may be higher as compared to the hand layup or the spray layup process, but will certainly be lower than the conventional injection molding process. Due to high shearing action into the barrel and nozzle extensive damage to the fibers may take place, specifically in case of the conventional injection molding process.

So, there are few more disadvantages quickly we will go to go through them.

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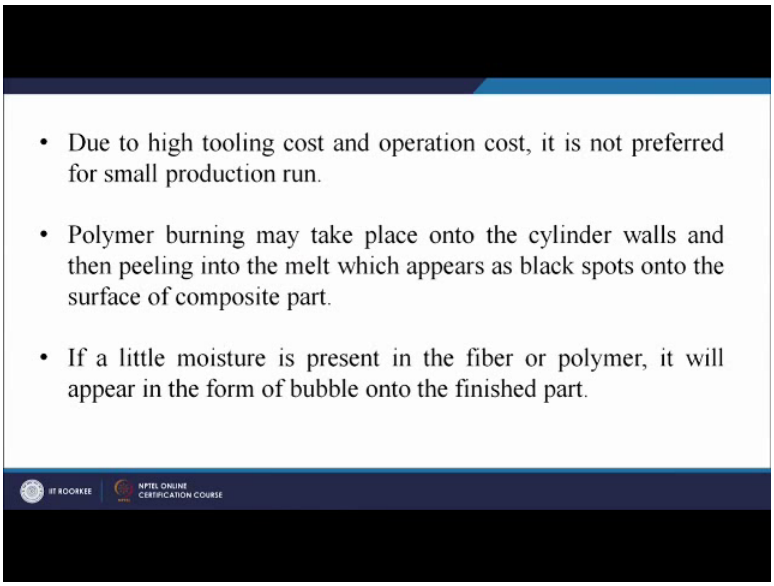

Due to the high tooling cost and operation cost is not preferred for small production run which was highlighted in the very first slide that we have seen; that in the injection molding process that process should be used for large volume mass production when large number of parts have to be made. The process is not suitable for a small number of parts.

Polymer burning may take place on to the cylinder walls and then peeling into the melt which appears as black spots on to the surface of the composite parts. Excessive heating may lead to this type of defect that is black spots on the composite part, because of the burning of the polymer which needs to be avoided. And if a little moisture is present in the fiber or polymer it will appear in the form of bubble in the finished part.

So, usually it is advisable that when you are going to go for injection molding the constituents or the raw materials must be put in an woven for a specific duration of time at elevated temperature to remove all the moisture. Otherwise this moisture may appear in the form of bubbles on the final composite product. So, that has to be avoided there are methods to avoid these kind of defects.

So, with this we come to the end of our discussion on injection molding process. In order to summarize we have covered the injection molding process for processing of polymers. In our discussion during processing of polymers. We have covered injection molding process for processing of composite products. We have also covered 2 variants of the

injection molding process in the form of reaction injection molding process, as well as the structural reaction injection molding process. So, in the next session we will focus our attention on other techniques on used for processing of polymer composites.

Thank you.