Processing of Polymers and Polymer Composites

Dr. Inderdeep Singh
Department of Mechanical and Industrial Engineering
Indian Institute of Technology, Roorkee

Lecture – 12
Rotational Molding

[FL] friends, welcome to our session 12 in our course on processing of polymers and polymer composites. We are in the process of discussing the various processes that are being used for processing of polymers worldwide. If you remember and if you have attended all sessions earlier, you may appreciate that we have already discussed casting thermo forming extrusion compression molding injection molding, processes for processing of polymers. We are still to start the process or start the process for learning or for understanding the processes that are used for fabrication of polymer matrix composites or polymer composites part.

So, today is our twelfth session of half an hour. And we have to complete the course in forty sessions of half an hour each that is 20 hours of discussion. Today our topic is rotational molding. So, as I have already emphasized currently we are focusing on processing techniques, that are used for processing of polymers or plastic parts. We are still to start with plastic composites or polymer matrix composites. So, rotational molding process is one such process that is used for processing of polymers.

Now, some of you may be wondering that every day we or every session, we learn about a new process about processing of polymers or plastic parts. Why? What is the need of? So, many different types of processes, why? If you see the processes are different based on different aspects. If you remember in the beginning of our course that is processing of polymers and polymer composite, we have seen that there are different types of polymers each polymer has got different properties. Now properties can be chemical property those can be physical properties those can be mechanical properties.

Now, for each and every polymer there is slight difference in properties here and there. Now because of the difference in the properties specially the chemical curing or the polymerization property. We have to see that what type of process can be applied for a particular type of polymer, if you see we have certain processes which are very well established for thermo set based materials or thermo setting materials. There are other

processes that are very good for thermo plastics, for example, injection molding mostly used for thermo plastic materials.

So, therefore, there is a distribution there is a classification of different types of processes also you may appreciate that depending upon the type of the product. And the volume of the product that we want to produce. Now type of product I mean to say the complexity the shape of the final product that we want to produce. And similarly the volume means that the number of products per hour or number of products per day. So, that will also require a different type of process there may be processes like rotational molding process that we are going to cover today is not a very mass production process may take a lot of time or maybe take a lot of cycle time for producing one part whereas, injection molding. If you remember the cycle time is 2 second to 60 seconds that in 60 seconds we can produce one product.

So, why that is possible because the size of the product that we make in case of injection molding is relatively smaller as compare to rotational molding, where the size of the product will be very large. It will be access symmetric large hollow product in case of rotational molding. So, the basic principle of processing of polymers or plastics remains same. That is, we have to heat the polymer we have to change the shape of the polymer using any diver mold arrangement. And finally, we have to cool the polymer. So, that it takes the desired shape.

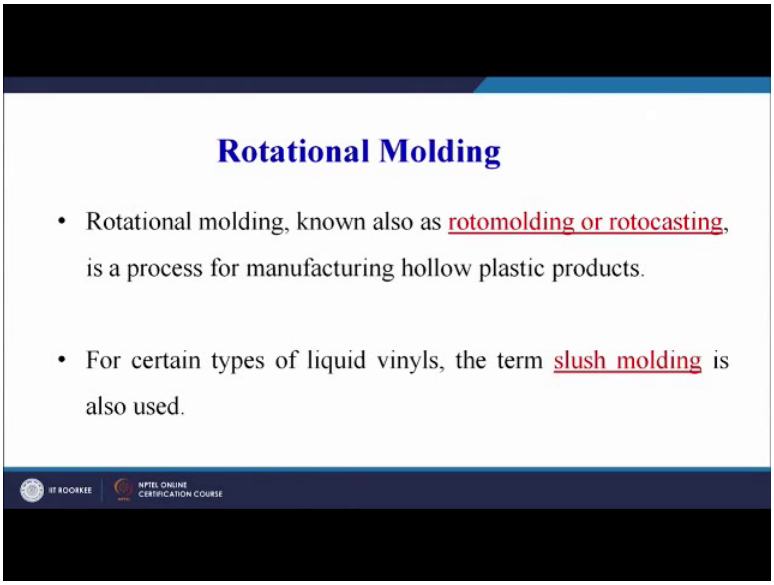
So, the 3 steps will remain same in almost all processes, but differentiation is in processes is based on the complexity of the final product the volume of production the surface finish that we want to produce the shape of the product and there can be other parameters and one of the parameters is the type of raw material or the type of polymer that we that we are using or that we use for making a particular product.

So, therefore, there are large variety of processes that are used for processing of polymers. And one such process is rotational molding. Now as the name suggests rotational and molding. So, there has to be an element of rotation that is there has to be something that is rotating and then we are molding it that is we are giving a desired shape to the polymer. First thing is as we all know there has to be heat now heat has to be supplied to the polymer. So, that it melts and takes the shape of the mold.

So, we will again go through the similar steps only, but here we will see that there is the change in the shape of the mold. There is the change in the way material is getting molded because in injection molding if you remember we inject we push the material either using a ram or plunger type of arrangement, or we sometimes use a screw barrel type of arrangement in extrusion also. We push the material through the die and it takes the shape of the die, but here we will see how the plastic will get deformed as per the shape of the mold. So, that is the point that we should keep in mind when we are going to discuss the rotational molding. Otherwise the heating of plastic is same the cooling of polymer or plastic is same, but how the material is getting deformed and taking a specific shape in this case a big large hollow shape that is the only thing that we need to keep in mind.

So, let us start our discussion on rotational molding. On your screen you can see in rotational molding.

(Refer Slide Time: 06:19)



It is also known as rotomolding or rotocasting. So, casting as you know casting process we have discussed in the very beginning. So, casting all of you know we a casting in case of metals you know, what do we doing casting of metals we have different types of furnaces. For example, tuple of furnace or reverberatory type of furnace. So, in a furnace we melt the metal, we bring the metal into the for the molding process. And the where

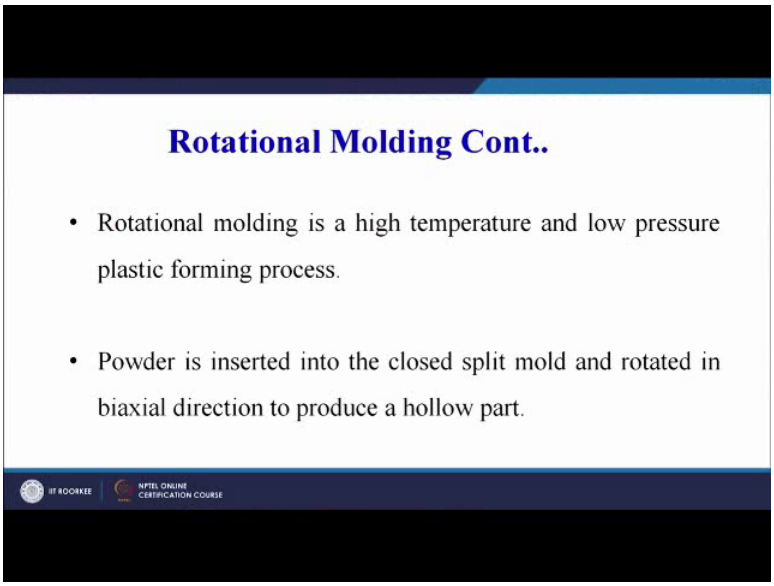
once we have the mold we pour it can be a sand mold it can be a permanent mold we pour the molten metal and it takes the shape of the mold.

Similarly, rotocasting means there we have to add a element of rotation and casting remains same. That your raw material is in the molten form and you put it in the mold and it will take the shape of the mold. So, rotocasting means roto word is added here which will add an element of rotation to the mold. So, rotational molding is also known as rotomolding or rotocasting. It is a process for manufacturing hollow plastic products.

Now, hollow plastic products means that there will be large exist symmetric product which will be hollow from inside for certain types of liquid vinyl's the term slush molding is also used. And if all of you have studied a manufacturing processes course the basic course, you will remember that there is a casting also that is called a slush casting technique. So, this is also sometimes called the rotational molding process is also sometimes called the slush molding process.

Rotational molding, we can again see is a high temperature and low plastic forming process.

(Refer Slide Time: 08:00)



Now, high temperature you know what is the meaning of high temperature, if you see the processes that we have already covered in many places we are supplying the heat, as well as we are supplying a lot of pressure also where as in case of rotational molding we will

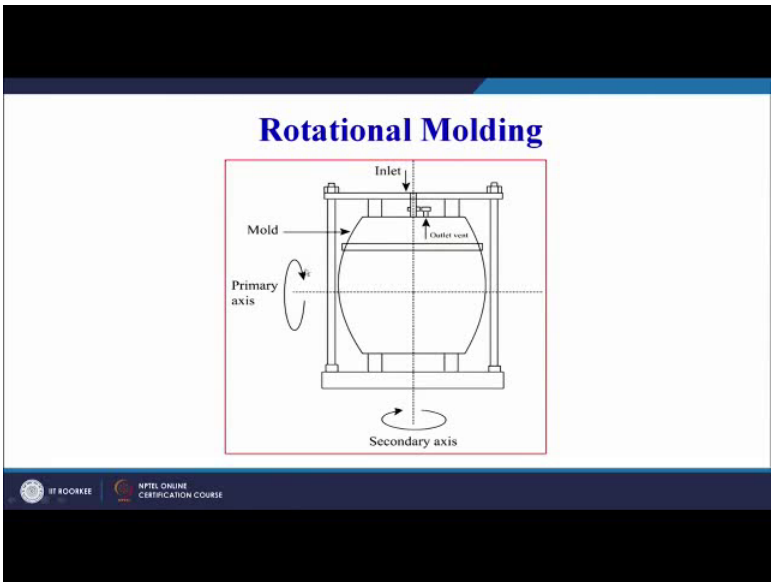
not be supplying any additional pressure it will be a force that will be acting to ensure that the molten plastic adheres to the mold cavity.

So, we will not be applying lot of pressure here. Therefore, the pressure requirement is low, but then on the contrary the temperature requirement is relatively higher. So, this point we have not considered in any of the previous processes. Because there we have a combination of both we have pressure also we have temperature also where as in casting process we do not apply any pressure on the molten plastic. If you remember in the first process that we have covered in processing of polymers was casting process. So, we directly melt the plastic and then pour it into the mold cavity and allow it to solidify a most primitive type of plastic forming technique.

But here the temperature requirement is higher and we will try to understand it with the help of a diagram also powder is inserted. So, the raw material can be in the form of a powder. So, a powder is inserted into the closed split mold. Now let us try to understand that these is the closed molding process that the mold is close as you remember in injection molding also the 2 halves of the mold close and in between you have the die cavity or the mold cavity here also it will be a split mold types. So, the when once the mold closed down like this inside you have a hollow portion. So, we have to put our raw material which is in the powder or the pellet form inside the mold.

So, powder is inserted the closed split mold split mold means it is in 2 halves. And once it is closed it forms the complete mold. And the mold is rotated in by axial direction to produce a hollow part now this mold, that we are talking about which is a split mold which is a hollow mold it is rotated in by axial direction maybe we can say along one direction and then along the other direction also. So, by axial this is one axis this is another axis. So, it rotates in the by axial direction a very simple schematic of the rotation molding process on your screen. As I have already the last part whatever I have said 2 axis.

(Refer Slide Time: 10:36)



This is the primary axis dotted line is shown here primary axis and then there is a secondary axis this line is the secondary axis.

So, the mold this is the mold this is the hollow mold, it is written here this is mold. So, this mold now rotates about both the axis it rotates about the rotation is shown here secondary axis as well as it rotates about the primary axis. And the raw material is put inside this hollow mold. So, this is the inlet from here we can put the raw material in the form of powder or a pellet inside the mold.

Now, what are the things that we can control here just by looking at the diagram. If we common sense if we apply, we can see what we can control what we need to take care of when we are doing rotational molding. So, if you can just give a thought on what can we control very easily, you will come to know one operating parameter is already mentioned that is it has to rotate along one axis and then it has to rotate about the other axis that is we have to see the number of rotations both along the primary axis as well as along the secondary axis. We have to see the speed at which that those rotations will take place.

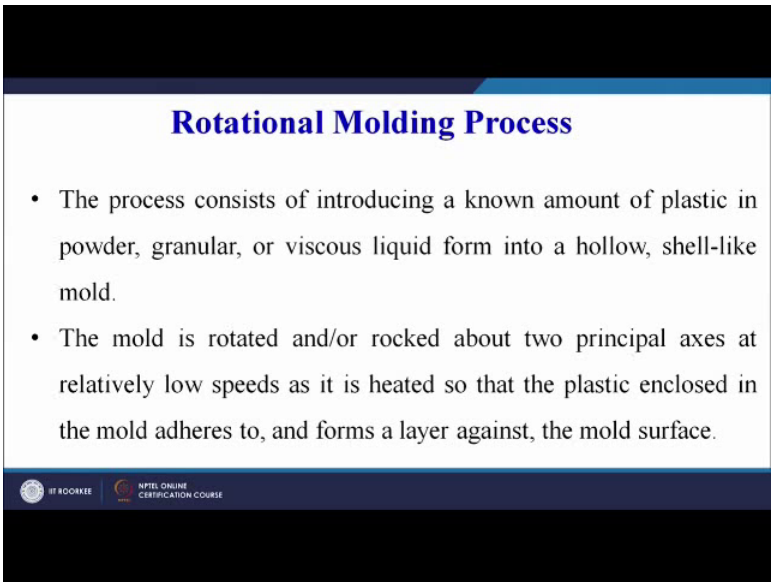
So, that is another parameter that we need to control. We need to control the amount of material that we are putting inside the mold. Because that will define the thickness of our product that we are making. We need to decide the temperature that we are going to provide to this mold or the heat input that we are going to provide to this mold. So, that

the raw material that we have put inside the mold melts down and takes the shape of the mold.

So, very briefly I have tried to outline the parameters that we need to take into account for producing a hollow part or hollow plastic part using the process of rotational molding. Just to list them again one is the number of rotations along both primary and secondary axis. The speed of rotation the amount of raw material the heat input that we are given to the mold. So, these are the important parameters that are coming from this diagram that we need to control in order to make a good quality product. Still if there able to control these parameters optimally still there are chances that we may get defect then another parameter that are just occur to me is the holding time. That is the cooling time for which the 2 parts of or 2 halves of the mold will remain in contact or in the closed position.

So, even after supplying the heat we will continue the rotation and we will allow the molten plastic inside the mold to cool down. So, that our product becomes rigid and once we open the mold we get our product successful. Or successful product or successfully we get our product that we have found inside the mold cavity. So, whatever I have tried to explain with the help of a diagram. Let us now try to understand it with the help of the language and I think once you read this sentences are the process will automatically become clear to all the learners.

(Refer Slide Time: 14:00)



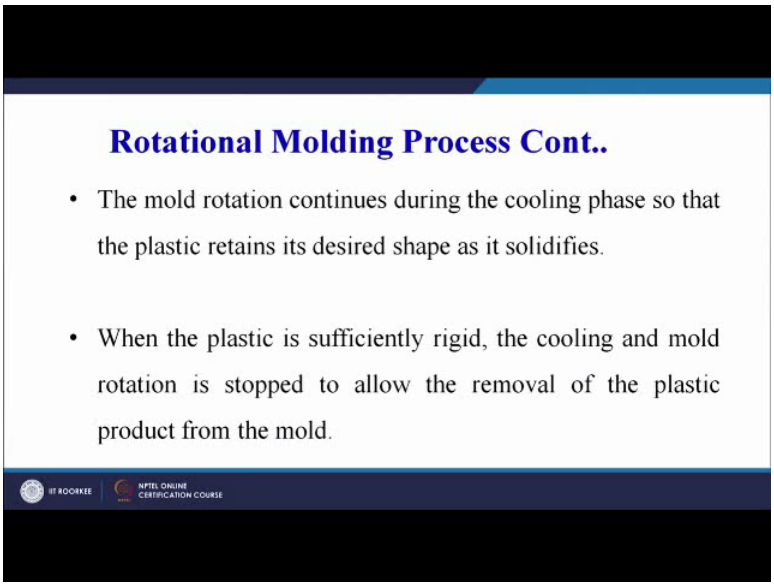
Now, the process consists of introducing a known amount of plastic. So, first thing we have to remember that we will input a known amount of material. It cannot be larger than the optimal value it cannot be lower than the optimal value. Why? Because in both conditions we will get the defective product. So, first thing is we have to put a known amount of the plastic in the powder granular or viscous liquid form.

So, you can see 3 types of input we can give we can either, give the input in the form of powder we can give it in the form of granules, we can give it in the form of viscous liquid into the hollow shell like mold. So, the mold in this case is hollow it is a split type of a mold. Especially viscous liquid is written because most of the thermo sets that we get are in the form of viscous liquids. The mold is rotated and or rocked about so, it may not be that complete rotation is done. Depending upon the final shape of the mold or final shape of the product that we want to make. The mold can be rocked also that is know complete rotation is not there only rocking. For example, sometimes we put young kids or maybe young infants inside a rocking cradle. So, we that is the rocking movement of the cradle we can just try to relate it with the rocking movement.

So, the mold is not rotated it sometimes maybe given a rocking movement also about the 2 principle axis at relatively low speeds. So, the speed in this case will not be very high it will be a slow speed at which the rotation will be given. And different books you will get the different critical speed at which the rotation can be given, but in general low speeds are advisable as it is heated. So, that the plastic and closed in the mold adheres to and forms a layer against the mold surface.

now as the mold rotates at a slow speed along both the principle axis the material that is inside the mold will be melted because of the external heat that is being supply to the mold. And this molten plastic will because of the force that will be generated because of the rotation will be pushed against the wall of the mold and will stick to the mold wall and take the shape of the mold. And that would exactly be the shape of the final product that we want to produce.

(Refer Slide Time: 16:41)

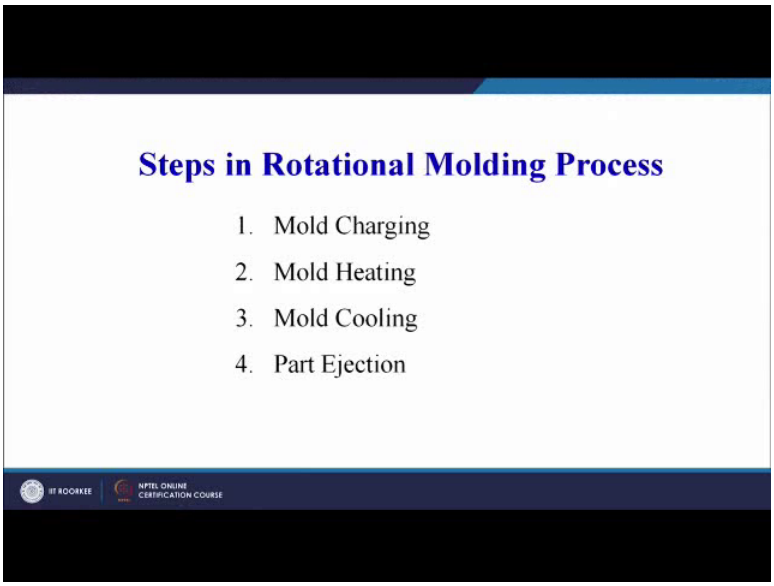


The mold rotation continues during the cooling phase. So, that the plastic retains it is desired shape as it solidifies. So, plastic is in the molten form the rotation is continues and a thin layer or the desired thickness of the layer has formed all around the mold cavity. That is inside all around the inside portion of the mold cavity or the hollow mold and we will keep the rotation going on until and unless the plastic has solidified and taken a rigid form. So, that once we open the mold we get our final product.

So, the mold rotation continues during the cooling phase. So, that a plastic retains it is desired shape as it as it solidifies. When the plastic is sufficiently rigid the cooling and the mold rotation is stopped to allow the removal of the plastic product from the mold. So, before taking out the product the rotation is stopped the mold is opened and finally, the product is taken out from the mold. As it is a split type of mold there is a provision for opening this mold and taking out of the final product.

Now, what are the steps whatever sentences we have studied now they have been summarized in 4 major steps involved in the rotation molding process.

(Refer Slide Time: 18:07)

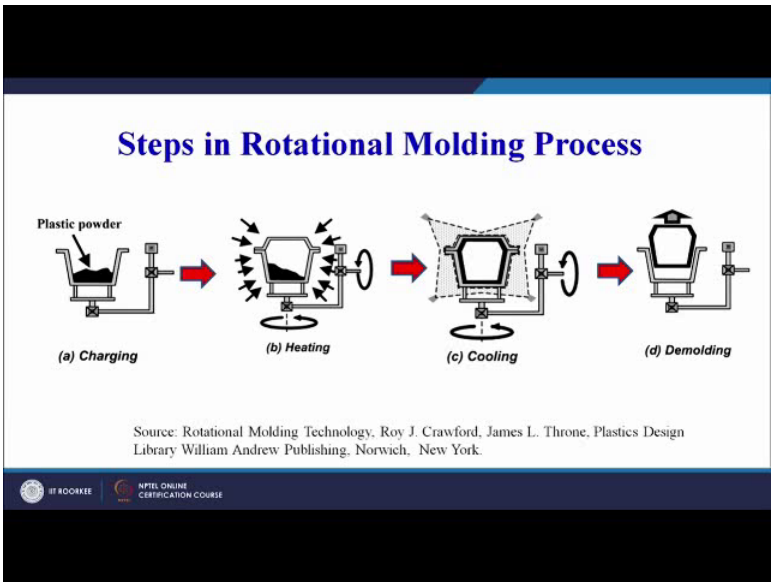


First is the mold charging. Mold charging means adding the raw material in the form of granules in the form of powder in the form of viscous liquid into the rational mold or into the mold. So, that is called mold charging. Then mold heating means heating the mold. So, that the charge that we have added into the hollow mold melts and attain sufficient viscosity.

So, that as the mold rotates this molten plastic sticks to the walls of the inner walls of the mold. Then once the layer of plastic has formed sorry at the inner section of the or in the at the inner portion of the mold oh hallow mold then the we will go for cooling. Rotation will continue and once the cooling has taken place thus product has become sufficiently rigid we will open the split mold and the part ejection will be carried out we will take out the part from the mold.

So, basically 4 important steps are there. Mold charging mold heating mold cooling and part ejection. This has been adopted from the source rotation molding technology by Roy J Crawford James L throne that is plastic design library.

(Refer Slide Time: 19:32)



A diagram is very you can say well representing the whole process that we have already understood. You can see here this is the mold, split mold this is one half of the mold the top half of the mold will close this mold and then the rotation has to be done.

So, we are putting the plastic powder inside here. The plastic this black color is representing the plastic powder. This is step one charging next is heating. You can see here, the top part of the mold has now come into picture and the mold is now closed and this black arrows arrow had represent the heat as well as you can see, the rotation about this axis this is axis of rotation and this arrow depicts the rotation of the mold. Now we are supplying the heat also.

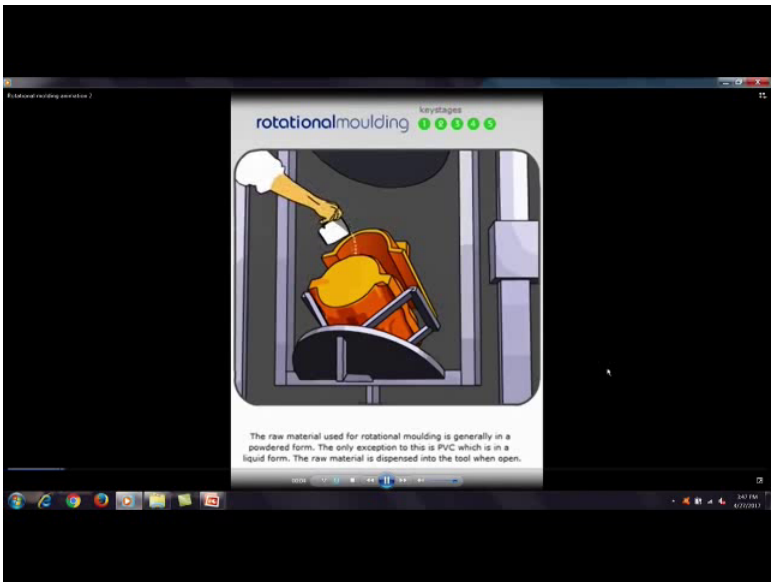
We are rotating the mold also and once the rotation starts the next step is you can see the plastic powder was input here it was lying at the bottom part of the mold. Once the rotation has started and the heat has been supply layer has been formed at the inner section of the hollow mold. So, this is the layer or the final product that we want to produce, this black layer inside the mold and the rotation is continuing during the cooling process.

Now, once the product has become rigid, we are stopping the process the you can see there is no rotation shown here. That is demolding process during cooling rotation is continuing during demolding. The rotation has being stopped the mold has been opened and finally, the product that has formed at the inner portion of the rotational mold or the

rotating mold is taken out. So, these are 4 major steps in the rotational molding process, charging heating cooling and demolding. You can see the final shape of the product is the exact replica of over mold. This is the mold air we can see, and the final product is exact replica of a shape of the mold that we have used for the molding process.

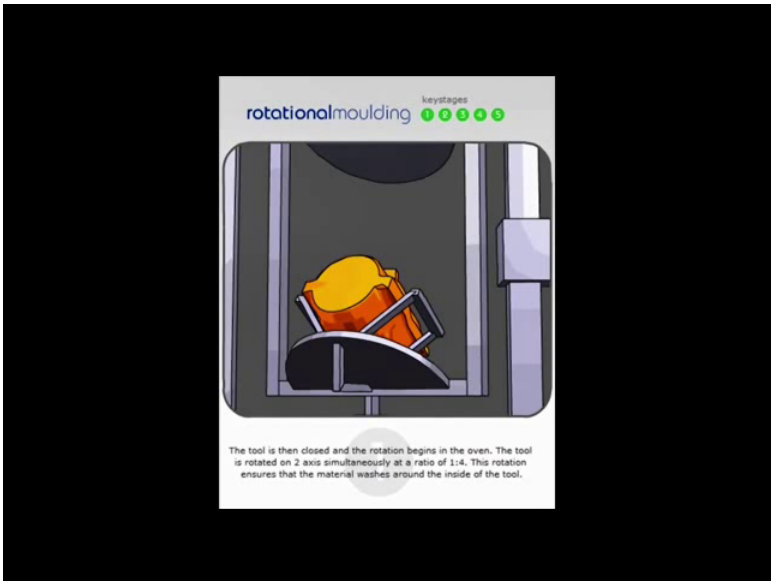
Now, we will try to understand it with the help of a video. And here also you can see how the input is given and how the mold is rotated the input is given.

(Refer Slide Time: 22:10)



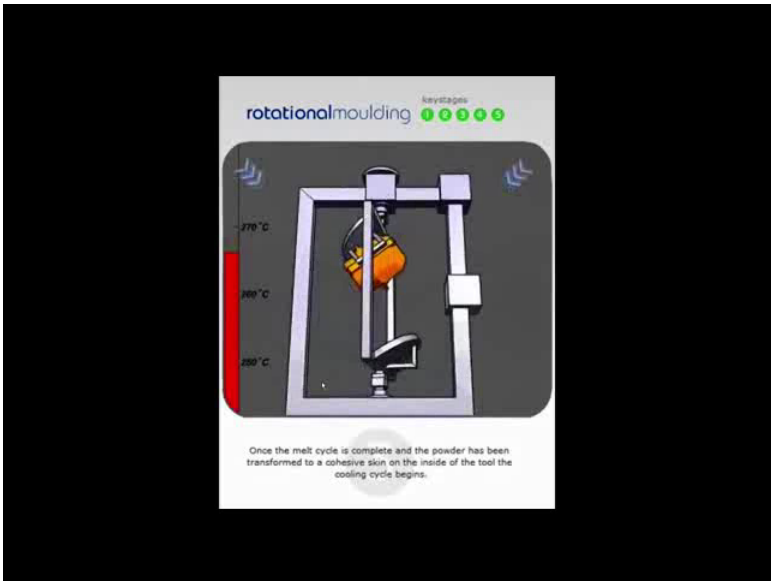
Now, you have a viscous liquid form, now the mold will close the mold has close.

(Refer Slide Time: 22:19)



Now, you can see the rotation about one axis here. Even the mold can rotate and the red arrows are depicting that the mold is supplied heat.

(Refer Slide Time: 22:20)



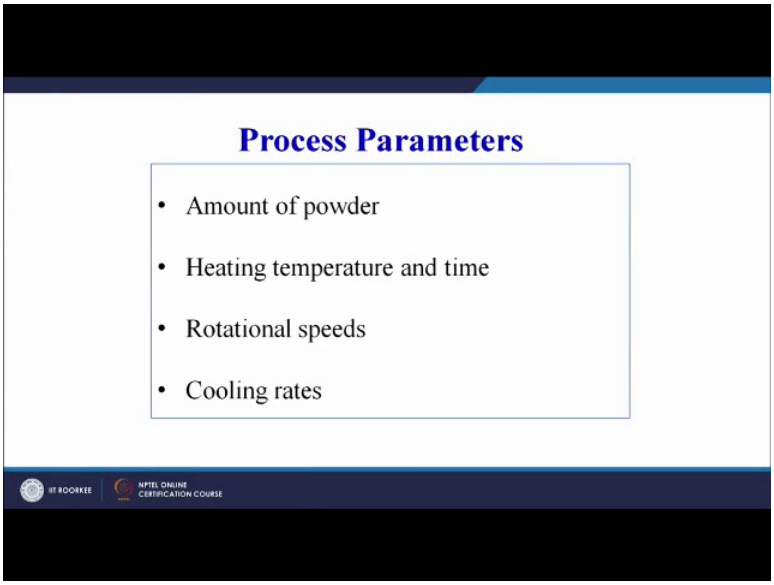
And on the screen you can see the maximum temperature attainable is 270 degree. So, the rotation now along the axis.

(Refer Slide Time: 22:58)

So, once it has cooled the mold opens and finally, the product comes out of the mold that is the ejection step. So, 4 major steps are there that is charging heating cooling and part

ejection. Now I think we have already discussed and I have explained the process parameters that we can control.

(Refer Slide Time: 23:23)



So, first is the amount of powder or charge it can be granules also it can be viscous liquid first thing is amount of raw material that we are adding into the hollow mold. Heating temperature and time.

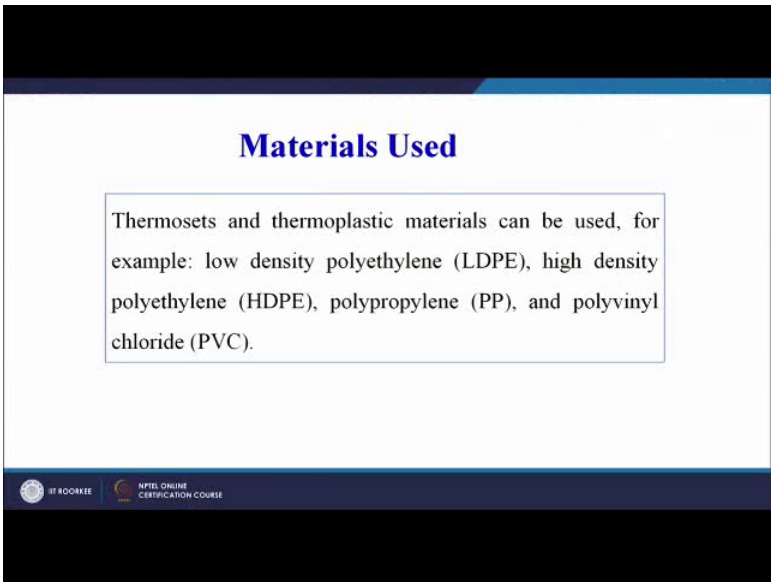
So, in the animation if you remember the temperature graph was showing 270 degree centigrade. So, we have to control the temperature that we are supplying. So, that our plastic melts inside the hollow mold. Then the time also we have to control we can control the time or we can control the number of rotations about a particular axis that is a for both the principle axis x and y direction. Then we can also control the rotational speeds I have already told that it is a low speed process. So, the mold will not be rotating at a very high speed, but still we can control the rotational speed depending upon the thickness depending upon the product quality that we desire. And finally, the cooling rate is also a parameter that we can decide.

So, these are 4 important process parameters there can be other parameters also, that play a very important role in defining the good quality product or the quality of the rotational molded product. Now what are the materials used for rotational molding. So, what are the raw materials used as we have seen there 3 types, basically we can input into the

hollow mold. What are these 3 types? First one is granules, second is powder, third is viscous liquid.

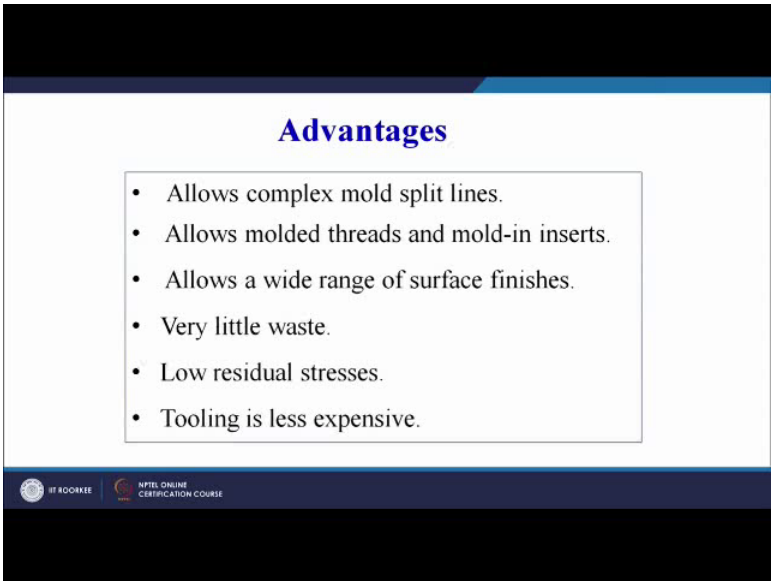
Now, if you see on your screen thermo sets and thermo plastic materials both can be used for making products using the rotational molding process.

(Refer Slide Time: 25:06)



For example, low density polyethylene LDPE HDPE polypropylene and polyvinyl chloride that is PVC. So, LDPE HDPE PVC PP all these polymers can be used as raw materials for making products using the rotational molding process.

(Refer Slide Time: 25:22)



Now, what can be the advantages for this process, because I think the process is absolutely clear to all the learners, what we can control in this process that is also clear. And what is the working principle of the process is absolutely known to all of you now what can be the advantages. Now the advantages are it allows complex mold split lines usually in case of injection molding we try to make our product in such a way that there is straight split line.

So, the mold divides the product into 2 equal parts. And then we make the product or sometimes it is in the one half of the mold only, but here in rotational molding it can give us an advantage of having the complex mold split lines. Maybe we can have the mold design of the mold in such a way that it can give us different types of shape. And if you see the diagram that we have seen there also it was not exactly the middle where we have the separate line is the major portion was at the bottom side and the minor portion was on the upper side.

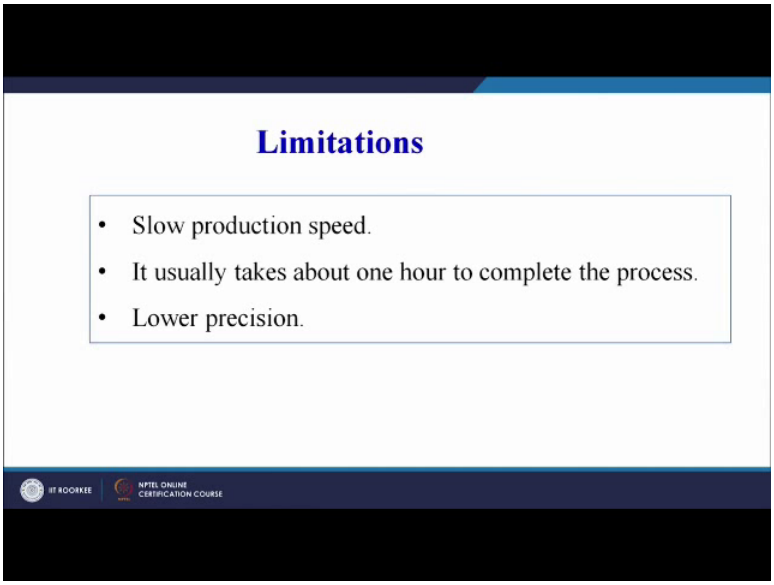
So, we can have flexibility in the mold design in case of rotational molding process. Second advantage allows molded threads and mold in inserts. So, we can pre place we can place before the start of the process we can place in the mold some inserts or threads that we want to have in our final product. And then we can input the raw melt it and final once the product we take out the molds these inserts and fasteners. Whatever we want to or threads that we want to have in our final product will be there in the product. So, that allows the molded threads and mold in inserts inside the product.

Then allows a wide range of surface finish. So, outside finish in a in any case will be excellent because that will be the exact duplication of the surface finish, that is there on the mold. And then that is one good advantage that the outside finish of our product will be very good or very well controlled very little waste, because if you remember in the beginning of todays session predetermined specific amount of material is only added and that gets converted into the final product.

Residual stresses involved are less because the pressure that we are using is less in this case, we have seen in the very beginning that it is a high temperature low pressure process tooling is less expensive as in the case of injection molding the die cost is may be a kind of a one of the limitations of the process, where it is very high, but in this case the tooling is not that expensive. What are the limitations of rotational molding process?

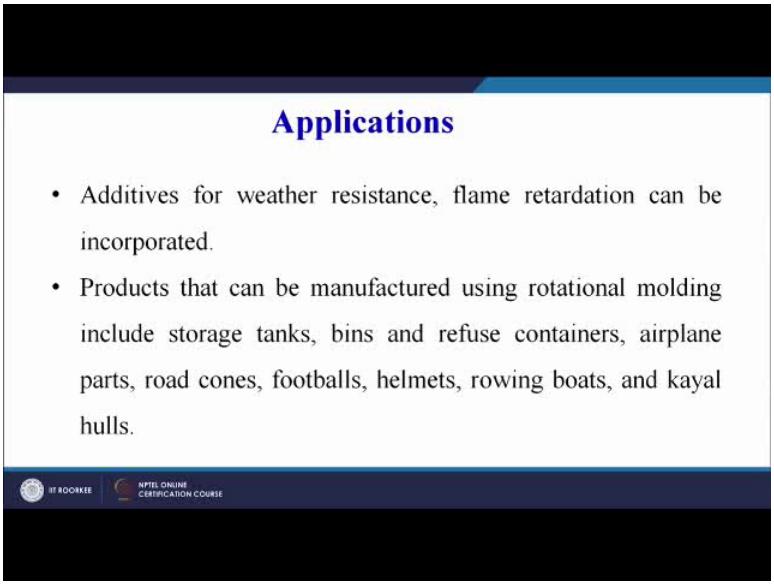
So, as we have seen it is a slow molding process because a rotational speeds are slow and it may take a longer time for making a product using the a rotational molding process.

(Refer Slide Time: 28:32)



It usually takes about one hour to complete the process that depends upon the shape the complexity of the final product, but in generally it may take a cycle time of 30 minutes to one hour and the precision is slightly less as compared to the injection molded products.

(Refer Slide Time: 28:57)



Now, what can be the applications of rotational molding process? In once specific application we can add the additives for weather resistance, flame retardation during the

adding of our charge into the rotating mold. Products that can be manufactured using rotational molding include storage bins, storage tanks, bins, refuse containers, airplane parts, road cones, footballs, helmets, rowing boats and kayal hulls.

So, there are. So, many different types of products that can be made using the, but if you see the list of products all the products are hollow cross sectional products. So, it is used for making large size products. It is used for making hollow products and most of the time they will have a axial symmetric axial symmetry that is they will be symmetric about one or the 2 axis.

(Refer Slide Time: 29:50)

Now, you can see the application. And if you see the applications you will see all these applications have 1 or 2 axis of symmetry. Now this all of them are hollow in nature. So, once one thing that you can understand is rotational molding is a process for making large size plastic part axis symmetric plastic parts and which have axis of symmetric and are hollow in nature.

So, you can see the roto molded military cases the source of information is also highlighted on the screen. So, with this we come to the end of our section on rotational molding. And we will in the next session cover an important process. And all of use all of us make use of the products made by that process and the name of the process is blow molding. So, with this I close todays session maybe we will start our discussion on rotational molding in the next session.

Thank you.