Processing of Polymers and Polymer Composites

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Lecture - 09
Injection Molding – I

Friends, welcome to this session 9 on our course on processing of polymers and polymer composites. Just to give a brief glimpse of what we have covered till now, we have covered the basic properties of thermo sets and thermoplastics. We have seen the fundamental processes of casting. We have seen thermoforming. We have seen the process variants of extrusion the fundamental of extrusion process and in the last session we covered the compression molding process. So, we have covered varied types of processes. If you see extrusion is a continuous process, for making large long axisymmetric products, compression molding majorly flat products. Casting for thermo sets as per the dimensions of the mold. Thermoforming again we have seen the different variants closed mold process.

Pressure is applied through vacuum or through pressure or through the mechanical means. So, the basic principle remains the same, that we take a plastic we heat it we deform it as per the shape required finally, we let it cool. So, that it conforms to the desired shape. Many a time the shape of the product is very complex. Now for the complex product we have to device a process, we have to think that which process can help us to make this complex product. If you can try and open a plastic covering of a hand drill, you will see that the shape inside the number of ribs and bosses. Those are present there those are the things that are very difficult to make, these days no doubt there is there is rapid prototyping process which can help us in that.

But if we want to make on large scale at a very fast rate, in those cases I believe that injection molding process becomes indispensable. For small scale small number of parts only to make a few prototypes we can go for a rapid prototyping process, but in case of large scale production we will have to go for injection molding process. So, the basic application area of injection molding process is where we have large scale production, discrete parts have to be made means that is not a continuous part like a gardeners pipe these are discrete small parts. Then the volume is very large and the shape is very

complex. In those cases, we will go for injection molding process, which is one of the most widely used commercial plastic processing techniques or plastic processing process.

So, let us try to understand today the basic fundamentals or the basic we can say steps involved in a injection molding process. Let us see a simulation that how the injection molding works, and then maybe in our subsequent session, we will see what are the different types of products that are made by injection molding process. What is the influence of the operating parameters or the control variables on the injection molding process? So, that we will see maybe in the subsequent session. Today we will try to understand the basic working principle of injection molding process. Now let us start our discussion on the injection molding.

First let us try to systematize or to outline, what I have already explained in the introductory part of today's session.

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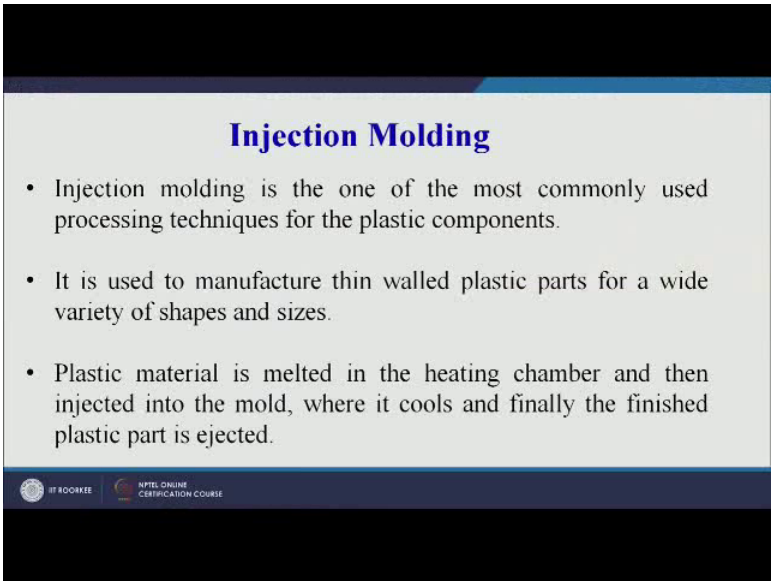

Now, injection molding is one of the most commonly I have told this is a commercial process industrial scale process used for plastic components. So, it is not something which we can say is in the research stage, already different companies are making different types of injection molding machines. And at IIT Roorkee we have a injection molding machine which we are using for conducting our research work. So, it is a

standard commercial process that is used for processing of plastic parts, it is used to manufacture thin walled plastic parts for a wide variety of shapes and sizes.

So, wide variety of shapes and sizes means that it is used for very complex to fairly simple parts. As well as thin walled parts means the thickness of the parts will not be very large which we can achieve in the compression molding process, but we cannot use very thick parts in case of injection molding process. Maybe there are reasons for that because we have to cool the part inside the mold cavity and that can be one of the reasons that this process cannot be used for very thick parts.

Plastic material is melted in the heating chamber and then injected into the mold, where it cools and finally, the finished plastic part is ejected. Now again the fundamental 3 steps are coming into picture the heating molding or forming and then cooling.

So, here you can see plastic material is melted in the heating chamber. So, heating part is coming injected into the mold, mold will deform the molten plastic into the desired shape. So, the deformation is coming into picture or the forming of the molten plastic is coming into picture. And finally, the cooling in the mold. So, that we get the final product. So, 3 steps common are coming again into picture that is heating forming and cooling.

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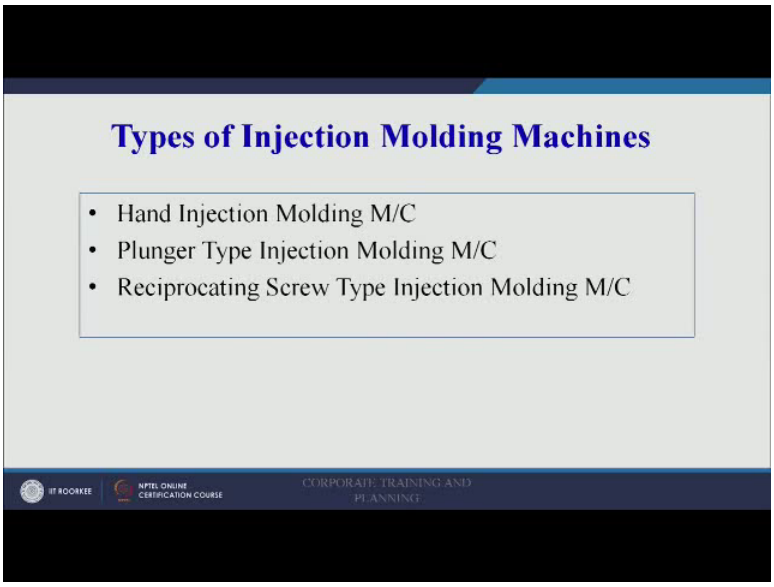

Now, based upon the applications there are 3 types of injection molding machines majorly used in industry. First one is the hand injection molding machine operated by man a manual to use for making small plastic parts. Then plunger type injection molding machine as I have explained the with the help of a syringe in one of the previous sessions.

That there is a piston cylinder type of arrangement in case of extrusion also sometime in some types of machines it is used. So, you have the molten plastic inside a barrel and then you use a plunger or a piston to push it out of the die. And in this case into the die in case of injection molding machine. So, plunger type injection molding machine and the reciprocating screw type injection molding machine. As we have studied in extrusion process that there will be a barrel inside there will be a rotating screw the role of the screw you have discussed v and the different sections of the screw also we have discussed. If you remember that there is a feed zone, then there is a melting zone and then there is a metering zone.

So, that type of arrangement exists in case of injection molding machine also, that is reciprocating screw type injection molding machine. The only difference that I must light I must highlight here between the injection molding machine and the extrusion process is or in the in the process mechanisms is that in injection molding the plastic will be melted and it will be pushed through either using a screw or using a piston or a plunger type of arrangement into the mold cavity. So, here the final product will be made is a discrete product depending upon the shape of the mold or the die. A whereas, in case of extrusion same principle the plastic is in the melted stage are in the molten stage only.

And it is pushed by the plunger or it is pushed by the rotating screw in many cases 2 screw extruders are there. The 2 screws, but the product will come out that die continuously. So, we will get large scale production, but a continuous axisymmetric product can be made or we can say a continuous product with not with much varying cross section of a constant cross section continuous product can be made using the extrusion process. So, as learners we should keep in mind sometimes this question is very common. That whatever difference between extrusion process and injection molding process in context of plastics then this should be able to answer that exclusion is a continuous process. So, we are long constant cross section products are made, whereas,

in case of injection molded injection molding, thin walled discrete products are made may be independent products are made with thin walls.

So, we will not get very thick walled products in case of injection molding. So, basically 3 types of machines are in use. First one is a hand injection then the plunger type injection molding and finally, the reciprocating screw type injection molding and no need to get confused in this we will try to understand it with the help of a diagram also.

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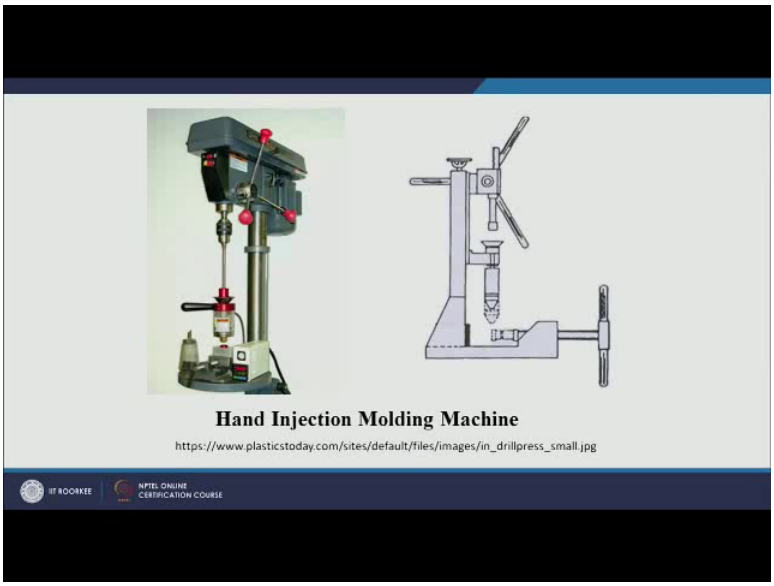

Here you have a hand injection molding machine. We can see there is a lever and we can rotate this lever. So, this will apply this will actuate the plunger. And then this plunger will apply the pressure the molten plastic will be pushed into the mold cavity of the die and it will take the shape of the die. The small plastic buttons that we use on our shirts can be made using the hand type of injection molding machine. So, here we can see the red part is shown that is the final part may be that has come out of the die.

So, this can be we can see most simple form of injection molding. So, we have to fuse a plastic we have to push the plastic into the mold cavity, open the cavity to get the final product. So, simple type of injection molding machine.

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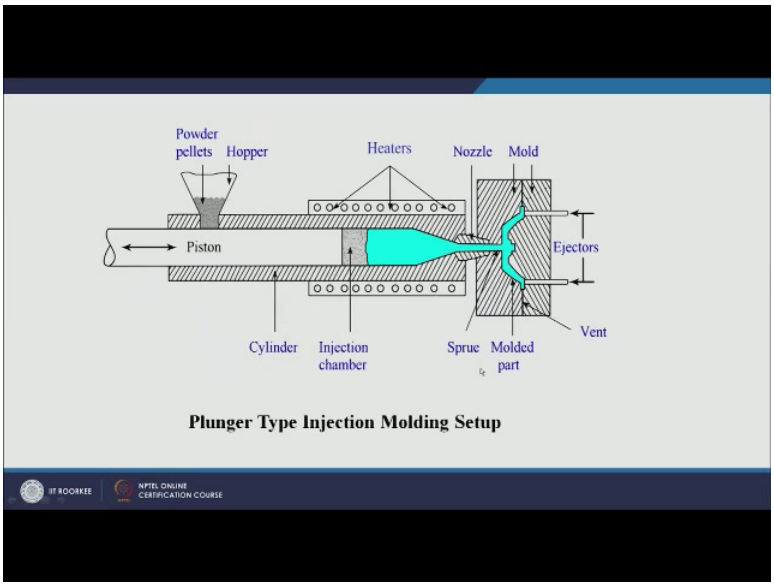

On your screen you can see a plunger type of injection molding machine. This is a piston or a plunger. So, our powder or the raw material is coming from this hopper. This is the hopper in between there are plastic pellets. Raw material. So, the raw material enters into this cylinder and then there are heating there is heating arrangement here you can see heaters are there this he heaters can be through the entire length of the cylinder.

So, because of the heat the plastic will melt and then this piston will push this molten plastic into the mold. This is the mold we can see. The mold is in 2 parts one is a movable part another one is a fixed part. So, the fixed part is attached to the nozzle here and the movable part can move or slide in this longitudinal direction.

Similarly, in case of compression molding machine we have seen, here also we will have the ejector pins. This part the final part that we have made this blue colour part you on your screen we can see this part is fabricated. This part will move along with the movable part of the mold. And finally, the ejector pins will give a slight tap on the part. So, that it is pushed out or it is you remo released from the mold that is a movable part of the mold.

So, we will see what are the various steps involved, but here in this case the major thing that needs to be emphasized is the injection mechanism. Here we are using a piston type of injection mechanism. So, piston will force this molten plastic through this nozzle into

the mold cavity. So, the mold cavities created by 2 mold halves. One is a fixed mold half and another one is a movable mold half. So, this is one thing.

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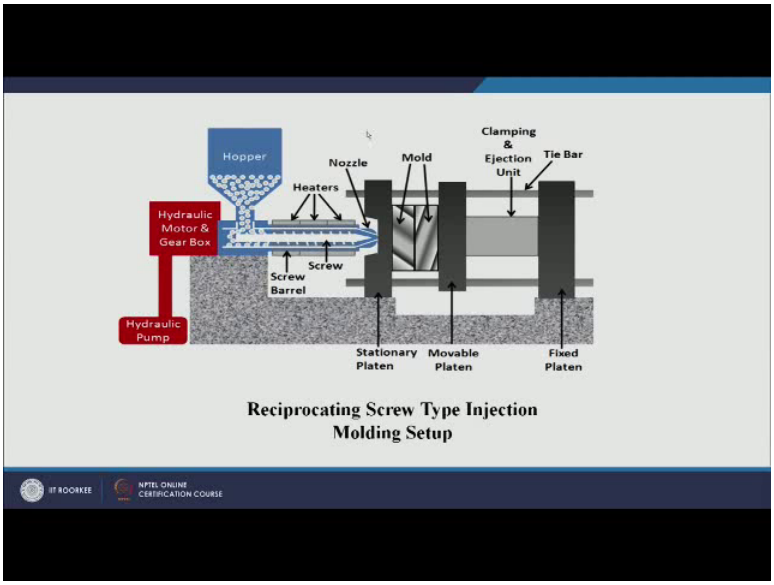

In second case there is a rotating screw, that pushes the molten plastic through the nozzle into the mold cavity. This is the mold 2-part mold here, and then this slides over these 2 tie bars. The movable part of the mold will slide over these 2 tie bars and then maybe it will move in longitudinal direction.

So, when it will come close to the fixed part of the mold, the mold will get closed in between we will have our mold cavity. And that mold cavity will be the exact replica of our final product that we want to make. So, in this case our we can say oh injection mechanism is a screw type of injection mechanism. So, this is a screw inside our screw inside our barrel. So, here is a screw and the barrel has a heating arrangement here. We have the heaters which will heat or melt the plastic. The raw material is again coming from the hopper. So, the only difference between a screw type of injection as well as the plunger type of injection is in the mechanism through which we are pushing the molten plastic into the mold cavity. In piston type we will use a piston or a plunger inside the cylinder to force the plug molten plastic into the mold cavity, where as in case of screw type we will use a rotating screw to force the plastic or the molten plastic into the mold cavity we will try to understand this.

With the help of a animation also. So, that is the basic difference.

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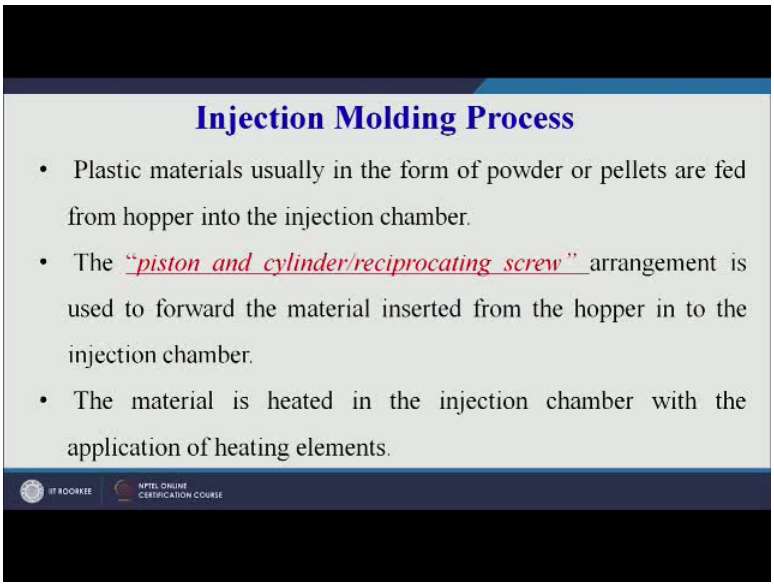

So, this is on your screen reciprocating screw type injection molding setup. Now let us try to understand the basic working principle of injection molding process. Plastic materials usually in the form of powder or pellets are fed from hopper into the injection chamber there is a hopper in which we will put our pellets and this will then come in to the injection chamber which can be a barrel. So, a piston and cylinder reciprocating screw. So, piston and cylinder is one type of mechanism reciprocating screws and other type of mechanism which we have understood in our previous slides. So, any of the mechanism that type of arrangement is used to forward or push the material inserted from the hopper into the injection chamber.

So, that the these 2 arrangements are there as we have already seen. The material is heated in the injection chamber with the application of heating element. So, that also we have understood. The molten plastic material is then injected into the mold through the nozzle. That also we have understood that first the raw material in the form of pellets or powder is will come from the hopper it will enter in to the injection chamber the injection chamber as a heating arrangement all through the periphery.

Now because of the heat coming from the heaters, the molten the nozzles sorry the pallets will melt and these molten plastic will then be pushed either using a piston cylinder arrangement or using a reciprocating screw type arrangement. And this will be pushed through the nozzle. So, we have reach the nozzle that is one now that is one

part where we have the molten plastic now. So, what are the various steps let us go back we have a injection chamber in which we have 2 arrangements either a piston or a cylinder or a reciprocating screw. Prior to that we have a hopper from whichever raw material in the form of pallets is moving down. Now this pallet or solid raw material because of the heating arrangement around the barrel will melt and this molten plastic is fed through the 2 different types of arrangement depending upon the types of machine that we are using at nozzle. Now what is going to happen at nozzle we are pushing there is a pressure from backside.

So, because of this pressure the plastic will flow and enter into the mold cavity. Or we should use the word injected into the mold cavity because the name of the process is injection molding. So, the material now through the nozzle will be pushed into the mold cavity. So, the molten plastic is then injected into the mold through the nozzle, that the molded part is cool cooled quickly in the mold there are cooling arrangement or cooling coils or cooling ducts in around the mold which will form a forged cooling type of system. Why because in the whole process we need to cool the final product. Why in many cases in most of the cases injection molding will be used for thermoplastic type of material and as we have seen in our previous session.

On compression molding also that for complete curing or complete molding or completing the process we need to cool the from the plastic parts. In case of compression molding also we have the cool the plastic part, therefore, it is not widely used for thermoplastics because the process cycle is very long. Similarly, as I have already highlighted injection molding process is used for thermal plastic parts only and thermo plastic parts needs to be cooled before they are finally, ejected out of the mold. And therefore, we need to accelerate the rate of cooling and therefore, we will have a cooling system inbuilt in our machine around the mold, we may have may be cooling jacket or cooling coils or maybe cooling chamber in which whether rather air circulation or water circulation is provided depending upon the type of thermoplastic that we are using.

So, the molded part is cooled quickly in the mold. So, quickly means we have a artificial arrangement of cooling. The final plastic part is removed from the mold once the process is complete.

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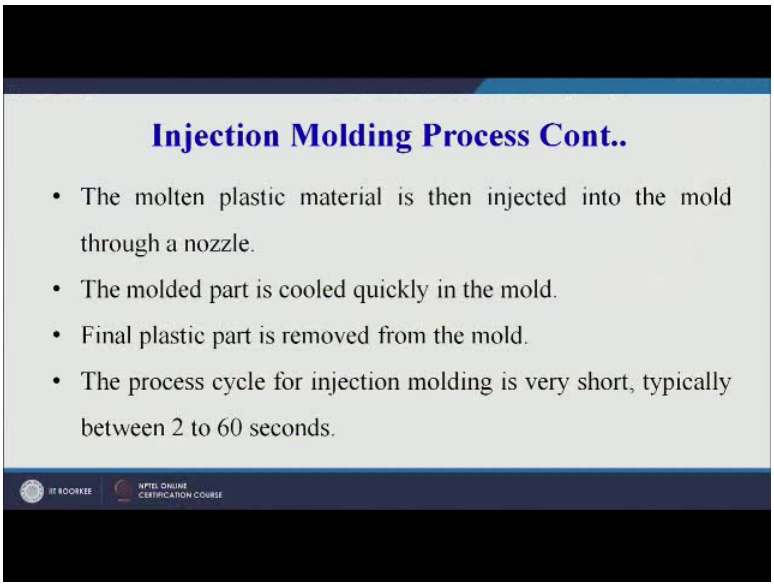

The final plastic part will be removed. And we will see in the animation that how the part is removed from the mold cavity. The process cycle for injection molding is very short means it is very fast process. Typically, between 2 to 60 second. So, you can see may be we can make number of products in 1 hour, may be 60 seconds means 1 minute. So, in 1 hour we can make 60 different parts using the injection molding process.

Now, basically the whole injection molding cycle is can be divided into 4 important steps.

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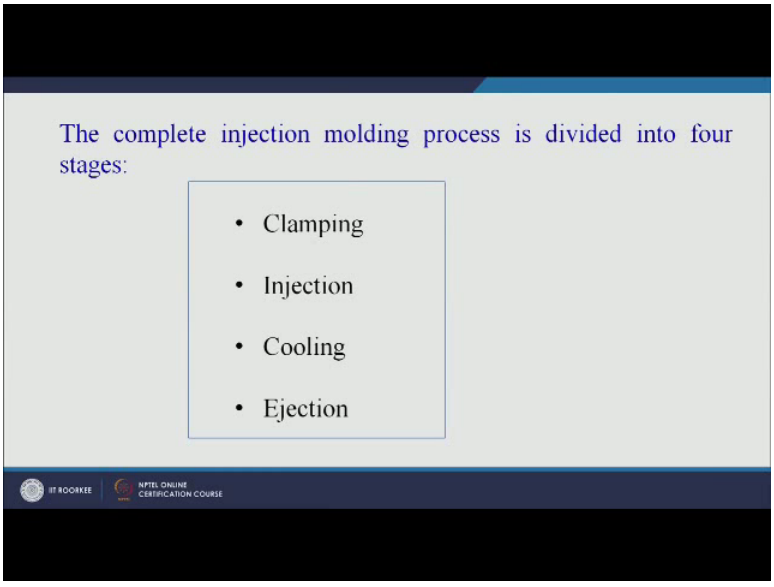

So, the complete injection molding process is divided into 4 stages or 4 steps. We can see we will try to understand all these 4 steps one by one. So, first one is clamping then injection then cooling and then ejection. Now clamping means the closer of the 2 parts of the mold. Now in this case we have one fixed part of the mold that is connected to the nozzle. There is a movable part that moves over the tie bar. As soon as the process starts the mold is in open stage. Now we will discussed just one cycle of processing or fabricating one part.

So, one mold half is attached to the nozzle. Other part will open up and the product will be removed. Now the next cycle will start. This movable part will move it will come close to the mold oh sorry fixed part of the mold. So, when these 2 halves of the mold will close down we will have the cavity cut inside which is the exact replica of the final product that we want to make. So, the fixed part of the mold, the movable part of the mold close down together. So, we that that step or that stage is called as the clamping. Now we have the mold cavity inside the 2 halves of the mold and the mold as closed it has been clamped. So, clamping force is required to keep the mold clamped. So, first stage is clamping. Once we have the mold cavity inside the 2 halves of the mold.

The next stage is injection. So, already through the hopper the pallets polymer pallets have travelled down into the barrel or the injection chamber. Because of the heaters provided there the molten plastic has been heated it is maintained in the molten stage. And because of the screw or the piston cylinder type of arrangement it is pushed through the nozzle into the mold cavity. And that stage or that step is called as the injection. So, first we have close the mold, then we have injected the molten plastic into the mold. Now we will keep the mold closed there will be air or water circulation around the mold. So, that the cooling is accelerated. So, the third stage is cooling it can be natural cooling dependent upon the requirement it can be forged cooling through the water circulation or the air circulation.

Finally, once the product has solidified inside the 2 mold halves, the movie half of the mold will move back and it is desirable that the plastic part made inside the 2 halves of the mold travels with the movable the half of the mold. And finally, there is are ejector pins as was the case in case of compression molding these ejector pins will give a slight tap on the plastic part and the plastic part will be detached from the movable half of the mold and it can fall down into the collecting bin or the bucket or the box. So, this is these

are the 4 stages one is the clamping closing of the mold injection of the molten plastic cooling of the plastic part. And finally, the ejection of the plastic part form the mold cavity. So, these are the 4 stages.

I have tried to explain to the best of my ability. And now will try to read these 4 stages what has been put in the form of slides.

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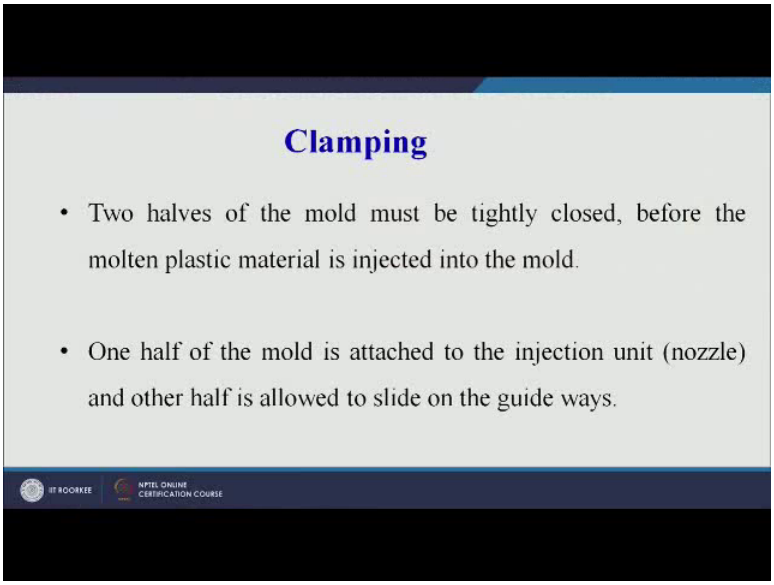

Now, clamping. 2 halves of the mold must be tightly closed before the molten material is injected into the mold. One half of the mold is attached to the injection unit that is nozzle and the other half is allowed to slide on the guide ways or the tie bar.

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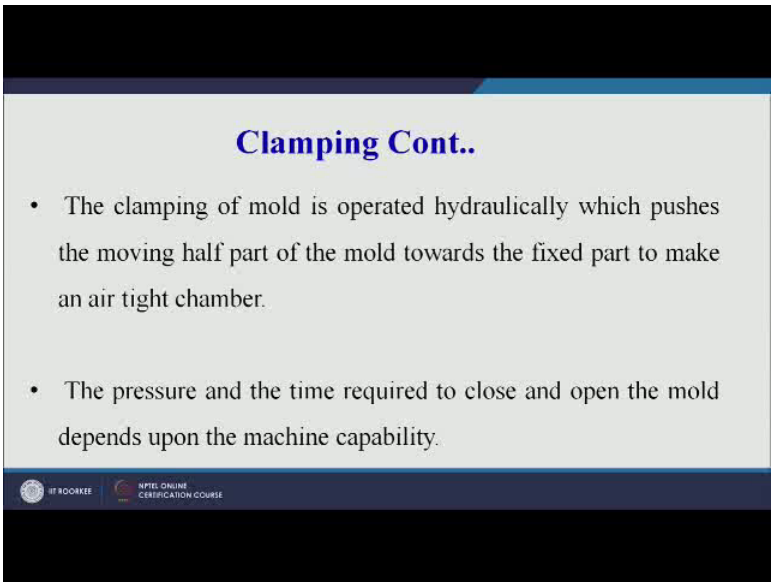

The clamping of the mold is operated hydraulically, which pushes the moving half of the mold towards the fixed. Half of the mold to make a airtight chamber. So, 2 half of the mold will closed and then we inside we will have your mold cavity. The pressure and a time required to close and open the mold depends upon the machine capability.

So, each machine has specifications at what is a maximum clamping force that machine can apply. Now once the mold has been closed, then we inject the molten plastic the plastic material is melted by the application of heat and forwarded through the piston towards the nozzle and finally, into the mold cavity.

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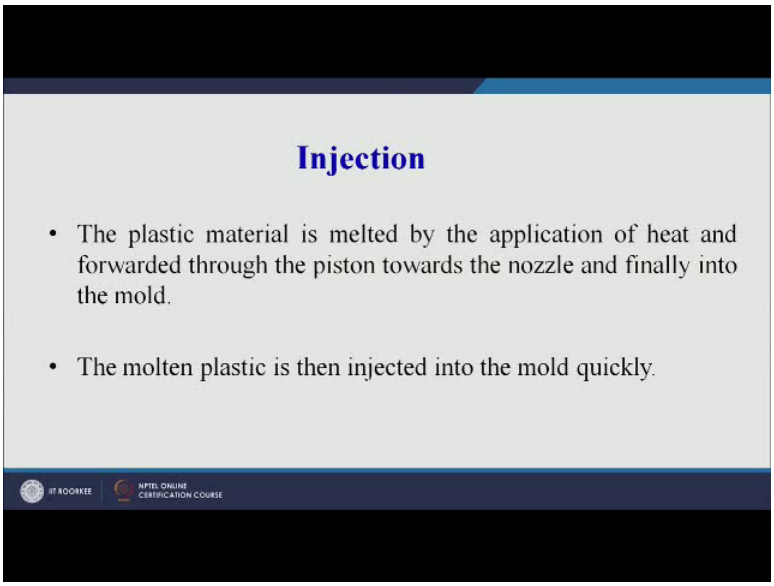

The molten plastic is then injected into the mold cavity. The amount of material that is injected into the mold is referred to as short volume. Now this is a new term that is coming in our discussion that is short volume.

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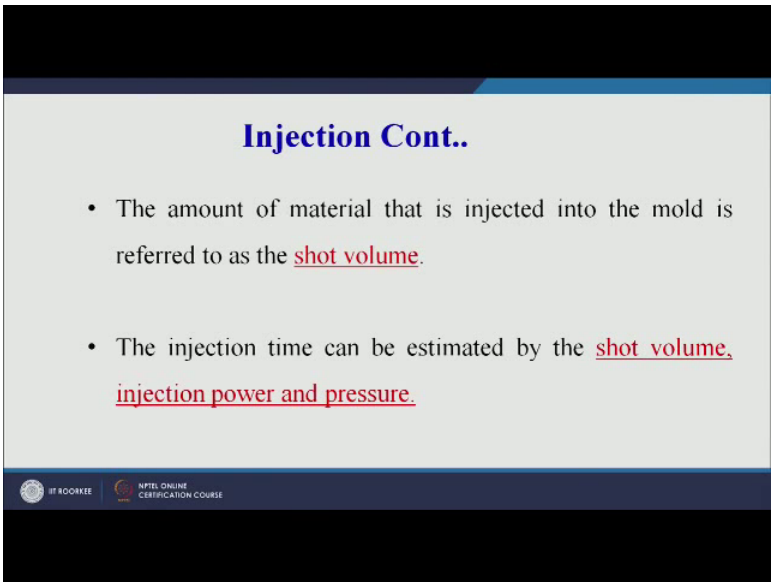

Now, short volume is the metered amount of molten plastic that we want to inject inside the mold cavity. So, the amount of material that is injected into the mold through the nozzle is called as the short volume. The injection time can be estimated by the short

volume injection power and pressure. So, we can control the pressure that we are applying to force the molten plastic.

Into the mold cavity and we will see the influence of each of these parameters on the quality of the injection molded part. In our next session today we are trying to just understand the basic stages of the injection molding process. So, our injection tangent for how much time we will inject the molten plastic that will depend definitely it will depend on short volume as well as the pressure that we are applying to the molten plastic to force it into the mold cavity. Now let us try to understand the injection molding through the process of simulation.

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So, here we have very good simulation for the injection molding process. Www dot tronicarts dot de.

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So, this is the pellets coming down this is the hopper.

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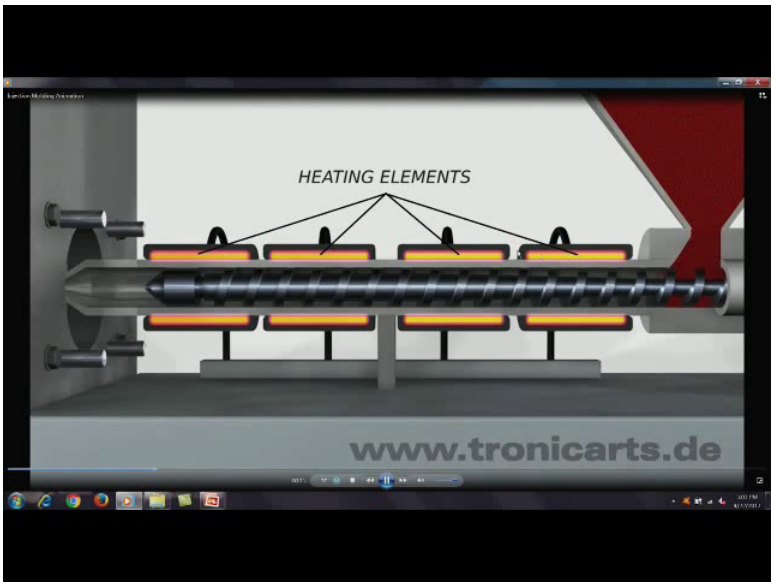

These are the heating elements heating elements 4 heating elements around the injection chamber.

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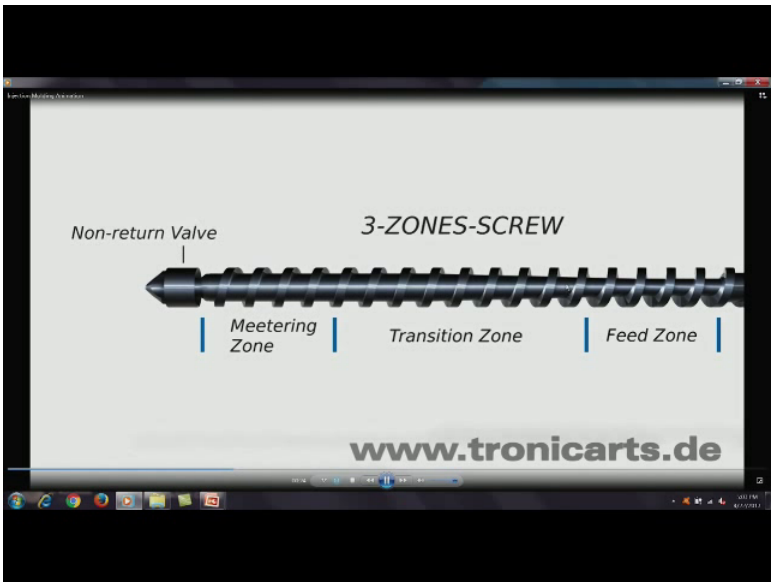

So, this is a showing a reciprocating screw type of injection molding machine, metering zone transition zone. So, these are the pellets red colour pallets that are coming down.

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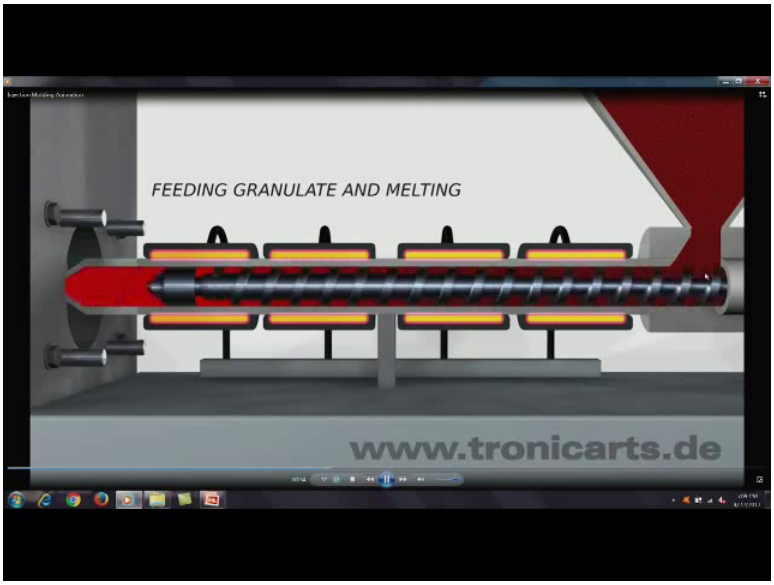

Now, the screws rotating and the material is moving down the cause of these heating elements it will get melted and this is a nozzle. So, here with this is the mold.

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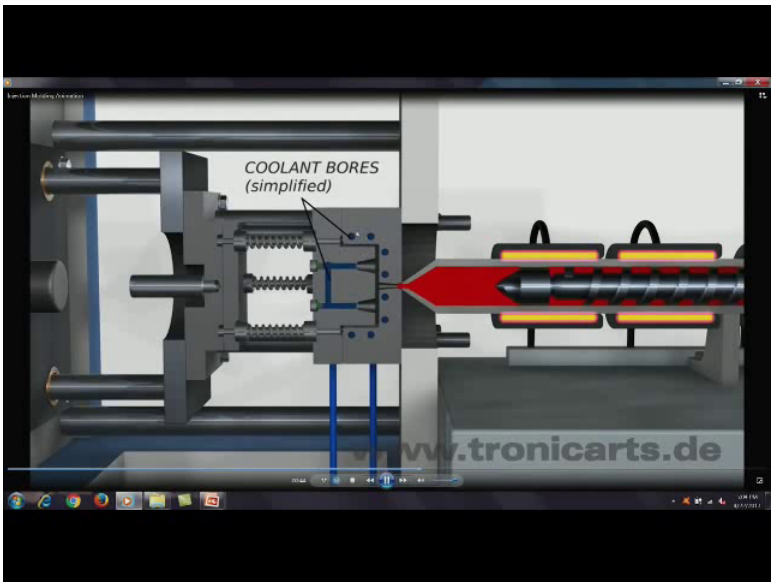

The mold is closed. We can see this is a closed mold. And these are the blue colour portion are the cooling coils now this has forced the red colour plastic into the mold.

this is a fixed part of the mold, this is the movable part of the mold. This is the final product that we want to make. So, this is movable part of the mold has moved and the product has been released. We will see another injection process.

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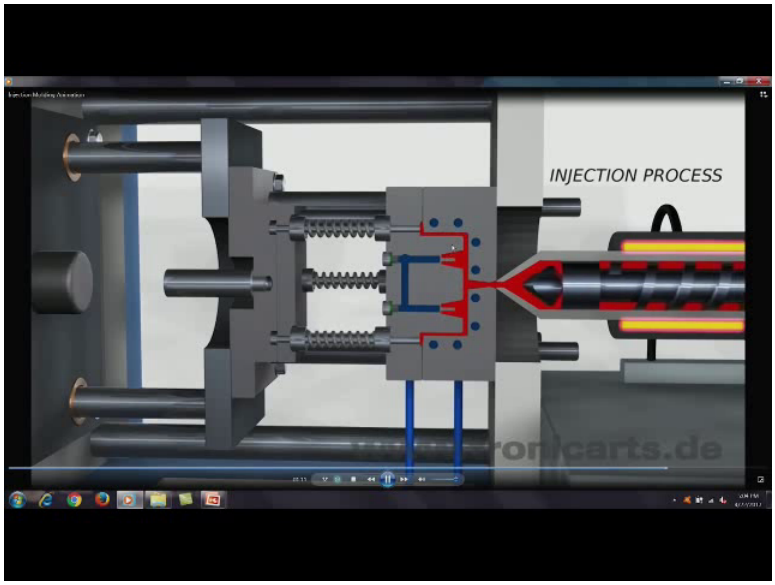

Again it has been filled. The movable part will move back movable part of the mold. It has moved back and the it has been pushed out.

So, you can see I think the process. Now is very clear to all of you, that from the hopper the raw material is coming into the injection chamber. Then there is a then there is a rotating screw type of arrangement. It is forcing the plastic or the molten plastic through the nozzle into the mold cavity.

The heaters are attached all around the barrel or the injection chamber, which heats the molten plastic melts the molten plastic. And once it is injected into the mold cavity the cooling circulation of water or air cools the part inside the mold cavity only. And once the part has solidified after a particular holding time the movable part of the mold will move back the product will also move along with the movable part, and then the ejector pins will just give a little tap on this part that has that has been formed. And it can be then finally, collected. So, this was the continuous process and you can get large number of parts maybe 50 to 60 parts in an hour or in if the sizes short volume is very less or may be small volume parts can be even larger number can be produced on a early basis.

Now, let us see what are the different types of materials used for injection molding process. Majorly used for thermoplastics we can see acetyl acrylic, nylon polycarbonate, polyether ether, ketone polyethylene, polypropylene polyvinyl chloride.

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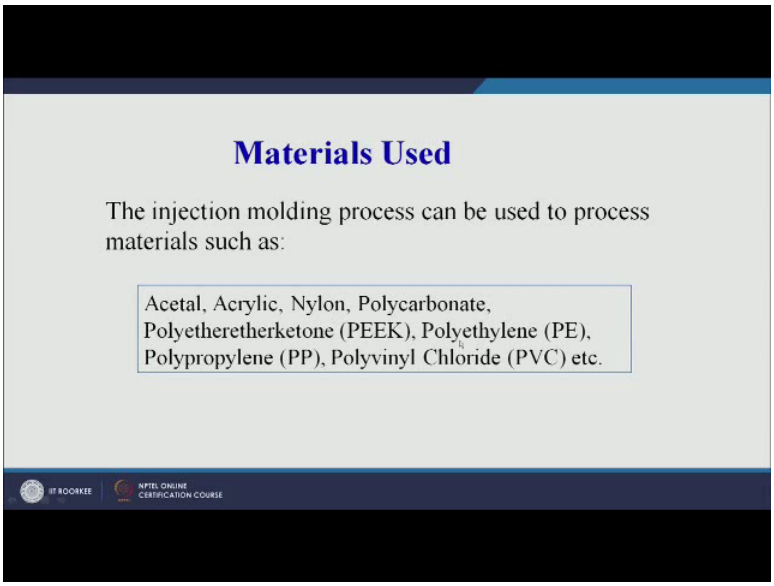

So, majorly used for thermo plastic parts. What are the applications?

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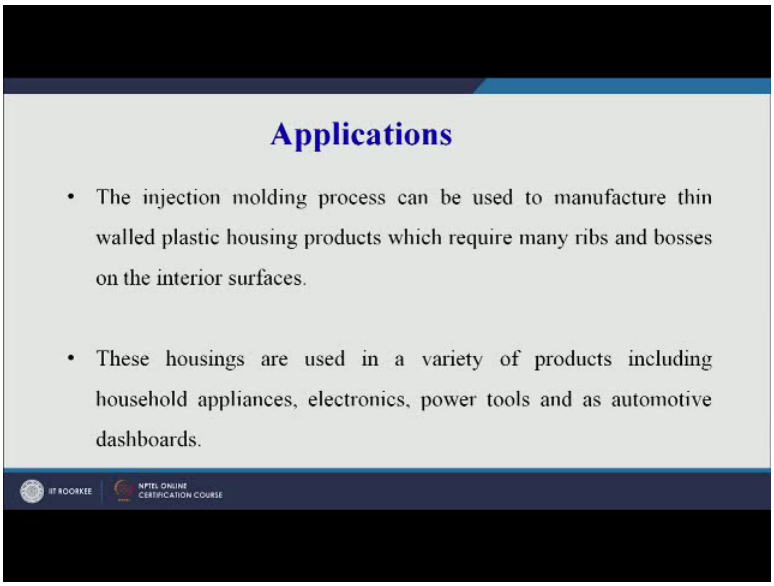

Now, the injection molding process can be used to manufacture thin walled plastic housing products, which require many ribs and bosses on the interior surfaces. Now if you remember in compression molding, we have discussed the ribs and bosses or 2 many ribs and bosses are not possible in case of compression molded parts, but those are possible in injection molding parts.

These housings are used in a variety of products including household appliances electronics power tools and as automotive dashboards. So, you can see that these housings that we can make using injection molding process, find a number of applications. Thin walled products include different types of open containers or such buckets.

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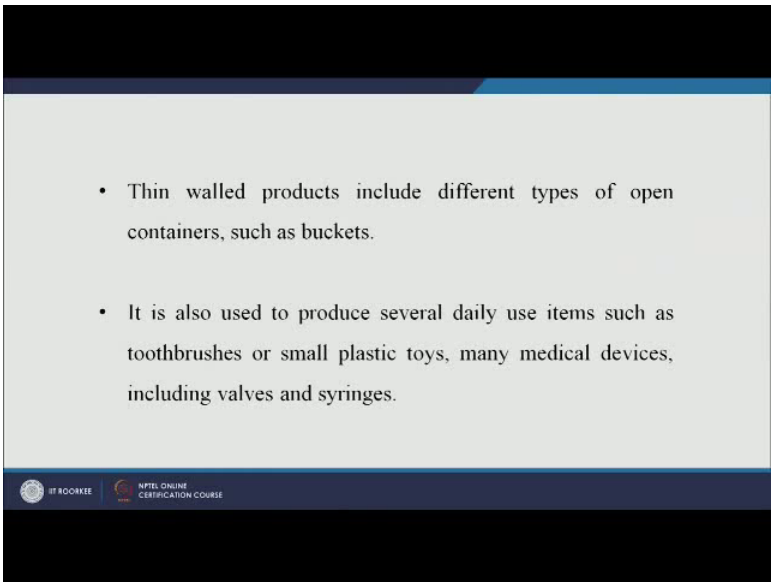

So, we use plastic buckets in our household. So, there are made generally by the injection molding process only. It is also used to go to several daily use items such as toothbrushes or small plastic toys many medical devices including valves and surgical syringes. So, injection molding process has got wide range of applications and different types of parts even the rear view mirror or of our motorbikes can be made by using the injection molding process.

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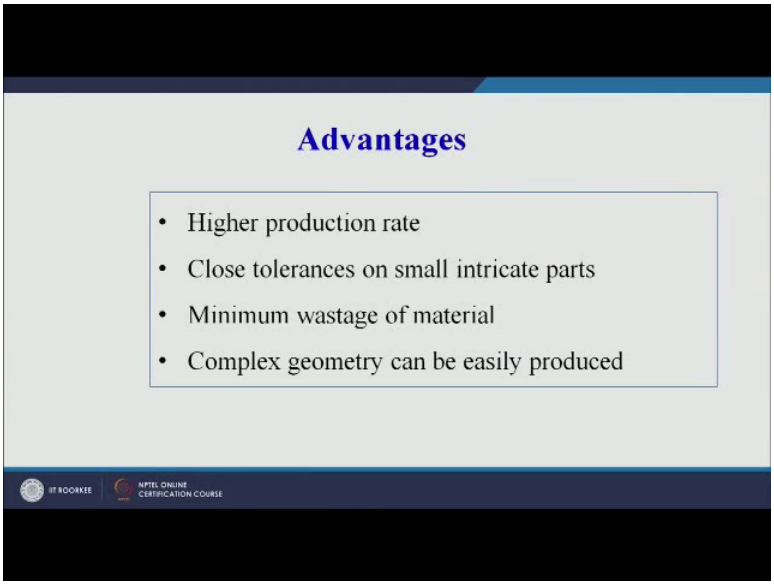

Now, what are the advantages of injection molding process. It has got higher production as we can see the number of parts produced per hour or very large. Even a single minute we can produced one part. Close tolerances is on small intricate parts. So, difficult to make the parts that we had which are difficult to make using the other processing techniques or plastic can be made using the injection molding parts. So, part complexity is not a limitation only thing, that if the part is very complex it is very difficult to fabricate the die or the mold for that part, but once the die and the mold is possible or it can be fabricated it is it then becomes a very fast process of processing of complex parts also.

So, the may wastage of material is less, complex geometric and easily as I have already highlighted. This process is suitable for difficult to process complex geometries. What are the limitations now? As I have already told that the mold is the most important part of injection molding machine and the fabrication on molds is one of the limitation.

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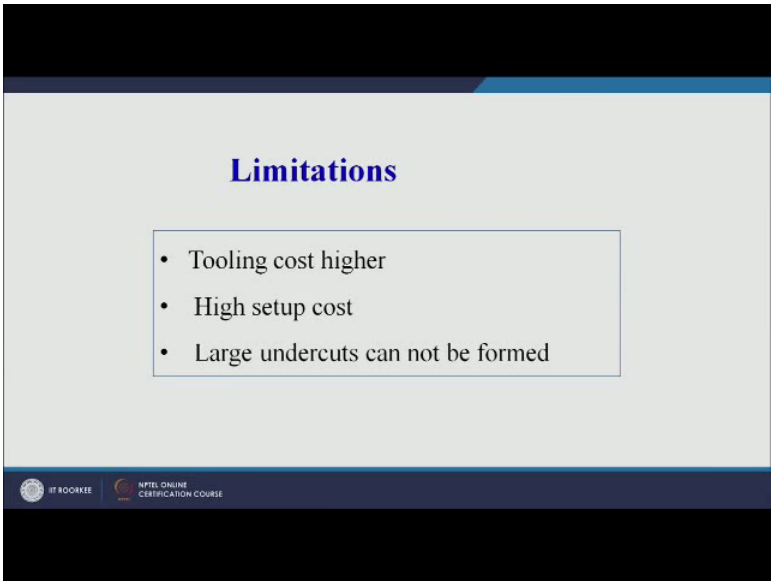

So, the tooling cost is very high. For example, if you have seen the plastic chairs that we use in our day to day life, the mold cost of that chair is very large. So, the mold is the most important part. Once we are able to fabricate the mold then the process is fairly simple. Set up cost is also high as well as large undercuts cannot be formed.

So, each process has got it is own limitations that the kinds of ribs and bosses which cannot be formed in other plastic molding techniques can easily be formed using the

injection molding technique. So, with this we come to the end of this session on injection molding. In next session also we will discuss the finer details even a little bit of we can say the influence of the various parameters of injection molding on the process, that how we can control the parameters of injection molding process in order to make a good quality part using this process. So, in injection molding second session we will discuss the finer details of the process as well as the discussion on the operating variables.

Thank you.