Processing of Polymers and Polymer Composites

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Lecture - 08
Compression Molding

[FL] friends, welcome to lecture 8 in our course on Processing of Polymers and Polymer Composites. Just to you give a glimpse of what we have covered already. We have covered the basic properties of thermosets and thermoplastics. We have seen the basic fundamental manufacturing principles or the process mechanisms of few processes which are used for processing of polymers.

Just to revise; we have covered; if you remember casting process for polymers, we have covered thermoforming process for polymers, we have also covered in the last session; if you remember extrusion process for polymers. So, three processes we have already covered; those are casting, thermoforming and extrusion.

Now, our target is to discuss the fourth process which is a widely used commercial process; that is compression molding. As the name suggests, compression we are going to apply compressive force on the plastic to deform it as per the shape of the product. The three basic principles or three basic steps will remain the same; that is we have to heat the plastic, we have to deform it; form it as per the shape of the mold and we have to cool it depending upon the requirement.

Rather we are using a thermoset or we are using a thermoplastic; in case of thermoset, we will keep our mold hot for the entire process cycle, in case of thermoplastics we will allow it to cool down so that the product may get solidified. So, depending upon the requirement; what type of requirement we have, but the three stages or three steps will remain the same. We have to heat the plastic, we have to deform it by changing its shape and finally, we have to cool it so that it takes the desired shape of the product.

So, we will see in compression molding; what is the process details? What type of machine is used? Or what is the schematic of the machine? Then we will see; what are the types of molds that are used? Then finally we will see, what are the advantages? What are the limitations? And what are the application areas of compression molding

process? So, we will also try to understand the process with the help of a small animation in which we will see that; how the process actually operates, how the upper half of the mold and the lower half of the mold combine and apply pressure on the molten plastic to give it the desired shape.

So, let us start our discussion on compression molding today.

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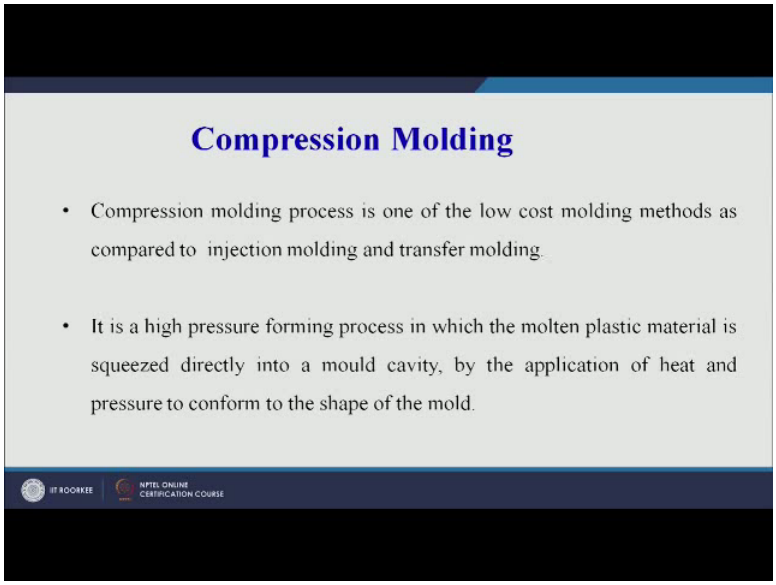

Compression molding process is one of the low cost molding process, why is it is low cost? Because of the set ups that we use, because of the control parameters that are there in compression molding; they are easy to control and this low cost we are comparing it; with injection molding and transfer molding. So, maybe injection molding we have not covered till now, but maybe in the subsequent sessions. We will talk about injection molding of plastics also.

But as compared to injection molding process; compression molding is setup, is comparatively cheaper or maybe it is a low cost process as compared to injection molding. It is a high pressure forming process in which the molten plastic; now let us understand it word by word.

Molten plastic is the first word, it is a high pressure that is first word; high pressure molten plastic second. So, it is the high pressure forming process in which the molten plastic material is squeezed directly into the mold cavity, by the application of heat and

pressure. So, there are two process parameters here we have to supply heat also, we have to supply pressure also to conform to the shape of the mold. To become or to change the shape of the plastic as per the shape of the mold and for that we require heat and pressure. So, these are the two important parameters that we need to control.

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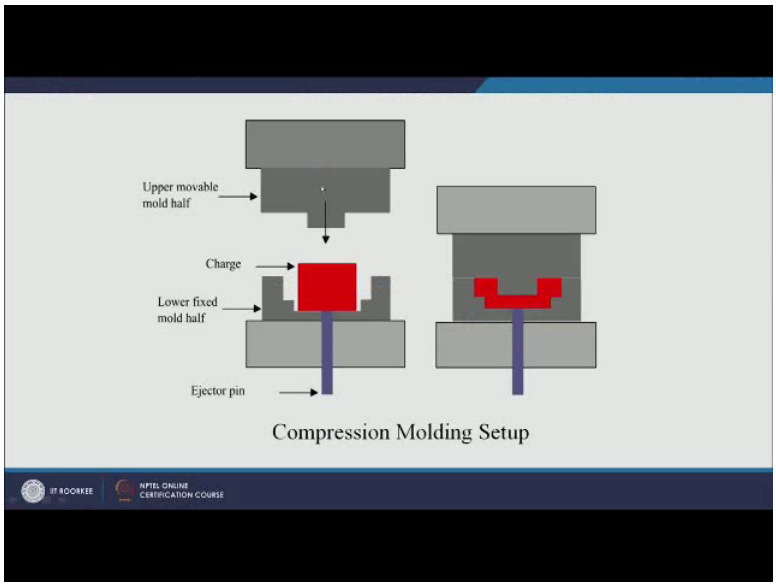

You can see; the basic schematic of the compression molding setup, I will read it for you; we have a upper movable mold half. Movable means this can move up and down; then there is charge which we usually call as the raw material. So, this red block is basically the raw material that we will keep in between the upper and the lower half of the mold. Then there is lower half of the mold; which is fixed, it will be fixed on the machine bed. So, it cannot move only the upper half of the mold can move up and down; that we will see it and try to understand with the help of animation also.

Then there is a ejector pin. Now what is the role of the ejector pin? As the molten plastic is between the upper and the lower half of the mold; when the two mold halves will close, the cavity between the two mold halves will be the product that we want to make and it will conform to the shape of the product that we want to make. Now this product may stick to the bottom half of the mold and there is a tendency for this plastic product to stick to the lower half of the mold. In that case, our ejector pin will be helpful.

So, the ejector pin will just give a slight tap; it can be nomadically or hydraulically actuated as soon as your process cycle is complete; that is the product has been formed,

the two mold halves now open; the product is there in between the two mold halves. This ejector pin will give a slight top to the product and the product will be removed from the lower half of the mold. So, there that is the basic purpose of providing the ejector pin.

The second image on the right hand side is the closed position; this is the open position of the mold and this is the closed position of the mold. In closed position, you can see the top half and the bottom half of the mold; have matched. So, they have formed a cavity inside and the cavity inside is exact replica of the final product that we want to make. You can appreciate that this is a two dimensional image of the compression molding setup, there will be a third dimension also.

So, basically we are seeing here that suppose this is the z direction and this is the x direction. So, we are seeing the z and the x dimension of the product, there will be a y dimension of the product also; which we will see in the animation that we can make a completely 3-D product; using a compression molding setup. So, you can appreciate now that this is a very very simple process; the mold is divided into two halves, one is the lower half mold and another one is the upper mold half.

And finally, we put our raw material inside the two mold halves and then we apply the pressure. Now, this pressure is sustained pressure as long as your product is not ready; we will keep this; so, that we call as the holding time.

When the two parts of the mold will be in matched position; that is the second diagram on the right hand side you can see; this diagram. So, then they are in the closed position; as long as they are in the closed position, that position; that time we call as the holding time. So, we can control the temperature, we can control the pressure, we can control the holding time and depending upon the type of the plastic; that we are using as a raw material for the compression molding process, these three parameters will change.

The temperature control will change, the holding time will change, as well as the pressure that we are applying will change. So, we will now see that what are the process parameters that we can control? And what are the types of molds that are used? But before going to all these specific details about compression molding, let us first to read what I have already explained in the previous two or three slides. Now, in compression molding of thermo sets; the mold remains hot throughout, the entire cycle.

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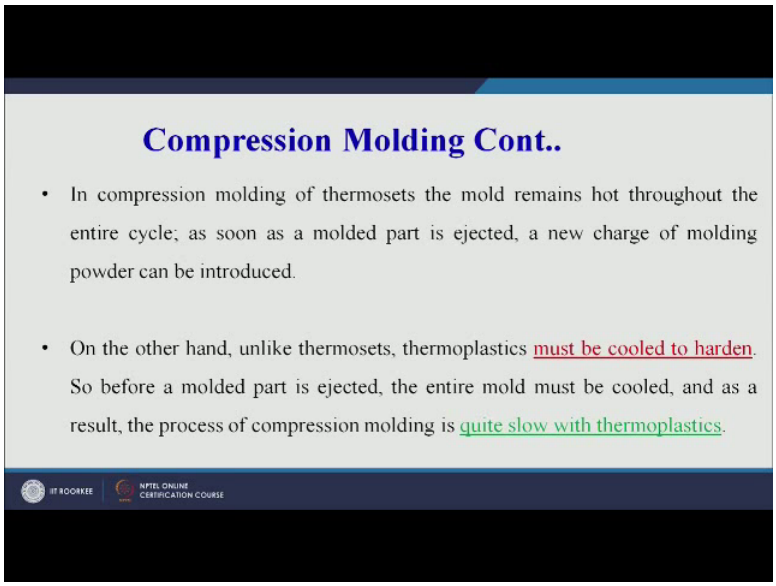

As soon as a molded part is ejected, a new charge of molding powder can be introduced.

Now, for the whole cycle; the mold will be in the hot condition. Now, why in case of thermosets; as you remember; we have seen in our first week of discussion, that there are two types or two broad categories of plastics; that is thermosets and thermoplastics.

For thermosets; to cure we have seen that we add some hardener. We add some catalyst which accelerates the rate of curing. So, the curing process for thermo sets can be further accelerated if we do it under the hot condition or under higher temperature. So, that is the basic principle that when we are making a product out of a thermo set, then if we keep the mold under hot condition; our polymerization process is accelerated and there is a good amount of saving in terms of time.

We can do it under ambient conditions also, but the curing process may take a larger or longer time for the product to get solidified. But if we are doing it under hot conditions; the process gets accelerated and we save one time; we can make the same product with same mechanical properties, but in a lower time or in a shorter time. Therefore, in case of thermo sets; specifically we maintain the mold under hot conditions so, that we save on time and are able to accelerate our product process cycle and make more number of products; maybe on hourly basis or on daily basis. So, that is one thing that we have to keep in mind.

On the other hand, unlike thermosets; thermoplastics must be cooled to harden. Now, these are the two broad differences; thermo sets have to be kept hot to harden, thermoplastics have to be cooled to harden. So in case of thermoplastics; if we are using as a raw material, so what we will do? We will put the thermoplastic charge inside the mold cavity, we will heat it; the thermoplastic will melt, we will pressure; thermoplastic will change the shape; take the shape of the mold. And finally, we will cool the mold so that our product becomes hard and we can open the mold and take out the product.

So, that is the difference between the type of raw material; thermoset is used different process cycle. If thermoplastic is used; different process cycle, but the first two steps remains the same, that is we have to heat the raw material and we have to deform it in the mold cavity. So, the mold here is in two parts; the upper half and the lower half.

So, now to just to summarize; in compression molding thermosets, the mold remain hot. On the other hand, unlike thermo sets; thermoplastics must be cooled to harden. So, before a molded part is ejected; the entire mold must be cooled in case of thermoplastics. And as the result the process of compression molding is quite slow with thermoplastics. So, when we are using thermo plastics as a raw material; the process is slower because we have to cool the mold before we eject our final product from the mold cavity.

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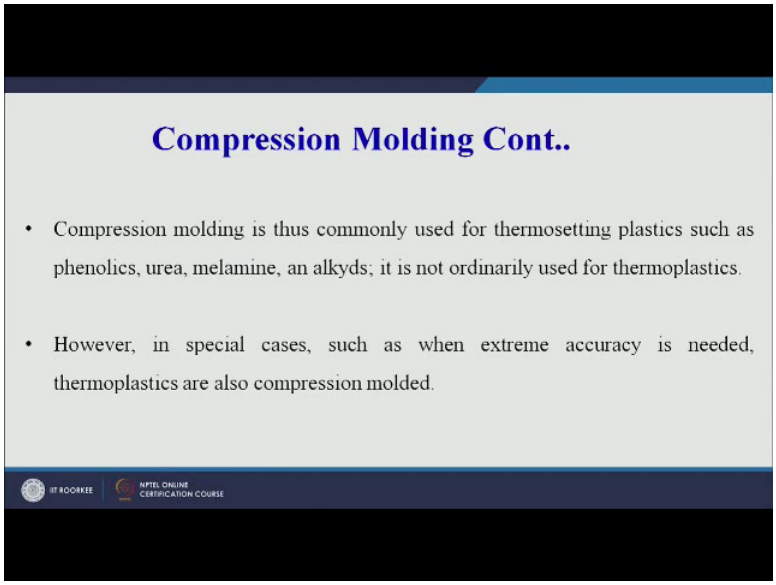

Compression molding is thus commonly used for thermosetting plastics; such as now what are the materials that are commonly used for compression molding process? That

those are phenolics, urea, melamine and alkyds; it is not ordinarily used for thermoplastics as it has to be slow process because we have to cool the mold after every cycle; however, in special cases such as when extreme accuracy is required; we want a very good surface finish, we want a very good dimensional accuracy; thermoplastics can also be compression molded. So, that is one important point to keep in mind; that under what special circumstances thermoplastics are compression molded.

As we have seen in the schematic, mold design is the most important part of the complete compression molding setup; why? Because at this point, in the mold only the product is being formed and the mold is in upper half and the lower half; so, what are the different types of mold designs that are used in compression molding? That is given on your screen.

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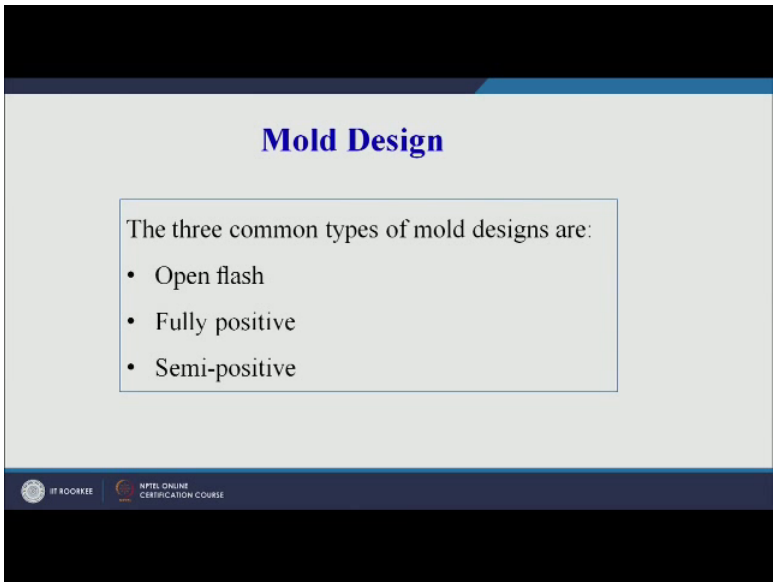

We can see the three common types of mold designs are; open flash, fully positive and semi positive. So, we will see each one of these and then we will try to see the diagram and try to understand that what are the advantages as well as limitations of the three important types of designs that are mold designs used for compression molding process.

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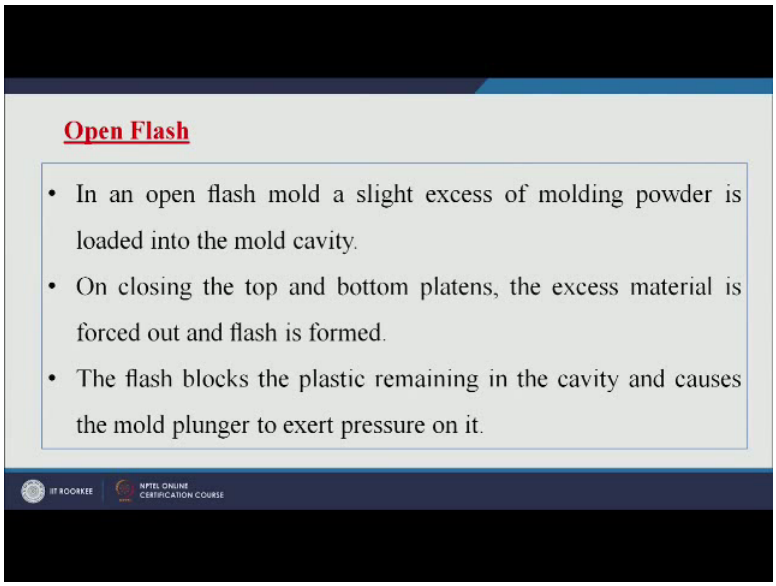

First type is the open flash type; in open flash mold, a slightly excess of molding material is loaded into the mold cavity. First point we should keep in mind; that as per the amount of charge required inside the mold cavity, we will keep slightly additional material inside the mold cavity. On closing the top and the bottom platens; that is the top and the bottom halves of the mold; the excess material is forced out and a flash is formed.

The flash is very common phenomenon in plastics; especially in compression molding. The excess material will come out between the small space that exists; or small lines that exist between the upper and the lower half of the mold. So, this on closing the top and the bottom halves of the mold; the excess material will come out as a flash and therefore, the name of the mold design is also open flash type of mold design. The flash blocks the plastic remaining in the cavity and causes the mold plunger to exert pressure on it.

Now, once the additional part has come out or the additional powder or plastic has come out; it will avoid the other plastic to move out. And when the top half of that mold is applying the pressure on the plastic; it will be sustained pressure, it will be a uniform pressure and it will help in the formation of a good quality compression molded product. So, that is one advantage of a open flash type of mold design.

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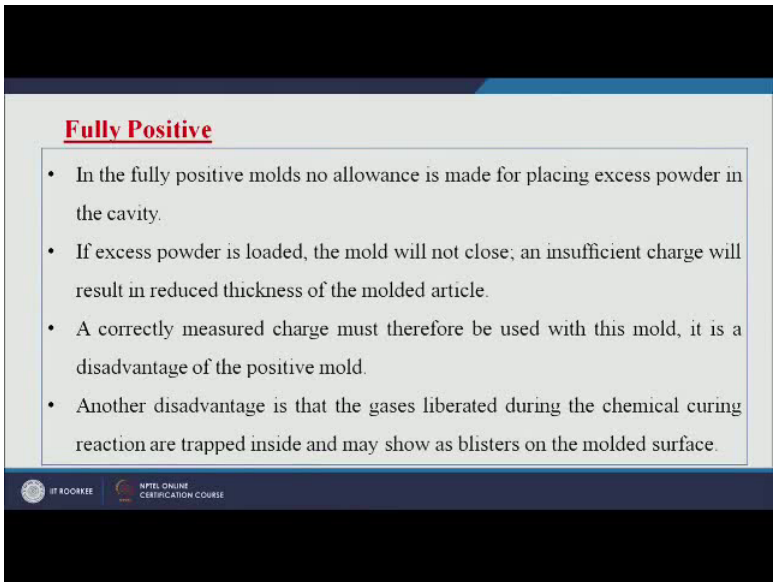

In case of fully positive molds, no allowance is made for placing excess powder in the cavity. So, here the metered amount; the exact amount of raw material is fed into the mold cavity. In case, excess powder is loaded; the mold will not close and insufficient charge; now we are seeing the two extremes. If we are adding additional raw material as in case of open flash type of mold, what will happen? The mold will not close; whereas, on the other hand; if an insufficient amount of raw material or charge is added, it will result in reduced thickness of the final product. Because, if less material is there; the mold cavity may not fill completely and we may get a defective compression molded product.

So, additional charge or additional raw material is not possible in case of fully positive and if the amount is less as then desired; even then we are getting a defective products or a defective product. A correctly measured metered charge must therefore, be used with this mold; it is a disadvantage of the positive mold. Another disadvantage is that; the gases liberated during chemical curing reaction are trapped inside and may show as blisters on the molded surface. So, this is maybe one disadvantage that the gases are not able to escape and they form kind of blisters on the surface of the compression molded part.

So, maybe two major disadvantages we have seen. The only advantage that I foresee in case of fully positive is that we are putting the metered amount of raw material and

therefore, we save on wastage because the flash that is formed in on the part. In case of open flash type of mold design has to be trimmed later on, so that will be wastage on part of the raw material that we are using. But fully positive exactly metered amount is input into the mold halves and therefore, maybe there are certain disadvantages, but we are saving on the wastage of the raw material.

Then, in order to compromise between the open flash type and the fully positive type of mold design; we have a semi positive type of mold design. The semi positive mold combines the certain features or best features of the open flash and the fully positive mold and makes allowances for excess powder and flash.

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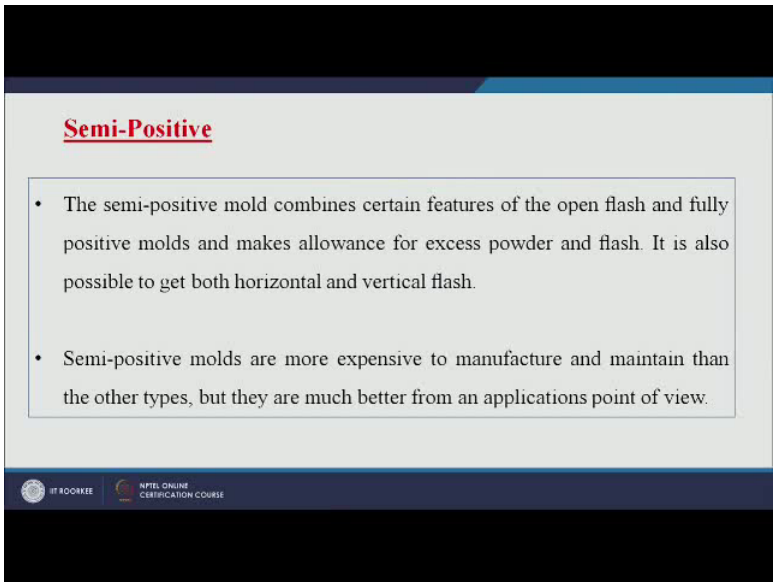

So, we will not exactly put the metered amount; slightly excessive raw material we will input inside the mold cavity. So, it will form slight amount of; or may be smaller flash as compared to a open flash type. And it is also possible to get horizontal and vertical flash; in case of semi positive type of mold.

So, semi positive molds are more expensive to manufacture and maintain than the other types of molds, but they are much better form an applications point of view. So, semi positive combines the best parts of two types of mold; that is the open flash type of mold and the fully positive type of mold. And the only thing, only disadvantage that we see in semi positive type of molds is that they are expensive to manufacture and maintain. So,

these are the brief summary of the types of molds that are used in the compression molding process.

Here we see the diagrams.

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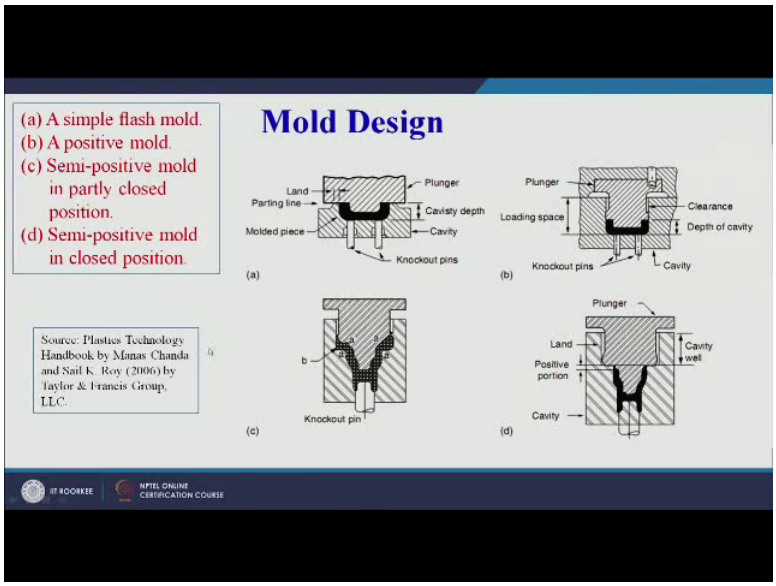

The source in this case is plastics technology handbook by Manas Chanda and Nail K Roy by Taylor and Francis Group. So, diagram is adopted from that source; now here we can see this is the upper part; sometimes it is called as the upper half of the mold, but in the diagram it is called as the plunger. This is the cavity or the bottom half of the mold and this plunger is having this excess portion which conforms to the shape of the final product.

And there is a parting line between the two; now here we can see flash will be formed. So, is a simple flash mold; so, excessive material will flow in between the space provided between the plunger and the cavity. And there we can see two knockout pins are there; these are the knockout pins that we call as the ejector pins also, which will give a slight tap to the product once it is ready and then your product will be pushed out from the mold cavity.

This is the second; is the fully positive mold, exactly metered amount of material is input and then again knockout pins are there and there is no excessive flash formed in a fully positive type of mold. And where we can see semi positive type of mold; so, it is in a

partially closed position and this is in a fully closed position. So, both advantages are there of a semi positive type of mold; slight amount of flash is also there; so the advantages of flash we get here and under the fully closed position; it completely fills the mold cavity and we say one certain amount of material; that goes waste in types of flash type of molds.

So, here less flash is formed in semi positive so, we safe material. And there is no chance of the mold remaining unfilled because we have put slightly additional material in the semi positive type of mold. Whereas, the chance of the mold remaining unfilled is quite possible in case of the fully positive type of mold.

So, the semi positive type of mold has certain advantages; both over the open flash type of mold as well as over the fully positive type of mold. So, just you can remember in the types of molds designs that are used in the compression molding process; as well as what are the advantages and limitations of each type of design.

Now, let us try to; we have seen the mold, we know the process, we have understood the schematic, we know that upper and lower half of the mold is there. Now, let us try to appreciate what we have seen or what we have discussed today with the help of an animation. So, we will see that here also there is upper and lower part of the mold and when the two halves of the mold combine together on your screen you can see.

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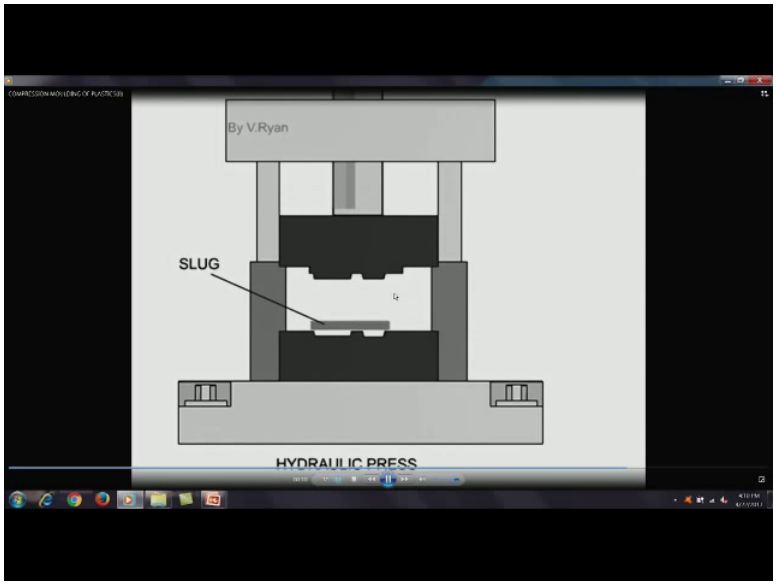

This is the upper half of the mold; which is movable, it moves up and down; the raw material has come, it moves down; deforms it apply the pressure, again a slug or raw material come, it applies the pressure; bottom half of the mold remains constant or stationary, only the upper half of the mold is moving. And here we have not shown; this we can see the knockout pin or the ejector pin. But this is coming out and the completely three dimensional shape is being formed.

Whereas this 2-D motion is shown, but the third dimension also is there; so, you can just have a look at the final product that is forming. See the final product that is forming, it is the three dimensional product and you can see the type of products that can be made; using the compression molding setup. So, I will close the simulation; now you can see that what type of product is formed.

Now, what are the important process parameters that we can control in case of compression molding process? We can see depending upon the type of mold design we are using; we can control the amount of plastic material; that is the raw material that we are going to input that is sometimes called charge

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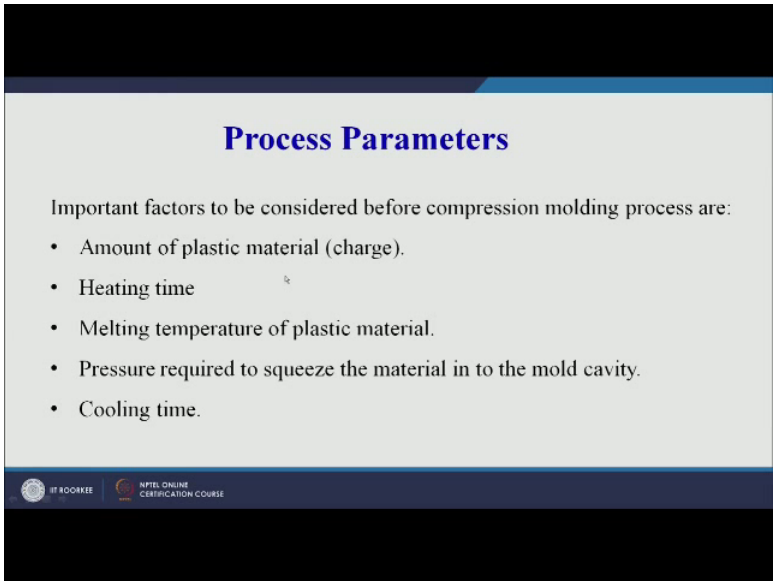

We can control the heating time; for how long our mold will be heated, if you remember in thermoset we will use a hot mold only. In case of thermoplastics; the process cycle is slow because we have to cool the product for full polymerization and therefore, maybe the heating time will be different in case of thermoplastics, it will be different in case of

thermosets. Then we can control the melting temperature of the plastic material which will be fixed, but we can control our temperature that we are giving as a input.

So, our temperature can be slightly higher than the melting temperature or exactly equal to the melting temperature of the raw material. Now, depending upon the type of raw material that we are using; we can control the temperature off the; set up or the machine.

Then we can also control the pressure required to squeeze the material in the mold cavity; so, that is also possible. We can also control the cooling time, we can call it as the holding time also; as long as the two halves of the mold are in contact with each other; that we can call as the holding time. That is also under our control, we can see that when the product has solidified, when the product has been formed; we can open the mold and finally, we will see that the product is ready. So, these are the most important parameters that are usually controlled in case of compression molding process.

Now, what are the materials used?

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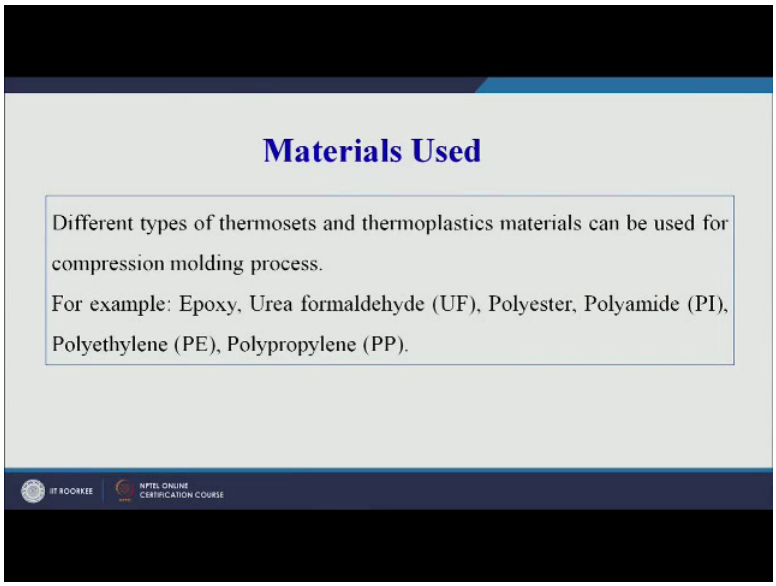

So different types of thermosets and thermoplastics can be used in compression molding process; for example, Epoxy; very common type of thermoset material, Urea formaldehyde, Polyester, Polyamide, Polyethylene, Polypropylene; all these raw materials can be used. So, Polyethylene, Polypropylene both are thermoplastics category and Epoxy, Polyester are in the thermoset category.

So, we can see that different types of polymers or plastics can be used for compression molding process and the final products can be made using all these types of material. So, we will see what are the different types of products that can be made, that can be fabricated, that can be processed using the compression molding process.

Now, what are the application areas? Just a brief summary or brief account of this thing has been given; that is the applications, you can see on your screen.

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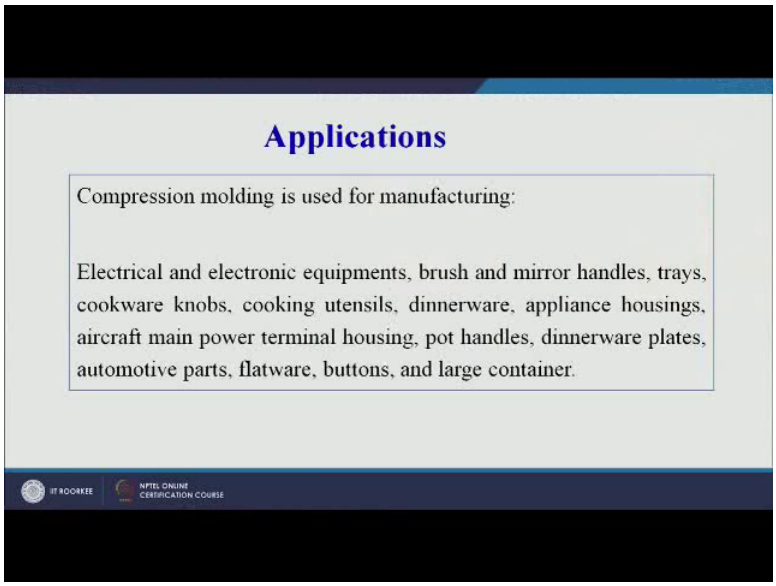

Electrical and electronic equipments can be made, brush and mirror handles, trays, cookware knobs, cooking utensils, dinnerware, appliance housings, can be made; aircraft main power terminal housing can be made, pot handles, dinnerware plates, already we have said; cookware or cooking utensils, automotive parts, flatware, buttons and large containers can be made.

So, there are lot many applications for compression molding process and it is a fully commercial process, industrial scale process and large number of companies are using the compression molding process to form different types of plastic products.

Now, what are the different types of plastic products? You can see on your screen.

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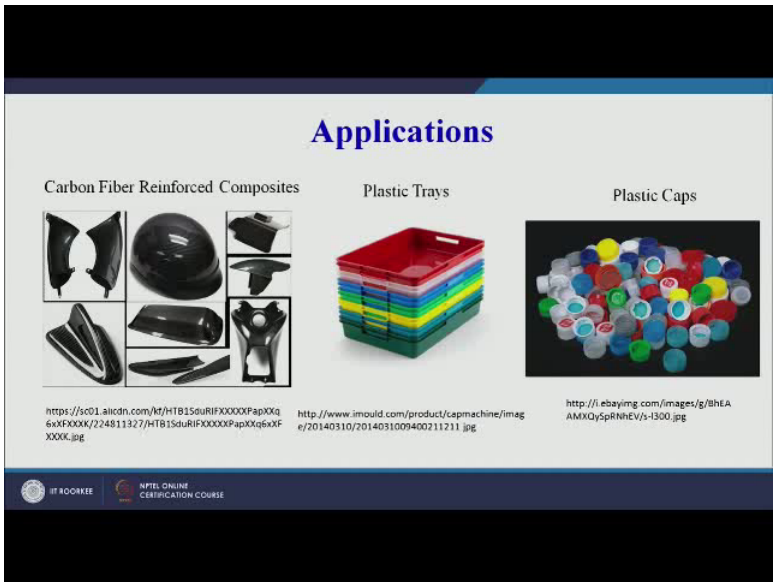

Plastic trays; all of us use these trays, when you travel by air; during the security check; these type of trays are there. So, you can make different types of plastic caps also using compression molding process; then even helmets these are the carbon fiber reinforced composites; right now our session is on compression molding of plastics.

But when we will cover processing of polymer composites, there we will see how these carbon fiber composites are made and what are the changes in the process; specially to may composite parts. But here as applications of compression molding; we can emphasize that compression molding can also be used for carbon fiber reinforced composites. And when we will go further in our discussion; in this course, we will see specifically compression molding of carbon fiber reinforced composite. And you can see the different types of products that can be made; using carbon fiber reinforced plastics.

The last part of our discussion is; what are the advantages and limitations of compression molding process?

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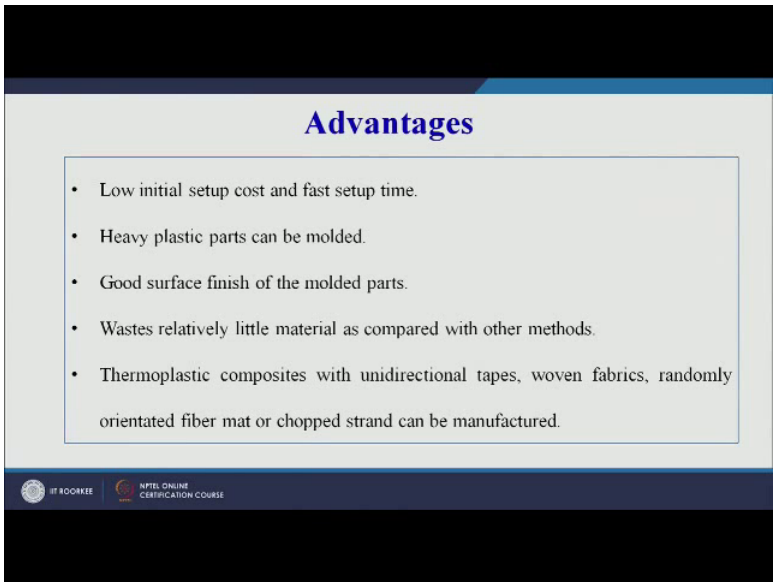

Let us quickly just have an idea about the advantages. Advantages are low initial setup cost and fast set up time; as compared to the other processes for plastics. Heavy plastic parts can be molded; heavy duty compression molding machines are available, through which we can make bigger, larger parts of plastics using compression molding. Good surface finish; as we can see, this is a closed mold type of process; there is a upper half of the mold, the lower half of the mold.

So, on both sides we can get very good surface finish; that is possible. Waste relatively little material as compared to the other methods; when we will see other method, we will see that there is lot of wastage of material. But in case of compression molding, the wastage is less, in case of flash type of mold; yes there will be some wastage in the form of a flash that is formed between the upper and the lower half of the mold.

Thermoplastic composites with unidirectional tapes, woven fabrics, randomly oriented fiber mat or chopped strand can be manufactured. So, this is basically the application that compression molding process can also be used for composite materials. And we have seen in the previous slide; that carbon fiber reinforced plastics can be made using the compression molding process.

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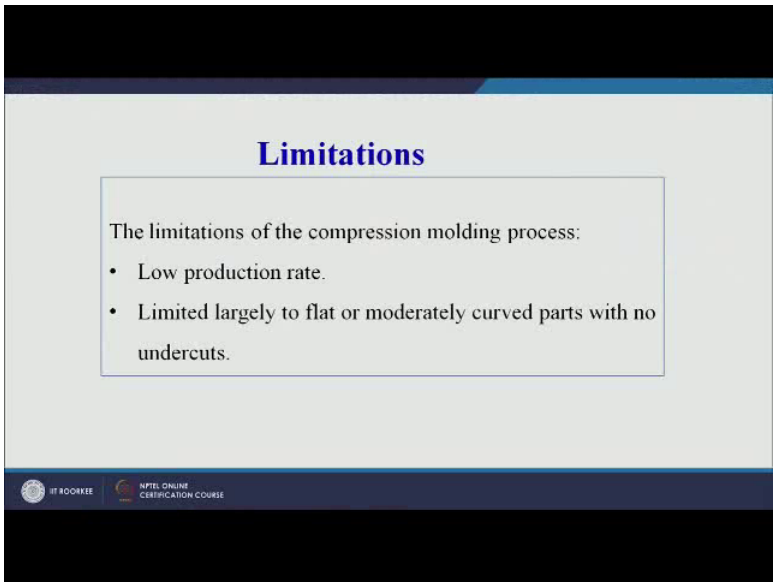

Now, what are the limitations? The limitations of the compression molding process are that it is; slightly slow as compared to the faster processes, such as injection molding that since we can make large parts in compression molding. So, it certainly off sets the time that is taken to form those parts. Limited largely to flat or moderately curved parts with no undercuts. So, that is a specific limitation; that it cannot be used for a very complex parts, which have undercuts or where all the three dimensions are maybe in reasonable proportion.

If you see the type of force again; I would like to take you to this slide, if you see that the products are largely two dimensional, the third dimension is not as compared to x and y dimension; the z dimension is not that large. So, you can see for all the products here; largely flat products or largely we can say plate type; sheet type products are made using the compression molding process.

So, with this we come to the end of our session on compression molding of plastics. Now, in our next session; we will discuss the injection molding of plastics or polymers. And once our discussion on processing of polymers is over; we will switch our discussion to processing of polymer based composites or polymer matrix composites.

Thank you.