Processing of Non- Metals

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Module - 4
Plastics: Properties and Processing
Lecture - 6
Thermoforming

A warm welcome to all of you, in this lecture on thermoforming. As some of you are aware that we are discussing in this particular module, the processing of plastics. Our focus primarily is to discuss that what are the various processing techniques or most commonly used processing techniques, which are used for processing of plastics. Let us let us just have a review what we have covered in our previous discussions or previous lectures in this particular module on processing of plastics.

We have started our discussion with the brief revision of what basically the plastic are, we have seen what are thermosets? We have also seen what are thermoplastics, the basic characteristics of the thermo sets and the thermoplastics, and the application area of thermo sets and thermoplastics. We have also tried to review some of the mechanical properties of the polymers, and we have also seen that what are the various types of structures in which the polymers usually exist.

Then we have focused our attention on the processing techniques, which are used for processing of plastics. If you remember, we have seen that what is a casting process specifically in context of plastics. We have seen what are the advantages limitations and applications of casting processes are? Thereafter we have focused our attention on some other techniques, such as we have seen transfer molding, we have seen compression molding, we have seen extrusion of plastics and we have seen the injection molding of plastics.

In our previous lecture, if you remember we have seen the basic details about the injection molding process. And for all these processes our focus primarily has been to understand that what is the basics of the process? How the process actually takes place? What are the raw materials that go in to the process? Finally, how these raw materials are converted in to the final product? How the shape is given to the final product and

how the final product is ejected out of the mold if a mold is used for converting the raw material into the final product.

In our previous lecture focus was on injection molding and today we are going to discuss another important process which is for processing of plastics, that is thermoforming. And thermoforming can also be done in a number of ways, basically there are some process variants which are available for thermoforming that we will try to understand with the help of diagram. But before going into the details of the thermoforming process as I have just revised what we have already covered in this particular module of processing of plastics.

I will just like to again emphasize that there are three important things which are usually happening in most of the processing techniques, for the plastics. If you remember that heating is the one of the catch words in which, the plastic raw material is heated. The raw material may be enable as in the previous lecture we have seen in the form of pallets or powder. So, we have our raw material which is available to us and this raw material is heated so the first catch word is heating.

After that once it has heated or it has melted the raw material that is a plastic in this particular case is given the desired shape. So, that particular thing or that particular stage, we can call as the forming stage, in which we are forming the shape of the final product, that we are going to make or which is our design requirement. So, the first stage is the heating stage, the second stage is the forming stage and in the forming we are taking the raw material which is in the molten stage in most of the cases and giving it a particular shape.

After forming, the product allowed to cool for a substantial period of time. depending upon the product cycle or the processing cycle. cooling is an important state. The last stage is the ejection of the final product from the equipment. Now, equipment can be mold or the died half or it can be any other equipment where the forming has taken place. So, basically there are three important stages which again I am revising because these are the stages which have taken place in most of the processes, which we have already covered.

Again I want to emphasize the processes which we have already covered, we have seen casting we have seen transfer molding, we have seen compression molding, we have seen injection molding, as well as we have seen extrusion of plastics. So, today our focus is on thermoforming. So, we will try to understand thermoforming process with the help of few diagrams, but one important point that is quite clear from the name itself, if you look at the name of the process thermo and forming, so basically it gives he clear representation of the basic processing stages involved in converting a plastic raw material into a final product.

Thermoforming, thermo may be just a layman I can say thermo some related to heat and forming as a layman we can say changing the shape or forming into a particular shape. So, basically what is happening is heating and forming. So, basically we are going to heat the raw material and deform the shape of the raw material according to the final design requirement or to the application for which the product is being developed.

So, basically here we will have two important stages in the process, that is thermoforming which means heating and deforming. So, we would heat the raw material and it would be deformed into the final product. So, what would be the type of raw material, and how it would be deformed and what are the important process parameters that would be taken into account, that we are going to discuss in the subsequent slides. So, let us with this particular introduction, let us start our discussion on the process of thermoforming of plastics.

Now, thermoforming is a plastic processing technique in which a thermoplastic sheets are formed with application of heat and pressure inside the mold. So, basically there two important process variables here that is the heat and the pressure and the whole process is taking place inside the mold. So, thermoforming is the plastic processing technique in which the thermoplastic sheet are formed. So, what is the type of the raw material here the raw material is in the form of a sheet in case of injection molding. If you remember, the raw material was in the form of the powder or the pallet, but in the thermoforming the raw material is in the form of a sheet.

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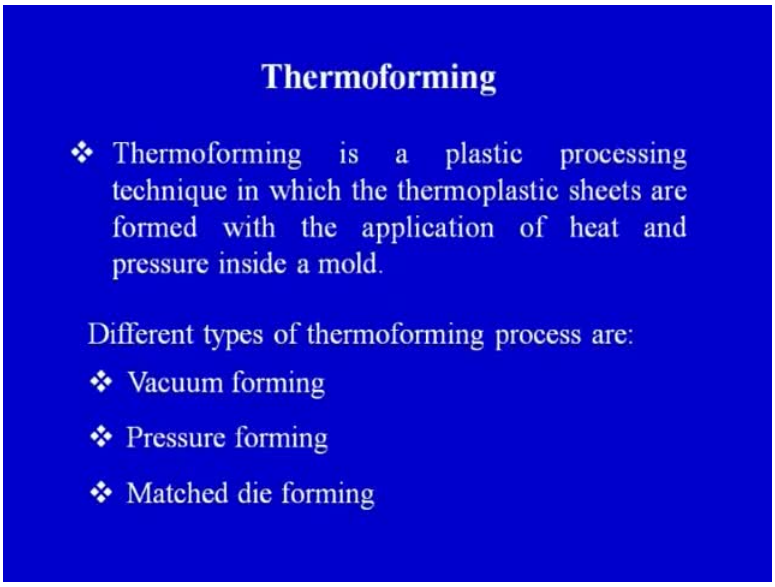

So, thermoforming is a plastic processing technique in which the thermoplastic sheets are formed with the application of heat and pressure inside the mold. So, we are going manipulate the heating mechanism and we are going to manipulate the pressure application, in order to define form a heated sheet into the desired product. So, the forming is going to take place inside the mold and the mold would conform to the shape of the final product or would conform to the details of the final product, that we want to produce.

That that we want to process, so we have different variants of the thermoforming process and we can say different types of thermoforming processes can be vacuums forming in which of the vacuum is used to deform the shape. We can have pressure forming and we can have matched deforming, so we would be seeing with the help of the diagram. What are these forming techniques? But prior to that from the name itself we should be able to get an idea that in this particular process, we are going to change the shape of the sheet into the desired shape, with the help of the heat and pressure. Now, let us first see the first process variant that is the vacuum forming process.

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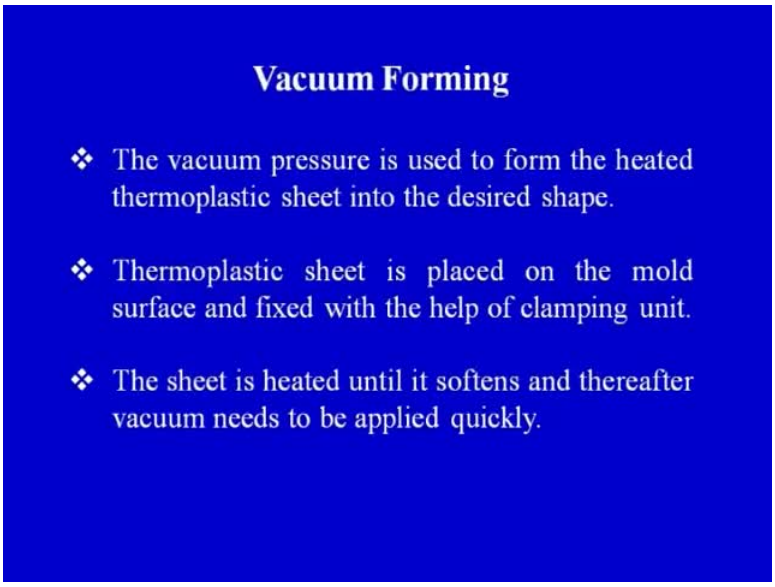

The vacuum pressure is used to form the heated thermoplastic sheet into the desired shape, so the desired shape would conform to the shape of the mold, but here the deformation would be activated by or would be achieved by the vacuum pressure. So, the vacuum pressure is used to form the heated thermoplastic sheet into the desired shape thermoplastic sheet is placed on the mold surface.

Fixed with the help of clamping unit, so we will try to understand this with the help of the diagram and the shape of the sheet is heated until it softens. Thereafter vacuum needs to be applied quickly, so first the sheet is heated. Then a vacuum is applied to deform the sheet according to the desired shape, so let us try to understand with the help of a diagram.

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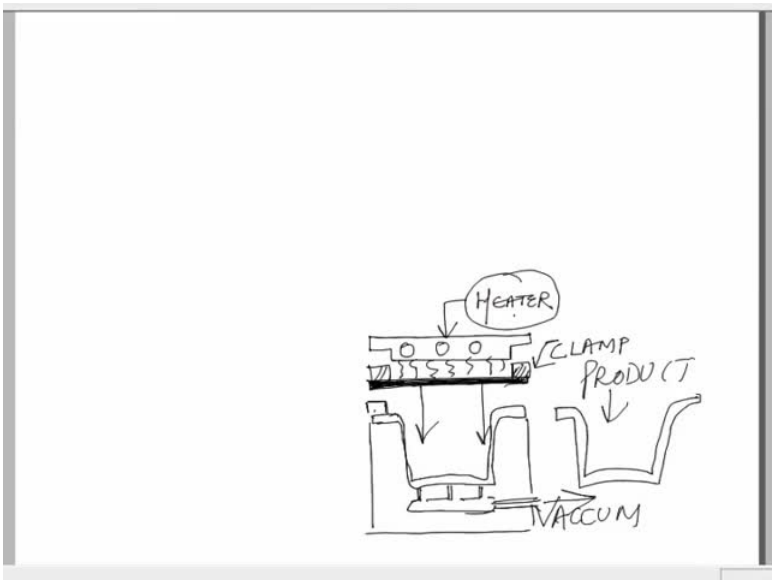

So, on your screen you can see, so these are we can say heater or the heating elements and we have the heat, which is going to heat the plastic sheet. Now, this is the plastic sheet on your screen this the plastic sheet, which is getting heated because of the heat, which is being supplied by the heater and then we need to clamp these sheet. So, that we are able to deform it according to the desired forming or the mold dimensions. so this is we can say the clamp or we can have clamps on both the sides.

So, first the important point in the case of thermoforming is that we need to have a heating arrangement, which is there on your screen we need to have a heated arrangement. This heat is going to heat this raw material, so the raw material or the sheet that we are going to deform that is the raw material in this particular case is in the form of sheet. This particular sheet has to be clamped properly, so we have the clamps here. Now, this is the first arrangement that is the heating that is coming from the word thermoforming thermo.

So, the first stage is the heating stage second stage is the deforming stage in which this particular sheet has to be deformed into the desired dimensions. So, the desired dimensions would be the dimensions of the mold because we will design our mold in such a way that we get our final product according to the dimensions of the mold let me draw the other part of this process. Now, I am going to draw on your screen you can see

this is the mold. Now, this is my sheet which has now admired to or conformed to the shape of the mold.

This particular sheet is going to come down like this, why it is going to come down from where it has got the indication, that it has to come down it has got the indication to come down, because the name of the process is vacuum forming. So, here we are going to apply vacuum. So, when we will apply the vacuum at this particular point it is going to apply a force on the heated sheet. The sheet has been heated because of the heating element it has soften and the soften sheet, when we have been bringing with the contact of mold and a vacuum is applied the vacuum sucks, that air between the mold and the sheet and the sheet gets a attached to the shape of the mold or to the wall of the mold.

So, basically what type of product we will get out from here we get a product of this type, out of this particular mold. So, this is my final we can say product that has been made by this thermoforming process and this particular variant of the process is called the vacuum forming. So, on your screen again I am going to revise this process because we know that there are two important things to be taken care of. First is the heating and second is the forming. So, the heating is done by the heater that is written on your screen.

So, heater is heating the raw material, the raw material is a available in the form of a sheet this particular sheet. When it gets soften, it is brought in contact with the mold and a vacuum is applied and this vacuum applies a pressure on the soften sheet. The sheet gets adhere to attached to the wall of the mold and after cooling the vacuum is withdrawn after cooling after withdrawing the vacuum. Sometime some amount of time is given for the cooling after the cooling process has taken place.

The sheet is finally, taking the shape of the mold and this particular sheet is later on taken out from the mold. We get the final product and the product is shown on your screen. So, there are two important stages that is heating and the forming the forming is being achieved with the help of a vacuum. So, let us now try to see to see this with the help of the text that is available in this slide.

So, vacuum forming in vacuum, forming the vacuum pressure is used to form the heated thermoplastic sheet into the desired shape thermoplastic sheet is placed on the

mold surface and fixed with the help of clamping unit the sheet is heated until its softens. Thereafter vacuum needs to be applied quickly.

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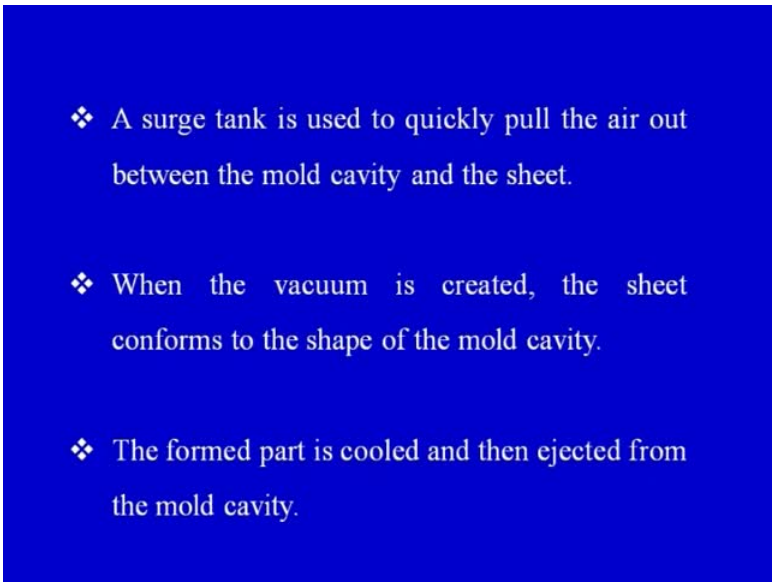

A surge tank is used to quickly pull the surge out from where the surge would be taken out, the air would be taken out from the place between the mold cavity. The sheet if you see the diagram, that we have drawn the sheet is attached to the clamping unit and we have a mold cavity between and there is a air. So, this air would be sent out by the vacuum and this sheet would be deformed like into the shape of the mold. So, surge tank is used to quickly pull the air out between the mold cavity and the sheet when the vacuum is created.

The sheet conforms to the shape of the mold cavity is the shape of the final product that we want to generate. So, when the vacuum is created, the sheet will conform to the shape of the mold cavity the formed part is cooled which I have already told and then it is ejected from the mold cavity and we get out final product. So, let us just try to revise the basic process of vacuum forming with the help of the diagram although I have the diagram, but here again we can see just to have a complete representation of the process once again I will try to revise what we have drawn in the diagram.

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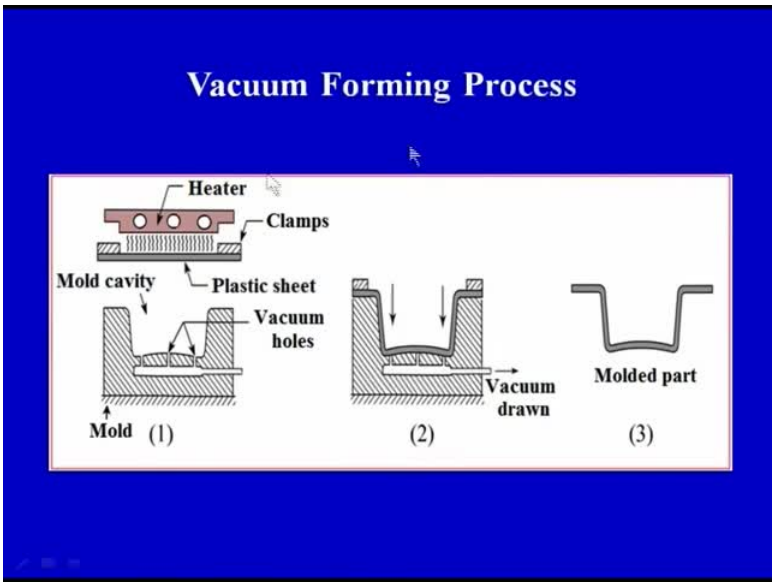

Let us see now the vacuum forming process we have the heater that is the heating arrangement. We have the two clamps to fix the mold fix the sheet that is the plastic sheet, this is my plastic sheet. So, this fixed with the help of clamps heating arrangement is there this, these two clamps sheet would be placed here after the sheet has soften. Finally, we will apply vacuum here and once the vacuum is applied the sheet would conform to the shape of the mold.

Finally, this is the final product, which has been removed from the mold after it has cooled down. So, there are two three stages on this stage, one is the heating stage in which the plastic sheet is heated by the heaters. Stage two where the vacuum is drawn and the vacuum is applied and the sheet conforms to the shape of the mold cavity. The third stage is the drawing out of the mold part from the mold, so basically the vacuum forming processes is completed in three stages in totality. So, the first stage is heating second stage is forming and the third stage is cooling and ejection of the final product from the mold cavity.

So, vacuum forming process is not at all we can a very completed process, but there are few things that need to be taken care of. That is how much heat has to be supplied? What amount vacuum is required? So, these are few important variables, which are to be taken care of and these variables would also dependent upon the type and the thickness of the shape heat that we want to deform most probably, there would be other

criteria also, which needs to be taken care of, but these are some of the important points, which would be there in our mind when we are going to be process any plastic sheet with the help of the vacuum forming process.

So, this is we can say a very simple representation of the vacuum forming process in which the sheet is heated to a particular temperature, where its softens and finally, is clamp to the mold. The vacuum is created the vacuum is applies a pressure on the sheet and the sheet conforms to the shape of the molt and finally, after the cooling of the product or the sheet the final product is taken out from the mold. So, this the we can say basic process of vacuum which falls under the a thermoforming of plastics.

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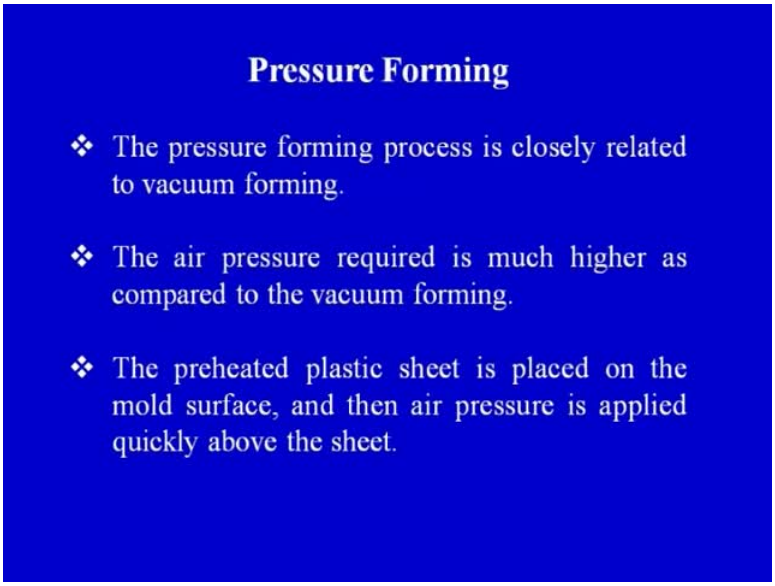

Now, let us come to the second process that is the pressure forming. So, basically the stages are seen that the sheet is heated to a particular temperature it softens on heated and the soften sheet is deformed. According to the shape of the mold cavity, but the method or the mechanism of applying the pressure defers in the vacuum forming. The vacuum is used to deform the shape of the plastic sheet or the soften plastic sheet and in pressure forming pressure is applied to deform the shape of the plastic sheet.

Now, how the pressure is applied we are going to understand with the help of a diagram. So, let us first have a overview of pressure forming process, the pressure forming process is closely related to vacuum forming, because the basic stage is seen only the plastic sheet is first heated it softens on heating. Finally, a pressure is applied to deform it according to the shape of the mold. Now, how the pressure is applied? The surge pressure is required is much higher as compared to the vacuum forming. So, here air pressure is applied to deform the sheet into the desired shape, the preheated plastic sheet is placed on the mold surface, which is as common step as compared to the plastic forming process.

Then air pressure is applied quickly above the sheet, so this air pressure will deform the sheet depending upon the invert would be the final shape of the mold would be the final shape of the product. So, the preheated plastic sheet is placed on the mold surface and then pressure is applied and under the influence of the air pressure the sheet would deform. It would take the shape of the mold and the shape of the mold would conform to the shape of the final product, that we are going to desire, which is desirable product that we want to produce for a specific application. Now, what are the application areas of the thermoplastic that we would be seen in the subsequent slides.

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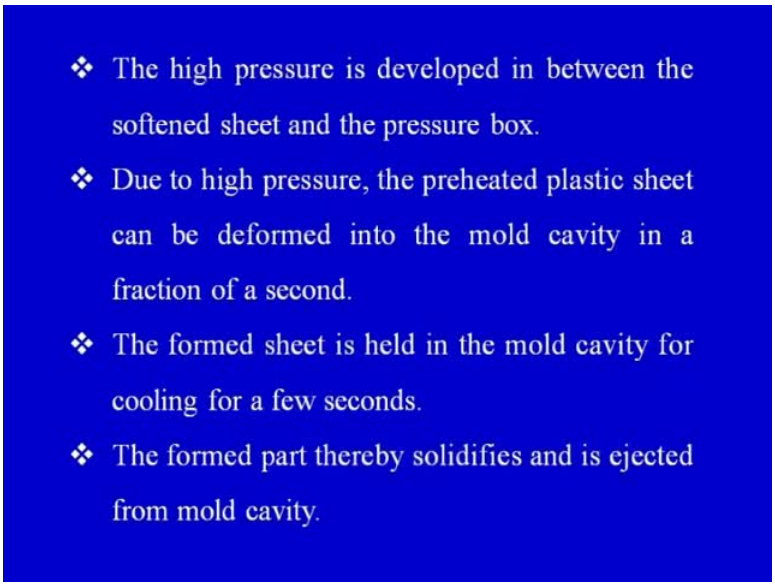

The high pressure is developed in between the softened sheet and the pressure box there is a box in which the high pressure is generated by the air. Here we will see with the

help of the diagram due to high pressure the preheated plastic sheet can be deformed into the mold cavity in a fraction of a second. So, we can say a large of number of parts can be made because the production rates can be high as the time required to deform the sheet under the application of the air pressure is not too high. So, it can be the time required is less.

Therefore, a large number of parts can be made if we are making the parts by the pressure forming process. So, due to high pressure the preheated plastic sheet can be deformed into the mold cavity in a fraction of a second. The formed sheet is held in the mold cavity for a few seconds, the formed part thereby solidifies and is ejected from mold cavity. So, if you see most of the steps that are involved in the processing of plastics are similar, but there are few variations here and there and we are going to get different types of products that can be made from different types plastics.

So, here also we can see that we are highly evaporated sheet this particular sheet is subjected to air pressure and at a very high pressure this sheet is going to conform to the shape of the mold cavity. So, we have a mold cavity or mold according to which we want to generate the final product, so basic step that is heat form and cool are same in this particular also. Here also preheated plastic sheet, we are forming it with the help of a pressure and we are allowing it to cool. As you can see the formed part if it cools and ejected into the mold ejected out of the mold cavity.

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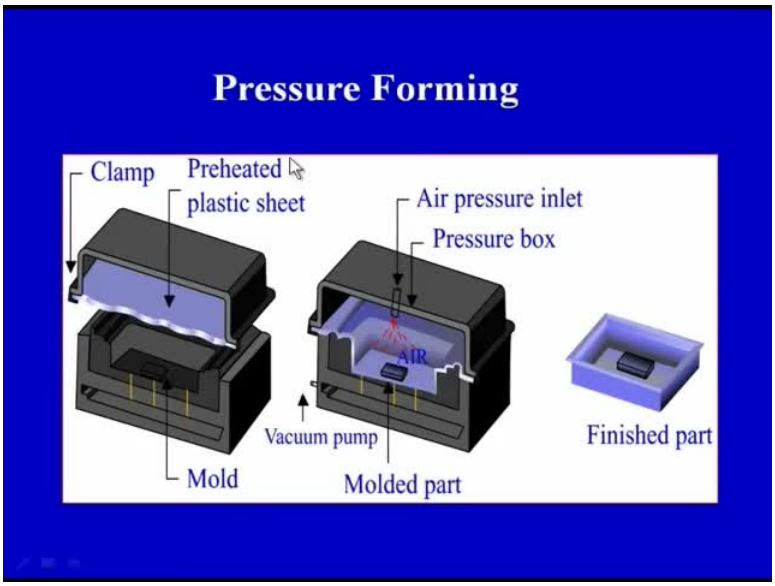

On your screen you can see a very simple representation of pressure forming process this is the pressure box. This is the you can see mold cavity it is written also very clearly mold it is the mold cavity. This is the preheated, plastic sheet this particular light blue color. This is the preheated plastic sheet we have the mold cavity and there are clamping arrangement these two are pressure box at and the mold half would be clamped to together and the air would be ejected at the high pressure. So, this is the step number one, this is the preheated plastic sheet we have our clamping arrangement in which, the mold would be clamped to the pressure box.

Then we have the air pressure inlet this is the air pressure inlet red color indicate that air at high pressure is being subjected to the sheet or we can say in other words preheated plastic sheet is subjected to a very high air pressure jet surge pressure inlet is there. This is the pressure box, it is mentioned here and because the pressure of the air this this preheated sheet, which has already softened, because of the heating action will deform to or will conform to the shape of the mold cavity. Now, according to the shape of the mold cavity we will get the final shape of the plastic sheet.

So, here we can see the stage three, in which we have got the finished part which was initially a flat sheet. Now, it has been deformed into a particular type of a box with the specified dimension. So, the geometry which was earlier a flat sheet now has been into a box by the application of heat and pressure, so we have a preheated plastics sheet which has been deformed under the application of air pressure into a box. So, this is the pressure forming process and we have already seen the vacuum forming process and from this diagram we can try to understand the difference between the vacuum forming and the pressure forming.

If we see in the vacuum forming a vacuum was used to deform the shape of a plastic sheet. In the case of the pressure forming, we have used the air pressure to deform the shape of the shape of the plastic sheet according to the final product and the final product in this particular case is a box type of a product. We can have different shapes depending upon the shape of the mold, so basically the principle is we have a preheated plastic sheet which is a soft sheet or it is softened because of a heating action. Finally, it is deformed under the application of air pressure and it conforms to the shape of the mold cavity. So, this is the basic we can say process of pressure forming, which falls under the category thermoforming.

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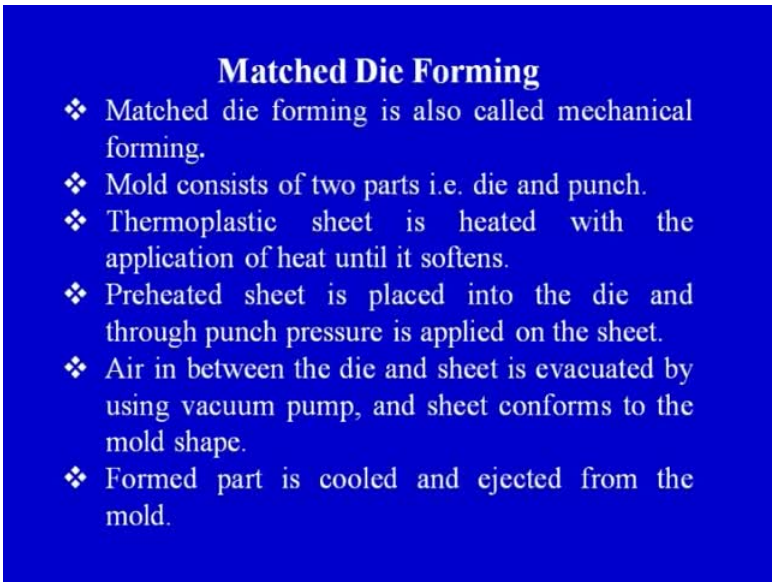

Now, let us see the third variant of the thermoforming process that is the matched die forming process, we will try to understand matched die forming also with the help of a diagrams. Let us see what are the salient points in case of the matched die forming, so matched die forming, it is also called the mechanical forming process. Mold consists two parts, that is the die and the punch. So, here the pressure would be applied with the help of a die and a punch type of a arrangement.

So, it is a mechanical action that is taking place between the die and the punch thermoplastic sheet is heated with the application of heat until it softens. This particular step is common in vacuum forming also pressure forming also. In die forming also, the raw material is here. Also it is in the form of a plastic sheet, which is heated to a particular temperature and a under the influence of the temperature it softens down. So, we have a softened plastic sheet, now we have to deform this sheet according to the shape of the final product which is our final product.

So, preheated sheet is placed into the die and through punch pressure is applied on the sheet, so through punch we are going to apply the pressure on the sheet. So, we have a die the shape of the die would conformed to shape of the final product. So, we have a product design and that design we want to produce in a plastic material. We have already taken the raw material in the form of a sheet, which we have heated to a particular temperature the sheet has softened and this softened sheet we have placed will

be between the die, and the punch and the pressure on the sheet would be applied through the punch.

It would be placed on the top of the die, so the preheated sheet is placed into the die and through punch pressure is applied on the sheet air in between the die and punch is evacuated by using vacuum pump. The sheet conforms to the mold shape or to the die shape. So, whatever mold we have made die we have made the sheet will conform to the shape of the mold the formed part is cooled and ejected from the mold the third stage is also common the final product is allowed to cool. Finally, it is ejected out of the mold or the die gravity.

So, basically first and the last stage that is the heating of the plastic sheet and the ejection after cooling of the final product is same in all the three process variants. That is vacuum forming, the pressure forming and mass die forming the only difference lies in the stage number two, that is the method and mechanism of apply the pressure or the method and mechanism of deforming the sheet into the desired sheet in vacuum forming.

We are deforming by application of vacuum in pressure forming, we are form deforming the sheet with application of air pressure and in mass die forming, we are changing the shape of the soft plastic sheet with the help of die and punch type of arrangement. So, the second stage is varying, but the first and last stage are common in the various process variants of the thermo forming process.

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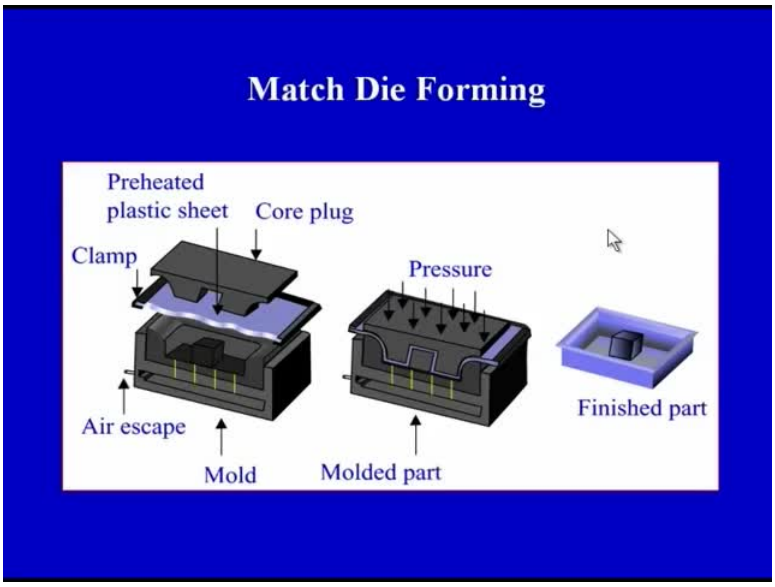

So, here again this is the similar type of representation. Here we can see, let me first show this is the mold or the die. So, we have the mold or the die which will conform to the shape of the final product and air between the we can say sheet and mold would be escaping through this port we have a port from where the air escape is activated or the air is allowed to escape. There is a clamping arrangement to clamp this particular top part, that is the core plug and the mold of clamping arrangement again present here, which was also present in case of pressure box and the mold which was seen in pressure forming.

So, we have preheated plastic sheet again this light blue color, this arrow indicates this light blue color sheet, this is the preheated plastic sheet. So, here the pressure is applied on the core plug, which we can say it can be a punch also. We have a mold we have a punch the shape of the punch is conforming to the final shape, that we want to generate and we have die cavity which is conforming to the shape of the final product. So, this is the molded part this is shown here, this is my molded part.

You can just see the arrow the movement of the arrow on your screen, so this is the final shape that would be achieved after the process is complete and the sheet is allowed to cool inside this mold cavity. So, we have preheated sheet we have a core plug and there is a we can say port which is provided for the escape of the air and finally, we get the finished part So, basically we can see again the three stages are there preheated plastic

sheet stage number one application of pressure by the punch and the die type of arrangement stage number two heating forming and cooling inside the mold.

Finally, the product or ejection of product from the mold and this is the usable product, which has been made by the mass die forming process. So, if you see the stages are common only the method and mechanism of applying the pressure is different in the three variants that we have considered, that is vacuum forming the pressure forming and the mass die forming.

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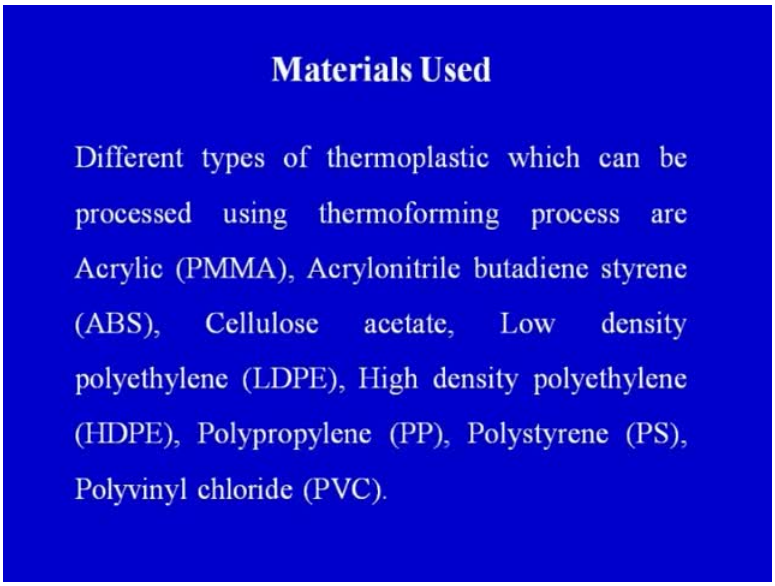

Now, what are the materials that can be used different types of materials can be used for thermo forming process. So, different type of thermoplastic which can be processed using thermo forming process are acrylic, acrylonitrile butadiene styrene, that is ABS, cellulose acetate we can have low density polyethylene LDPE, polystyrene, PS, polyvinyl chloride PVC. Different types of plastics can be processed.

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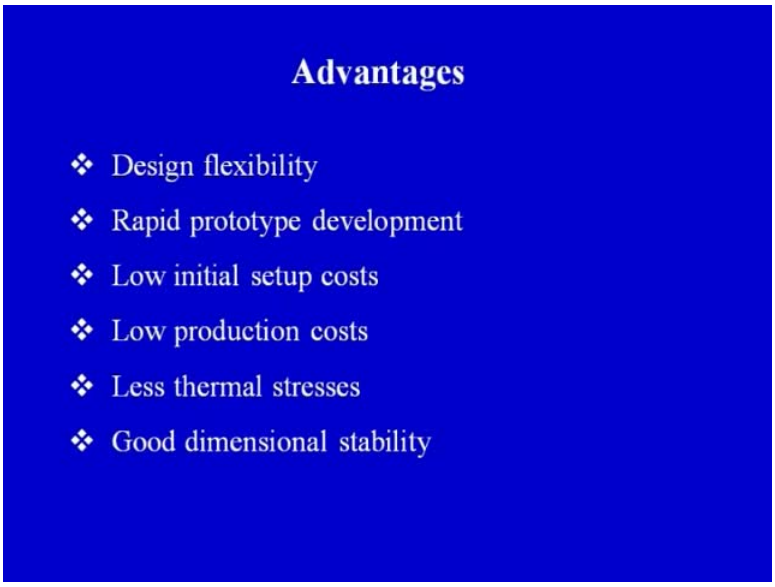

Now, what can be the advantages of thermo forming process you can see on your screen, first important advantage is the design flexibility we can get different type of designs by modifying the the shape of the mold. We can have different thicknesses, and we can have different types of materials which can be used as in the previous slide we have seen what are the different types of materials that can be thermoformed.

So, there is a wide variety of materials there are wide variety of shapes, there can be thickness also that can be varied even we can say different designs can be incorporated into the mold. So, different kinds of products can be made by the thermo forming process also the process has got the various variants that is the vacuum forming, the pressure forming and mass die forming. And depending upon the requirements of a particular design, we can choose the process.

Therefore, it is a versatile process and we have fair (( )) of design flexibility, which will be available with the thermoforming process rapid prototype is another advantage, because the process is fast. Very easily we can generate the prototypes specifically in this particular case that is the thermoforming. The setup cost are also not very high because here we have only two infra structural requirement that is we need to have a heating mechanism, which can heat the plastic sheet.

So, that sheet can be softened and the second infra structural requirement are the we can say one of the important inputs is the pressure the mechanism of applying the pressure. So, we need to have the mechanism of heating and we need to have a mechanism of applying pressure. So, applying pressure we have seen three different types of the pressure can be applied on the sheet.

Three different mechanisms are the vacuum air pressure or the mechanical action of the punch and the die. So, initial cost are low, why? Because heating and application of pressure can be done at a fairly reasonable cost. So, the production costs are low, because setup cost are also low thermal stresses are less in this particular case. Finally, the dimensional stability of the final product that we get is considerably good.

So, there are we can say lot of advantages, which are possible with the thermo forming process and this particular process is particularly suitable for a specific type of applications, that we would be focusing on our subsequent slides. So, let us see what are the limitations because these process has got lot of advantages, but there are certain limitations also which are there in this particular process.

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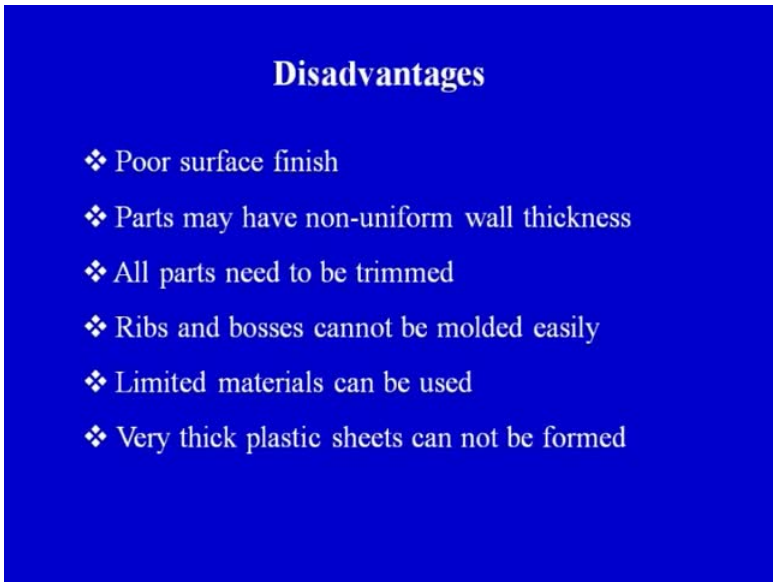

Now, what are the disadvantages in the screen we can see. It has got poor surface finish, sometimes the finish we get is not according to the desirable finish. That is designed into the product, now the product has been designed for a specific surface finish, but the because of the process details are process variations sometimes we are not able to get the desirable surface finish. Because you can see the way the way pressure is being applied sometime the uniform pressure may not be applied and the finish that we get may not be that good.

So, parts may have non uniform wall thickness, that is also one of the defects or one of the limitations of the process. This is also because of the method of applying the pressure, so when we are the pressure sometimes we may not able to deform the sheet uniformly. We may get extra thickness in a particular section and in some other particular section at distance, we may not get the uniform thickness. So, be the surface finish is one limitation the other limitation is that, non uniform thickness of the parts or the non uniform wall thickness of the parts.

All parts needs to be trimmed because we are using the clamping force, when we have clamped the parts clamped, the sheet and then we are deforming it, we need to trim it that clamped force. So, all parts needs to be trimmed, so additional we can say stage or step is added in the product processing cycle or the product development cycle, where a final trimming action is required in on all the parts that are produced by the thermo forming process.

Certain advancements and some process variants can be designed, where this action can be or this particular process of trimming can be nullified or can be minimized. Ribs and bosses cannot be molded easily because we have already seen that the one of the important limitation is the non uniform wall thickness and on top of that, if we have some ribs and bosses in the product designed there, the problem of uniform uniformity may further be aggregative.

So, even in a simple sheet sometimes we are not able to deform it uniformly and we do not get a uniform thickness throughout the cross section of the sheet or throughout the length of the sheet when we are deforming it into a different design, so this fourth point is very, very important in which the ribs and bosses cannot be molded easily.

As I have discussing again and again the part number two, in which we have seen that parts may have non uniform wall thickness. So, if we have a plastic sheet and we are deforming it according to the shape of the mold, the thickness that we are going to get may not be uniform. So, the non uniform wall thickness is one is one of the issues, why?

Because in the first two processes if you see, the vacuum forming and the pressure forming we are not having a control on both the sides of the product. In case of mass die forming, if you see we have control on both side. On one side we have the die and on other side we have the punch. So, we have control on both the sides, so we can expect that we may get a uniform wall thickness. But in case of other process variants there is a tendency that we may not get uniform wall thickness of the final product. So, on top of that if we add this ribs and bosses into the product design, we may further aggravate our problem.

So, the ribs and bosses cannot be molded easily using a thermo forming process. So, there are other process we cannot say that ribs and bosses cannot be made in plastic products, there are other processes which are suitable for making this type of product designs, but yes for thermoforming we have to access caution the product design necessities ribs and bosses.

Then, we can see limited materials can be used all types of plastic materials cannot be thermo form because of certain process constraints because we have to heat it it should soften on heating. It should have the tendency the material should have the tendency to be deformed into the desired shape without actually fracturing. So, we have to choose the material, which can only be thermoform because all materials will not have those characteristics of being formed, because here you can see two important stages that are heating and forming.

So, if a material is heated and when you apply pressure it may fracture or it may get damaged. So, those types of materials cannot be deformed easily. So, summary is that thermoforming is not suitable for all types of materials and when we are choosing the thermoforming process for making a particular product, we should be very cautious about the selection of the raw material. We should choose the raw material with a very, very intelligent. We should know that yes this particular material can be heated.

On heating this material will soften and on softening if we apply pressure either by vacuum or by air pressure or by with help of punch. This particular material cab be deformed into the desired sheet. So, that is important and we should always keep in mind that all not materials can be thermoformed. Blind application on thermo forming on all types of plastic materials may sometimes lead to devastating or failure results.

So, another important limitations, that very thick plastics sheets cannot be formed. So, very thick plastic sheets, why these cannot be formed? Because we are applying the pressure with the help of air or with the help of vacuum. So, very thick sheets cannot be deformed because lot of pressure would be required. If the thickness of the sheet would be increase or the thickness of the sheet would be very high.

So, thin sheets can be deformed easily by the thermo forming process, but if the thickness of the sheet is high, then we may have to go for some other process, rather than going for thermo forming process thickness of the sheet is also a limitation. So, let us now just summarize that what are the various limitations of a thermo forming process. So, the surface finish that we get of the final product may be poor in some of the cases parts, may not have uniform wall thickness part may not have uniform wall thickness.

All the parts need to be trained because of the clamping arrangement, which is provided for holding the plastic sheet. So, that training action is becomes a important partier it becomes imperative ribs and bosses, sometimes product has to be made by the thermoforming process. All types of materials cannot be blindly thermoform and a proper selection of the raw materials is important, if it has to be formed by thermoforming process. Finally, the thickness of sheets is also a limitation and if the thickness is high it cannot be thermoformed easily.

So, lot of advantages of the process are there, but there are few limitations also. But apart from these limitations thermoforming is widely used to convert plastic sheets into useable products. Now, we will focus our attention on the certain application areas of thermoforming, where the plastic sheets are thermoformed. It is useable product, so we will try to see what are the important types of products, that can be made by the thermoforming process?

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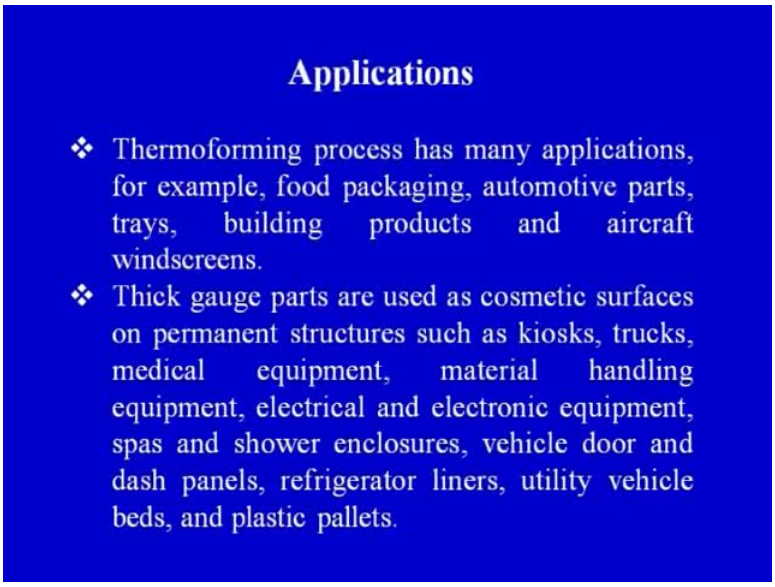

Let us see the applications thermoforming process has many applications. For examples it can be useful for making food packing sheets, automotive parts can be made by thermoforming process, trays building, products and aircrafts, windscreens etcetera are some of the applications of areas of thermoforming were the plastic sheet of a different types of plastics depending upon the final requirement is deformed, to get the desired product.

Thick gauge parts are used as cosmetics surfaces on permanent structures, such as kiosks, trucks, medical equipment, material handling equipment, electrical and electronic equipment spas and shower enclosures, vehicle door and dash panels, refrigerator liners, utility vehicle beds and plastic pallets. So, different sheets can be made and even if it is on the thicker side because we have already seen in the previous slide. Very thick sheets cannot be thermoformed, but a relatively thick sheet as compared to thin sheets thin sheets, Thin sheets application are given on the in the first point we have seen in the food packaging automotive parts or trays.

In thick if the thickness is slightly larger, then these particular plastic sheets can be used for so many different applications. Like these can be used as cosmetic surfaces. Cosmetic surfaces means surface which is visible or which is used for giving the finishing. So, cosmetic surfaces can be used like kiosks trucks, it can be used for material handling equipment or sometimes, vehicle doors and dash panels. So, large

number of applications are there for products which have been made by the thermoforming process.

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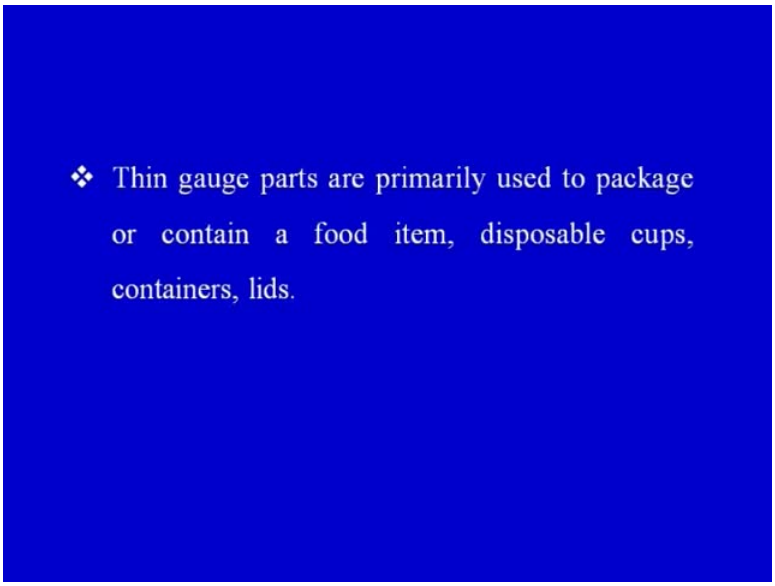

Other applications are, if the thickness is slightly more we have seen what are the applications. If the thickness is slightly less that is, thin gauge parts can be used to package or contain a food item, disposable cups or containers or sometimes lids, can be made by the thermoforming process. So, basically depending upon the thickness of the final product that is made is made by the thermoforming process, we can divide the applications also into thick gauge parts and thin gauge parts.

So, the thickness is on the parts higher side we will have applications which are listed in the previous slide. The thickness relatively less we can use it for food packaging items and lids of containers etcetera. So, with this we come to the end of our discussion on thermoforming and if you remember in today's lecture we have focused on the various process variants of thermoforming, we have seen as the words suggest thermo and forming basically two important stages are there, that is heating and deforming.

The plastic sheet which is the raw material in case of thermoforming is heated and on heating it softens and this softened sheet is then deformed under pressure. The may be applied using a vacuum or air pressure or in case of matched deforming, we can use the punch and die type of arrangement to applied pressure on this softened sheet. When the

pressure is applied, softened sheet would conformed to the shape of the die and it would take the shape of the mold.

The shape of the mold is according to the shape of the final product that we want to generate by the thermoforming process. We have seen that what are the important advantages of the thermoforming process and we have already also covered the limitation areas of the thermoforming process. and finally we have seen that in spite of having certain limitations, thermoforming process is widely used for processing of plastics. We have seen many application areas of the parts, which are made by the thermoforming process.

So, with this we finished lecture number 6 in our module 4 that is processing of plastics. And finally we have left with one lecture, in which we would be covering other important processes like the blow molding and rotational molding. Towards the end of the next lecture we would certainly focus on the secondarily process, because the plastic part has been manufactured using any of the processes. Now, some of the processes which we have already covered again I am going to revise.

We have already seen casting, extrusion, transfer molding, compression molding, ejection molding in today's class. We have seen thermoforming and in next class we will be discussing blow molding, would be covering rotational molding, so many processes are there. There are other processes which are also user processing of plastic, which have not been covered in this series of lectures on processing of plastics, there are wide variety of processes, which are used for processing of plastics. But the parts that we may are usually to near net shave.

Near net shave is that we get the final product that we want to use, but in certain cases these products have to be assembled with some other metallic product or sometimes these plastic products may have to be assembled with wood or with some other type of a plastic. So, for those assembly operations sometimes we may require to make holes inside the plastics or sometimes we may require to machine the plastics, so that we are able to fit the different parts together. So, in the end of this particular module that is in the end of our next class, we would focus on some basic aspects of the secondarily processing of plastics. So, with this introduction to our next class, we come to the end of today's discussion on thermoforming. Thank you.