

**Processing of Polymers and Polymer Composites**  
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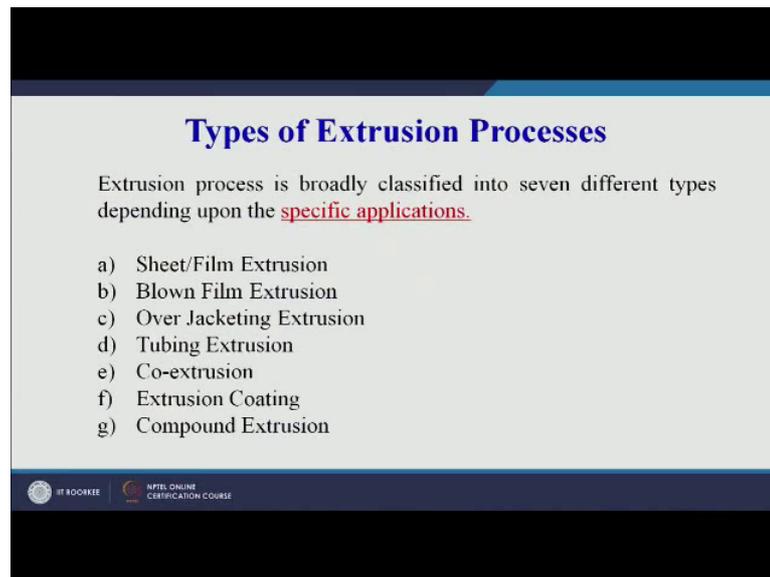
**Lecture - 07**

**Extrusion – II**

[FL] friends, welcome to this session seven on our course on the processing of polymers and polymer composites if you remember in the last session, we have discussed the process of extrusion and we have seen that what is the basic principle of extrusion also we have seen with a help of a video that how the process operates today our topic is extrusion only, but we will be discussing the various types of extrusion process because extrusion is used widely in industry for making different types of products now depending upon the type or the application of the product that we want to make using an extrusion process there are variants of the extrusion process that have been developed in industry and are being used widely and we have the number of products we see plastic sheets thin plastic sheets with different colours on the top we have a different colour on the base you have a different colour.

So, how those plastic sheets are made that we are going to see extrusion process is used for making those sheets, but what is the specific name of that process that we are going to understand today. So, the topic is long. So, we will quickly go through various processes whereas, there is the process which is slightly typical to understand with the help of a diagram. So, we have included a video for that process. So, that you are able to relate to the process you are able to see that how the raw material is coming and how it is getting converted into the final product. So, the process remains the same it is heating of plastic then deforming it through the die and then finally, cooling it in the form of a roll or the form of sheet or the layers of sheet. So, we will see that; what are the various types of extrusion processes in today's session. So, let us quickly start our discussion with the first process that we want to cover today that is sheet film extrusion.

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But before we do sheet film extrusion, let us see that how we can classify the extrusion processes on a screen you can see the extrusion process is broadly classified into seven different types and these are seven that we have collected, there may be other variants of extrusion also which may not be covered during this session seven types of variants we have highlighted here first one is the sheet film extrusion blown film extrusion over jacketing extrusion tubing extrusion co-extrusion; extrusion coating and compound extrusion.

So, the basic principle will remain same as we have seen in the last class that we are going to melt plastic then we are going to force the plastic for the molten plastic through the die and then finally, the product that is coming out of die will be cooled using either you air cooling or a water cooling apparatus or a water cooling arrangement. So, we will see one by one with the try understand with the help of a diagram that what is the basic working principle of each one of this process.

So, let us start with the sheet film extrusion on your screen you can see.

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### Sheet/ Film Extrusion

- The molten plastic is extruded through a flat die.
- The cooling rolls are used to determine the thickness of sheet/film and its surface texture.



Source: [http://img.directindustry.com/images\\_di/photo-g/50815-2828423.jpg](http://img.directindustry.com/images_di/photo-g/50815-2828423.jpg)

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There is a complete setup of the sheet film extrusion process you can see a molten plastic is extruded through a flat die as I have told in previous session if you remember the very first slide in the previous session was giving the different profiles of the products that can be made by the extrusion process and we have seen circular flow of profiles we have seen honey comb type of profiles we have seen square files we have seen rectangular profiles we have seen solid profiles. So, we can get different types of cross sectional profiles using the extrusion process, but this particular process that is specifically sheet film extrusion process is used for making sheets that is the films film is slightly may be the thickness is less as compared to a sheet.

So, sheet and film type of products can be made using the extrusion and the specific process is called as the sheet film extrusion how this is achieved you can very easily relate now that the die is going to give shape to the product. So, that die in this case will be a flat die and the opening of the die will represent the thickness of the sheet or the film that we want to extrude. So, on your screen you can see the raw material is coming from this side and it is moving through die and finally, it is collect getting collected in the form of a roll here. So, this is a final product being collected here and the raw material starts from this side passes through the die and then it is collected here. So, this is the simple example of sheet film extrusion the only change from the basic extrusion process is in the shape of the die.

The die in this case will be a flat die and therefore, we will get a sheet type of product the thickness of the sheet that can be obtained is in the range of 0.2 to 15 milli meter.

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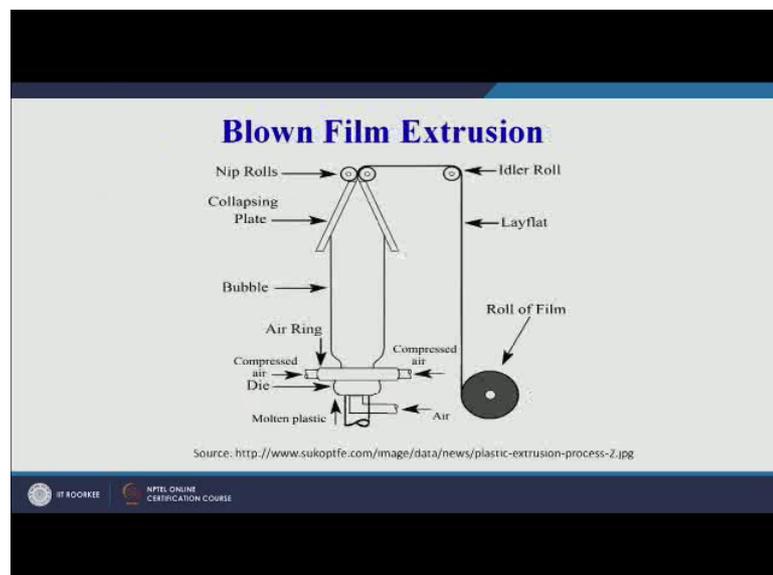
### Sheet/ Film Extrusion Cont..

- The thickness of sheet can be obtained in the range of 0.2 to 15 mm.
- The thin flat sheet or film of plastic material can be made.
- Generally, **polystyrene plastic** is used as a raw material in the sheet extrusion process.

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So, maybe we can get fairly thick sheet that is 15 millimeter the thin flat sheet or film of plastic material can be made that I have already explained generally the polystyrene plastic is used as raw material in the sheet extrusion process. So, the specific type of raw material that is used that is specific to sheet film extrusion process is polystyrene.

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Coming to the next form of extrusion process that is blown film extrusion here you can see this is the simple diagram of blown film extrusion there is a air inlet pressurized air

which will force the plastic against the mould wall the bubble will be created it will pass through the die on your screen you can see this is the die.

Die is written here. So, this is the die this is the air and compressed air is coming from both sides. So, the plastic molten plastic is somewhere here. So, it is blown; it is blown through the die and then it forms a bubble the bubble this is a bubble that is formed this is the mould. So, through the through the die you will force the plastic out and then centrally we will inject the pressurised air and this air will force the plastic to form a bubble and this bubble will move up and there will be a collapsing plate on top you can see these are collapsing plates and these collapsing plates will collapse, this bubble the bubble is coming like this and the collapse when as soon as the bubble hits the collapsing plates it will then again be moving as a film and the nip rolls are there through the collapsing place plates the bubble will collapse in to a sheet and or a film and the film will move over the roller and this is called lay flat that is the product is called lay flat and it will be rolled over the roller and the final part will be made.

So, the final product in this case will also be a film only, but depending upon the specifications depending upon the requirement depending upon the thickness that we want to make the processes may be different in the previous case that is sheet or film extrusion process, we are using a flat die here we are using a circular die through which the plastic will come out will form the bubble the bubble will collapse and then it will be taken to a roll where it will be rolled.

Now, let us try to understand this process that is blown film extrusion slightly may be complicated as compared to the normal sheet and film extrusion process, but certainly used for specific applications.

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**Blown Film Extrusion Cont..**

- The die is like a vertical cylinder with a circular profile.
- The molten plastic is pulled upwards (up to 4 to 20 meters) from the die by a pair of nip rollers.
- The compressed air is used to inflate the tube around the die.
- In the centre of the die there is an air inlet from which compressed air can be forced into the centre of the circular profile and hence tube creating a bubble.
- The extruded circular cross section may be increased 2-3 times of the die diameter.

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The dies like a vertical cylinder as I have already told with the circular profile I have told it is circular die and the plastic will be blown out with the help of pressurised air the molten plastic is pulled upward up to for four to twenty meters from the die by a pair of nip roller. So, this is from centre air will be injected on the nip rollers will pull this plastic up if you see the previous diagram these are the nip rollers.

So, the nip rollers will pull the plastic up. So, the molten plastic is pulled upward from die by the pair of nip rollers that compressed air is used to inflate the tube around the die. So, that you will see in the diagram or in the animation that how the process actually operates in the centre of the die there is an air inlet from which the compressed air and forced into the centre of the circular profile and hence the tube creating a bubble. So, the bubble will be created by pressurised air that we pass through the centre of the die and then this bubble will collapse with the help of collapsing plates the extruded circular cross section may be increased to 2 to 3 times of the die diameter.

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**Blown Film Extrusion Cont..**

- The bubbles are collapsed with the help of collapsing plate.
- The nip rolls flatten the bubble into a double layer of film (called **lay-flat**)
- The wall thickness of the film can be controlled by **changing the speed of the nip rollers**.
- The lay-flat can be spooled in the form of roll or cut into desired shapes.
- Bottom side of the lay-flat is sealed with the application of heat, and cut across further up to form opening; hence it can be used to make a plastic bag.

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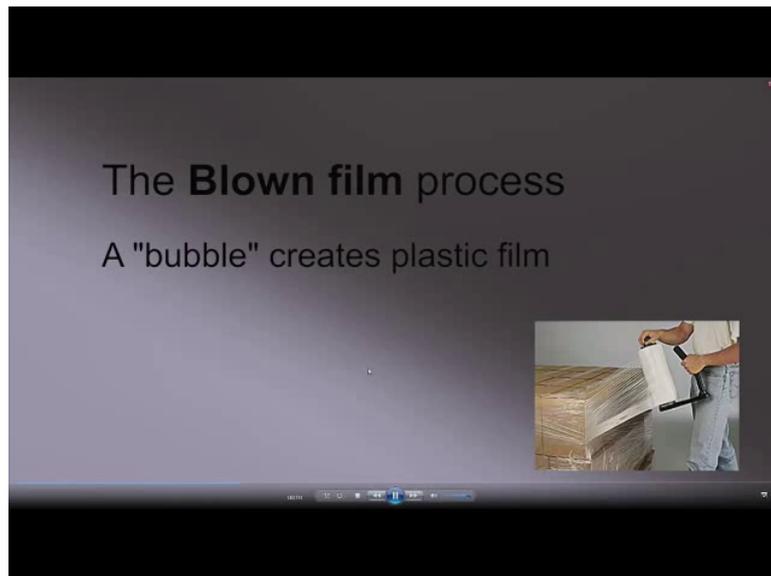
The bubbles are collapsed with the help of a collapsing plate which I have already explained the nip rolls flatten the bubble into a double layer of film called the lay flat.

I have already told the final product in case of this extrusion blown; blown film extrusion process is called a lay flat the lay flat can be spooled in the form of a roller cut in to desired shape that is a final product is collected on the roller bottom side of the lay flat is sealed with the application of heat and cut across further up to the opening. So, we can make plastic bags also with the this thing maybe from the bottom when this bubble is moving up the lower part we can seal with the help of a heat any heating arrangement and the top part can be cut. So, we get a plastic bag based on this process which is not possible in case of a flat or where the die is flat or which is sheet or film extrusion process. So, in blown film extrusion process we can make plastic bags which is not possible in case of it is possible, but we will apply.

We need to apply another steps for making the plastic bags because the output that we are getting in case of sheet or film extrusion process is a sheet of material. So, that sheet if we need to convert it into bag we need to do additional process we need to s take 2 sheets then join them together and then seal them from the edges then only we can make a bag, but here since the bubble is getting created we can very easily make a plastic bag .

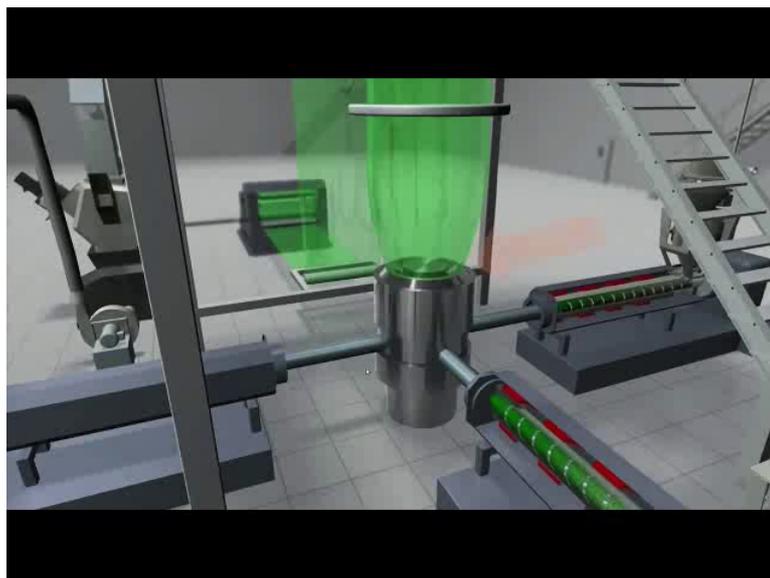
So, let us now try to understand this process with the help of a video.

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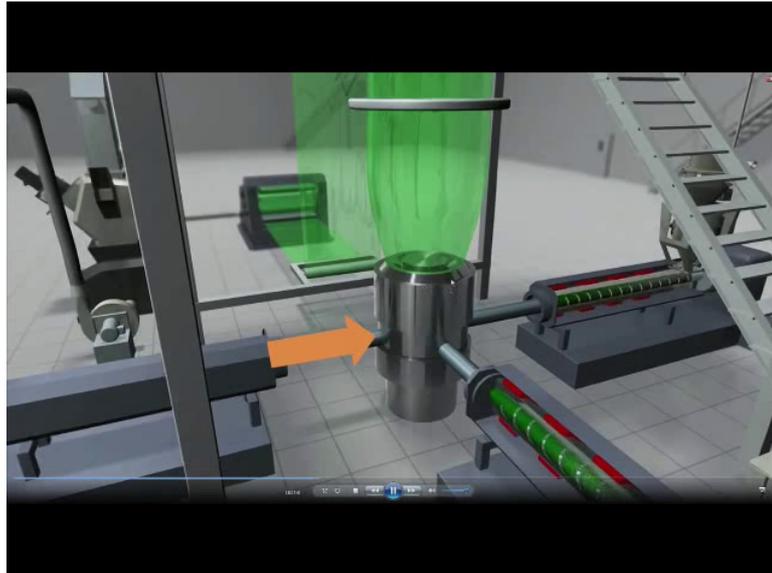
So, this is the blown film process.

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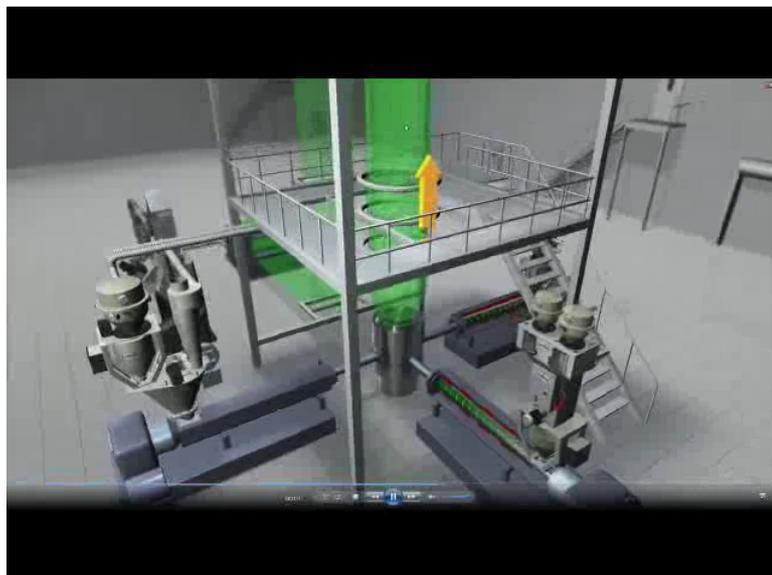


Here you can see here is the die arrangement through which the pressurized air is forcing.

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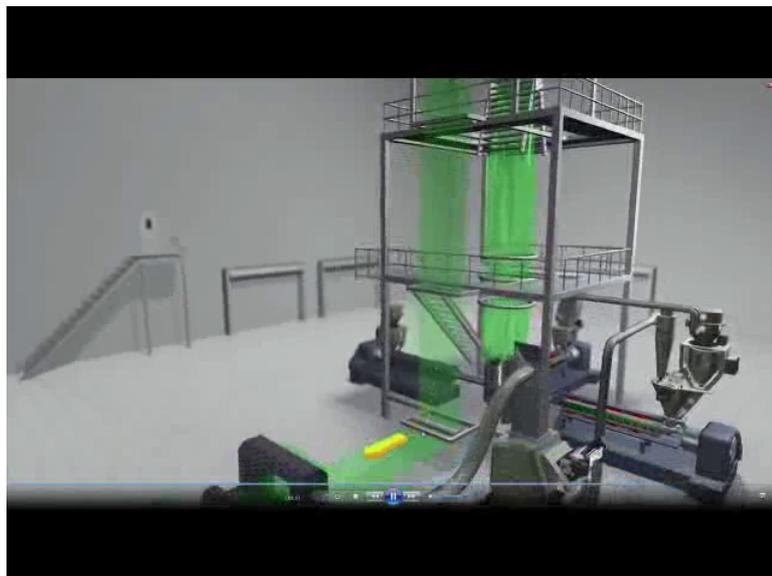
And this bubble is getting created. So, you can see this is the bubble and these are the collapsing plates through the collapsing plates.

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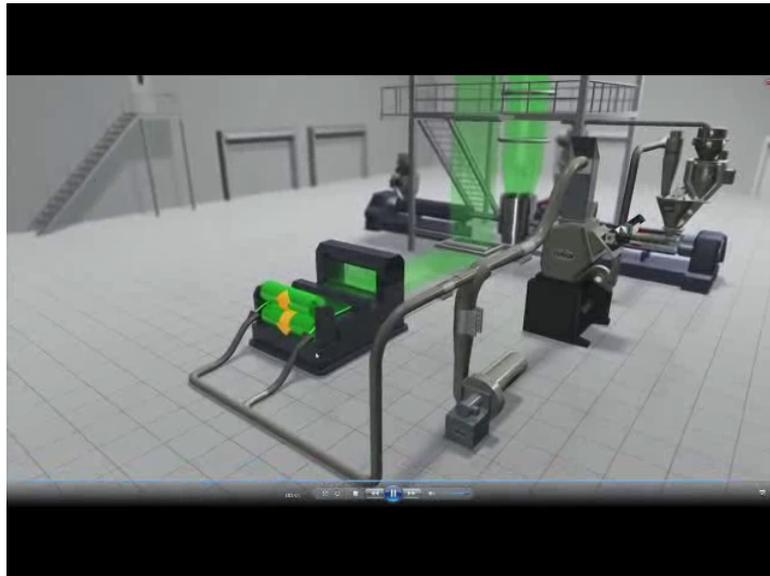


The bubble collapses into a form of a sheet and this is a lay flat that is moving down and finally, getting collected here in the form of the final product.

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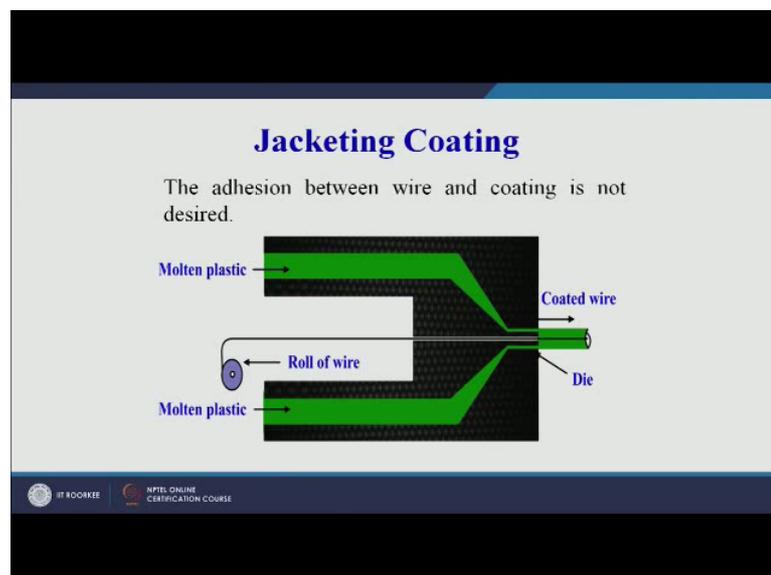
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So, in this case the bubble is created with the help of pressurized air and then it is collapsed and after collapsing the lay flat is formed and we can make plastic bags using the blown film extrusion process.

Let us now try to understand very quickly the other types of extrusion processes in today's session, we have already seen 2 types of extrusion processes or the variants of extrusion; the first one was the sheet extrusion or sheet or film extrusion the second one was the blown film extrusion the third one is the jacketing coating.

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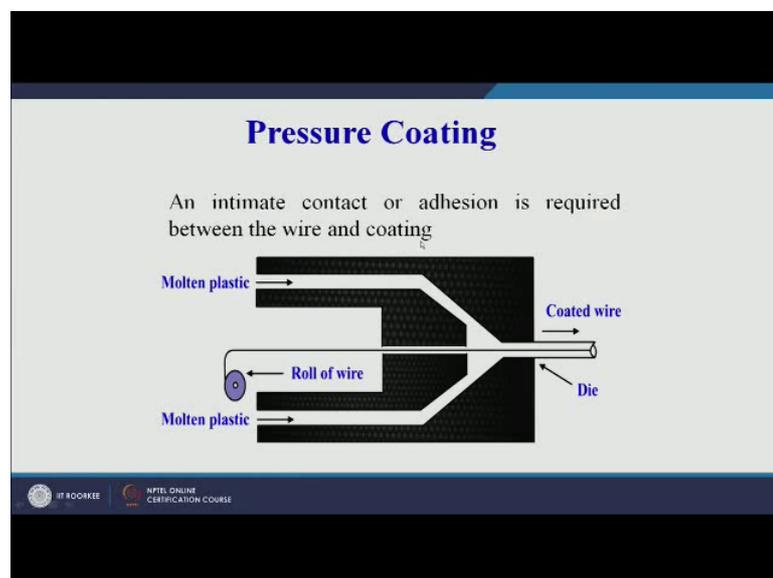


So, here you can see the normal extrusion process this is the roll of wire on which we want to provide a coating of plastic material the molten plastic green colour represents the molten plastic.

So, from both sides molten plastic is coming the wire is moving through the center and finally, we get a coated metallic wire. So, we get this thing. So, jacketing coating is used where the adhesion between the wire and the coating is not desired. So, this wire may not to be having a very good adhesion efficiency or may not be having a very good adhesion with the coated plastic, but yes the plastic is providing a coating over the wire where this type of application is there if you see wherever plastics are used they are poor conductors of heat and electricity. So, if we want a metallic wire to be insulated we can use a plastic coating over this wire.

So, that is the process where jacketing coating will come into picture, similarly slightly modified version of jacketing coating is the pressure coating.

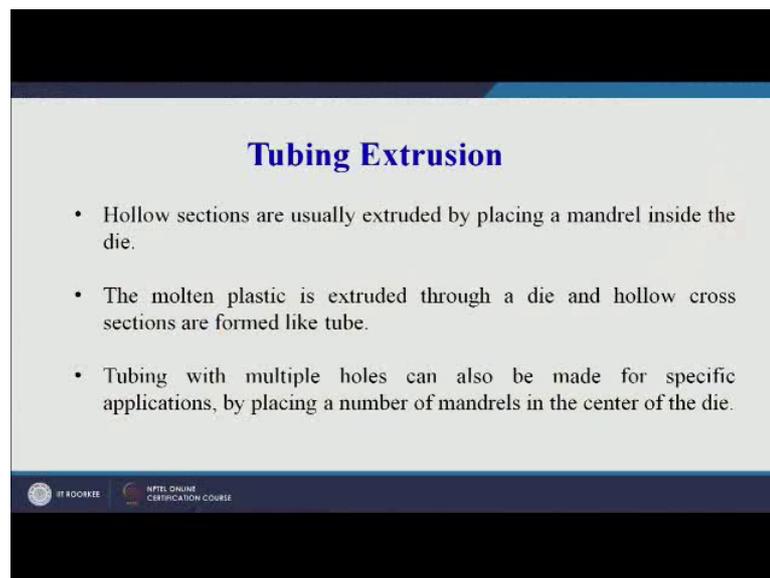
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And intimate contact or adhesion required between the wire and the coating. Now in some specific application if we require that the wire has to be coated by a plastic there should be very strong bond between the wire and the plastic in that case we may go for pressure coating technique which is a one variant of extrusion.

So, here the molten plastic again is coming through these 2 entrant points, then there is a roll of wire, but now the plastic and the wire are coming in contact at this point and from there both of them are moving together. So, the contact is a longer contact between the plastic and the wire therefore, the form of bond also among themselves and this bond then can be used for specific applications that the wire is bonded or it is having a strong adhesion with the plastic; the another variant of extrusion process is the tubing extrusion.

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**Tubing Extrusion**

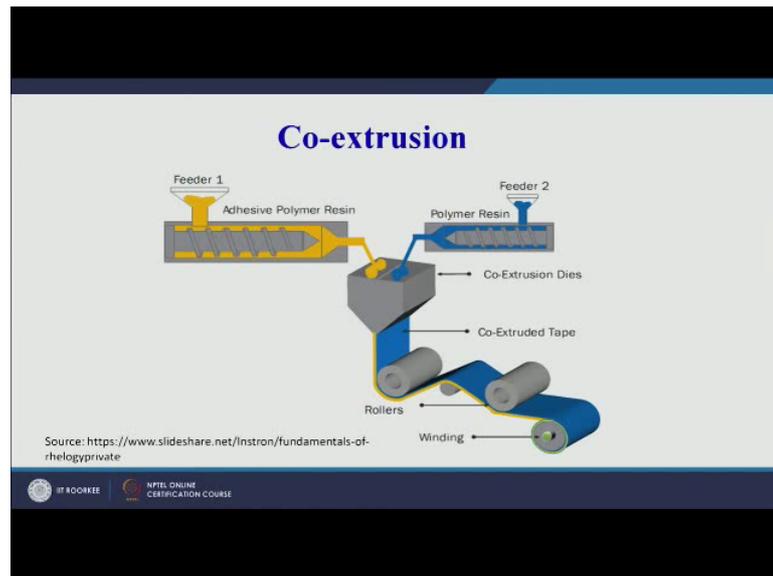
- Hollow sections are usually extruded by placing a mandrel inside the die.
- The molten plastic is extruded through a die and hollow cross sections are formed like tube.
- Tubing with multiple holes can also be made for specific applications, by placing a number of mandrels in the center of the die.

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Hollow sections are usually extruded by placing a mandrel inside the die similar to tube drawing process usually that is used for making the tubes metallic tubes.

So, hollow sections are usually extruded similar for plastics by placing a mandrel inside the die the molten plastic is extruded through a die and hollow cross sections are formed like a tube tubing with multiple holes can also be made for specific applications by placing number of mandrels in the center of the die. So, let us see with the help of a diagram. So, for tubing extrusion right now we do not have a diagram, but you can yourself imagine that there is a mandrel and through the mandrel there is a mandrel.

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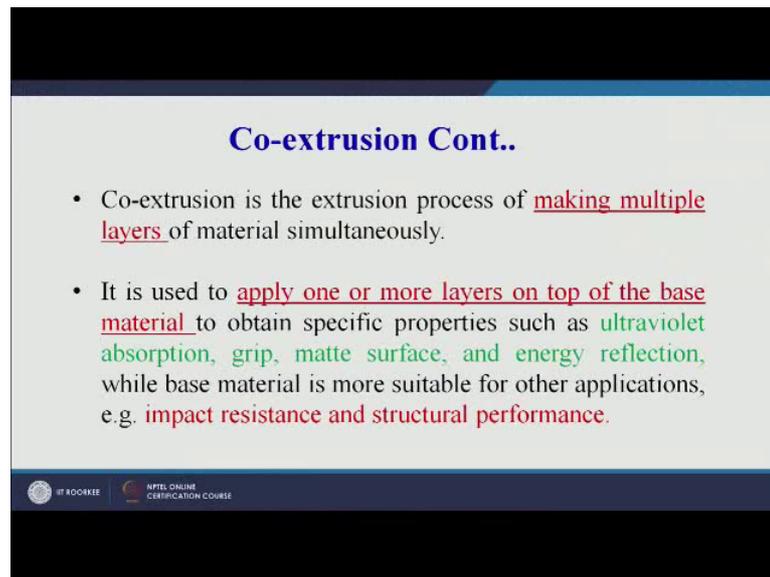
And the plastic is moving outside the mandrel. So, there will be a hollow cross section that we are producing the process is much similar as we use for making tubes of metals tube drawing operation.

Now, coming on to co-extrusion process in co-extrusion as the name suggests co and extrusion in co-extrusion there are 2 types of plastics that we are using this is a adhesive polymer resin 1 and polymer resin 2. So, we put both there are 2 feeders feeder 1 and feeder 2.

So, feeder one yellow colour it is pushing a yellow colour adhesive feeder 2 is pushing the blue colour adhesive. So, there deliberately the colours are different and you can see the final product the winding on the final product on the roller. So, the blue colour is coated over the yellow colour film or yellow colour is the adhesive and the basic polymer in this case is the blue colour polymer. So, this is the co-extrusion die through which both your adhesive polymer resin and the co and the polymer resin are moving together. So, co means the; it is combining if we take the English word cooperate co-operate means that we cooperate means 2 people help each other.

So, here also we have 2 different types of polymers one is acting as a adhesive another one is acting as a base. So, the adhesive and the base are combined together they cooperate with one another and make a third product which is round over the roller and collected for further use. So, let us just read 2 or 3 sentences related to co-extrusion process.

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### Co-extrusion Cont..

- Co-extrusion is the extrusion process of making multiple layers of material simultaneously.
- It is used to apply one or more layers on top of the base material to obtain specific properties such as ultraviolet absorption, grip, matte surface, and energy reflection, while base material is more suitable for other applications, e.g. impact resistance and structural performance.

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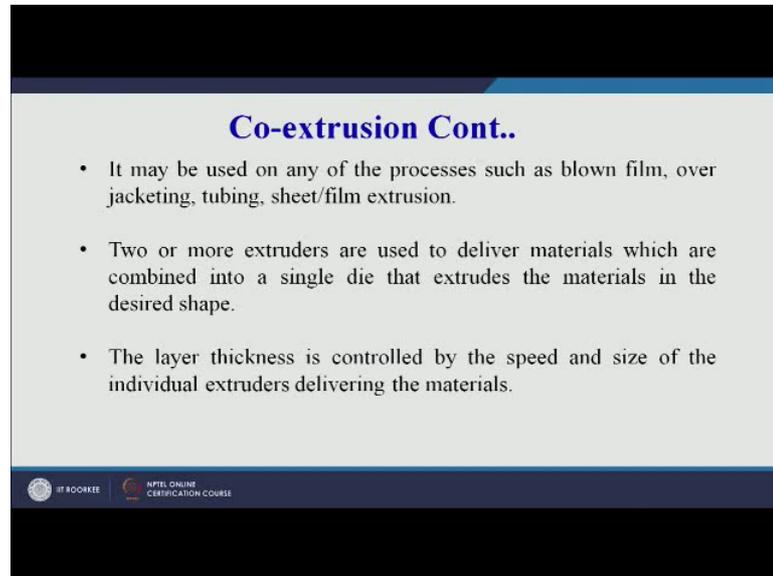
Co-extrusion is the extrusion of making multiple layers of material simultaneously, if you see the diagram there are 2 layers one is a yellow layer another one is a blue layer. So, the same thing is explained in the next slide that is co-extrusion is the extrusion process of making multiple layers of material simultaneously it is used to apply one or more layers on top of base material.

So, in our case the base material can be the blue polymer and the coated material can be the yellow polymer to obtain specific properties. Now why do we need to have 2 layers, we can have a thicker single layer of plastic also, but why do we need to combine 2 different types of polymers together, they are combined together to achieve specific requirements specific applications which are given air in green colour you can see if we want to provide ultraviolet absorption we want to provide grip, we want to provide matte finish or energy reflection or there can be other specific requirements also we want a specific colour at the top and the base can be of a different colour. So, that can also be achieved using the co-extrusion process many times impact resistant and structural performance can also be improved by using the co-extrusion process now the base material and be good for impact resistant and structural performance the top can be good for finish.

Sometimes we require a specific colour at the top then also we can go for co-extrusion process the top layer can be of that specific colour the bottom layer can be of any colour,

but it will add to the functionality by providing impact resistance or the providing some form of structural performance. So, co-extrusion is an important process of extrusion in which we can have combination of properties by putting 2 types of polymers together.

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**Co-extrusion Cont..**

- It may be used on any of the processes such as blown film, over jacketing, tubing, sheet/film extrusion.
- Two or more extruders are used to deliver materials which are combined into a single die that extrudes the materials in the desired shape.
- The layer thickness is controlled by the speed and size of the individual extruders delivering the materials.

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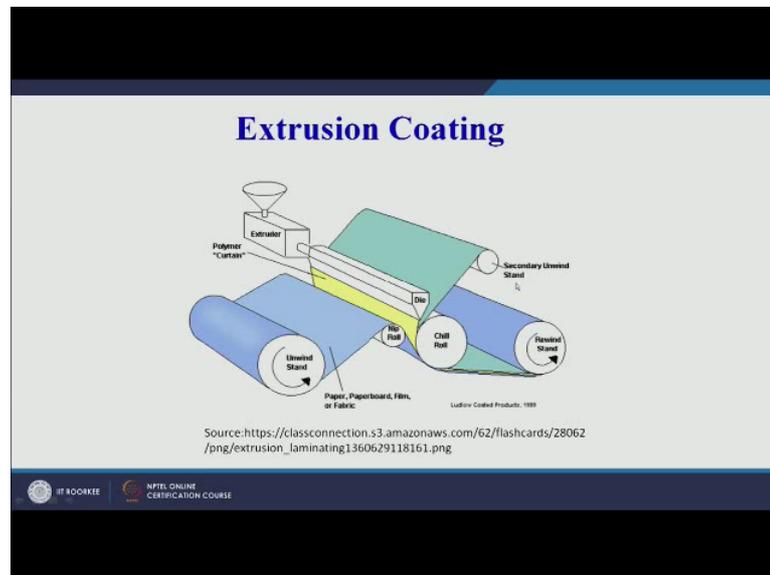
It may be used on any of the processes such as blown film jacketing tubing sheet film extrusion. So, maybe once our product is ready from all these processes we can go for co-extrusion and we can coat with some other layer of material that has to be a plastic layer only. So, we can combine the 2 layers together and make our third product and the first product can be made any of these processes.

For example from sheet film extrusion we first extrude a sheet and then that sheet we can coat with another layer of plastic using a co-extrusion process 2 or more extruders are used to deliver the materials as we have try to understand with the help of a diagram we have seen the diagram a yellow colour adhesive polymer is coming and a blue colour polymer is coming and in the co-extrusion die both are getting combined together . So, 2 more extruders are used to deliver materials which are combined into a single die that extrudes the material in the desired shape. So, 2 different extruders will extrude the material and then in the come co co-extrusion die they will combined together and finally, they will be pushed out and rolled over the final roller.

The layer thickness is controlled by the speed and size of the individual extruders delivering the material. So, one of the operating variables here can be the speed at which

the 2 extruders are operating. So, that the desired thickness of the final product can be achieved, then we have a slightly different variant from co-extrusion process that is extrusion coating in which we can this is the extruder here.

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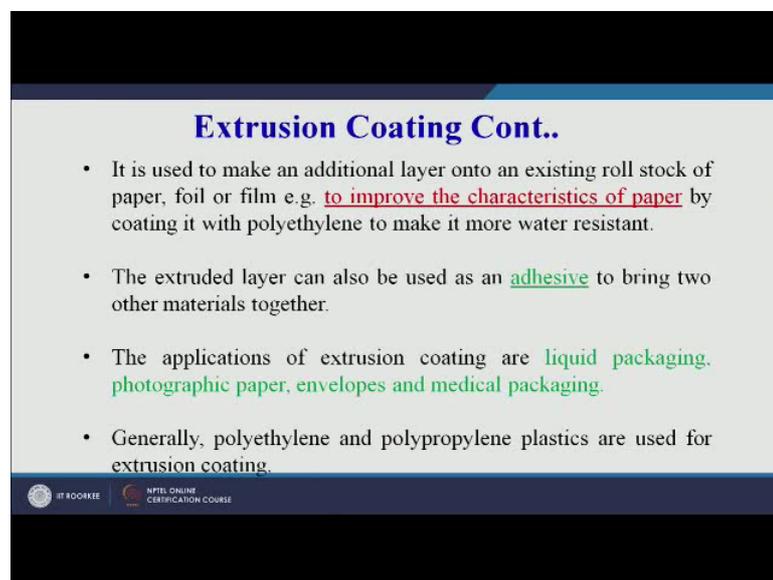
So, this is the curtain this is the secondary and wind stand these are rewind stand chill roll nip roll unwind stand. So, you can have one extruder that is extruding the material from here the another material is coming here you can see and the final product if the different colours are visible here, there is yellow colour also; this is a polymer curtain you can see this is coming from here one unwind stand is here secondary unwind stand is here. So, 3 different layers can be made.

So, extrusion coating can be done very easily 2 different unwind and rewind strands are there in rewind stand it will collect the material unwind stand, it will deliver the material. So, from one side we are delivering the material other film is coming from the extruder here you can see this is the extruder. So, 2 different types of a sheets polymer sheets are coming one is from here another is coming from the extruder and both are getting collected and the top is coming from the secondary wind stand also coming. So, all this is moving together and finally, getting collected over the rewind stand. So, coating is getting provided on your polymer curtain and. So, that is make the another form of extrusion in which we are extruding the material from here, but then simultaneously it is

getting coated also with the help of the unwind stands or the films coming from the unwind stands.

Now, extrusion coating just whatever I have explained we will try to understand it with the help of the diagram why we have done this. So, that whatever we discuss with the diagram; we also read it along with certain points. So, at the points become even more clear and you are able to understand that what the process actually is now extrusion coating.

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**Extrusion Coating Cont..**

- It is used to make an additional layer onto an existing roll stock of paper, foil or film e.g. to improve the characteristics of paper by coating it with polyethylene to make it more water resistant.
- The extruded layer can also be used as an adhesive to bring two other materials together.
- The applications of extrusion coating are liquid packaging, photographic paper, envelopes and medical packaging.
- Generally, polyethylene and polypropylene plastics are used for extrusion coating.

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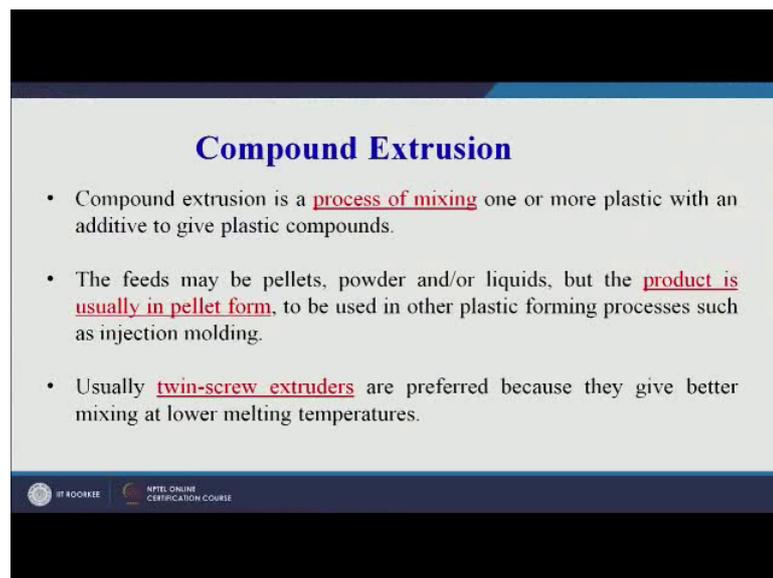
It is you to make an additional layer onto the existing roll stock of paper foil or film to improve the characteristics of paper by coating it with polyethylene to make it more water resistant.

This is one example given that you can sometimes you will see paper is coated with a thin film of plastic in order to make it water resistant and that type of products can be made using the extrusion coating technique the extruded layer can also be used as an adhesive to bring 2 other materials together sometimes we may deliver the adhesive coating on top of the paper also like we use the envelopes for sending of our letters on one side we have a coating and then it is a further covered by paper. So, first we remove that paper then we stick the thing and then we press it those type of making those type of things can be done using a extrusion coating what is there.

There is one paper, then there is a coating and there is another paper. So, that type of products can be made by using the extrusion coating technique the applications of extrusion coating are liquid packaging photographic paper envelopes as I have already told and medical packaging. So, this type of technique, you have paper maybe coming from one side then the adhesive is coming from the other side another paper is coming from other side and all 3 are getting combined together and getting rolled over the final roller and then they can be used for specific applications generally polyethylene polypropylene plastics are used for extrusion coatings. So, specifically 2 polymers are 2 plastic types are mentioned here which are used for extrusion coating technique.

Let us now see compound extrusion here there are single screw extruders double screw or twin screw extruders which are used for the process of compound extrusion.

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**Compound Extrusion**

- Compound extrusion is a process of mixing one or more plastic with an additive to give plastic compounds.
- The feeds may be pellets, powder and/or liquids, but the product is usually in pellet form, to be used in other plastic forming processes such as injection molding.
- Usually twin-screw extruders are preferred because they give better mixing at lower melting temperatures.

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Now, compound extrusion is a process of mixing one or more plastic with an additive to give a plastic compound.

Suppose we want to make mix polyethylene and polypropylene. So, we will take the pellets individual pellets of propylene and poly ethylene and put them in a hopper in that in a twin screw extruder and then we will extrude this through the die and we will get a third product which will be a combination of the 2 types of polymers that we are used as the raw materials. So, this type of extrusion process is called compound extrusion. So, compound extrusion is a process of mixing one more plastic which are with an additive

to give plastic compounds the feeds may be pellets as I have already told we can take polyethylene polypropylene pilot pellets.

We can mix them in the hopper and then we can through the barrel we can pass them through the die and we can extrude the final product which is a combination of the 2 the raw material is in the pellet form to be used and this can be used whatever output that we are getting from twin screw extruder or through the compound extrusion process can be used as a raw material for other processes such as injection moulding. So, when we will study injection moulding we will see that many times in order to have a combination of properties we will first mixed to your 3 plastics together in and then we will extrude them palletised them make them in 2 pellets and those pellets we will then take and use in the injection moulding as a raw material.

So, that we get our final product which has the desirable properties. So, this process is a we can say prerequisite for injection moulding process if we want to have specific properties for a particular product usually twin screw extruders are preferred because they give better mixing at lower melting temperatures. So, as in the last class we have seen that if we have large or higher temperatures, it may degrade the properties of the polymer. So, twin screw extruder have disadvantage that they provide us better mixing of the polymers better mixing of the plastics, but at lower temperatures otherwise if we go for higher temperature there are problems associated with the degradation of the material properties which we need to avoid. Now this slide is generally a summary of the types of materials that are used for extrusion process.

It is not specific to the last compound extrusion process only this is these are general materials which are used for extrusion process.

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## Materials Used

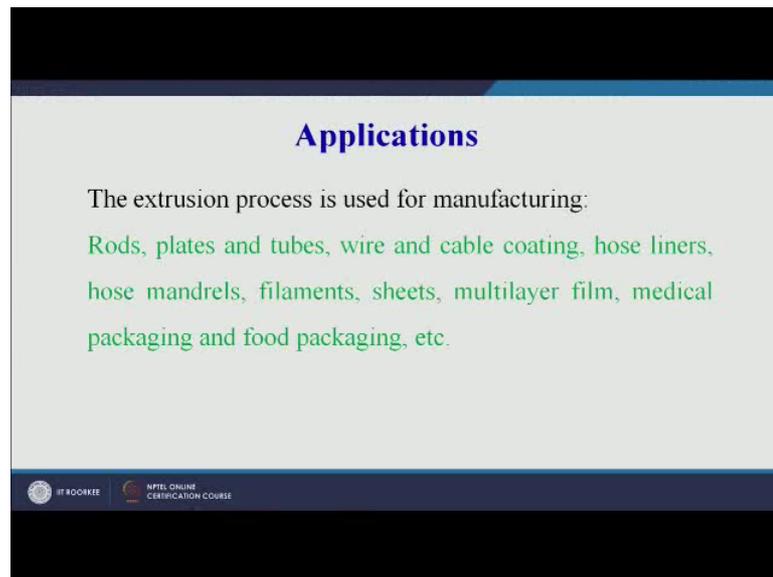
Different types of plastic material that can be used in extrusion process are:

Polyethylene, Polypropylene (PP), Acrylic, Nylon (Polyamides), Polystyrene, Polyvinyl Chloride (PVC), Acrylonitrile Butadiene Styrene (ABS) and Polycarbonate.

These are polyethylene polypropylene acrylic nylon polystyrene PVC acrylonitrile butadiene styrene polycarbonate. So, these are the standard polymers plastics that are used for as a raw material in case of extrusion process to get the desired products the products can be tubes the products can be films the products can be any form of continuous products that we can make. So, majorly it is a large scale continuous process and the it is fully automatic process and then we can use these raw materials to convert them in to the desired products we have seen different types of extrusion process is that we will summarize towards the end of our lecture.

Now, what are the applications I was just telling you in the just may be in the previous slide; what are the application that these materials can be used for making different types products.

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**Applications**

The extrusion process is used for manufacturing:

Rods, plates and tubes, wire and cable coating, hose liners, hose mandrels, filaments, sheets, multilayer film, medical packaging and food packaging, etc.

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So, here you can see you can make rods, plates, tubes, wire and cable coating as we have seen jacketing extrusion we have seen pressure extrusion. So, they are we can provide coating over a wire hose liners can be made hose mandrels filaments sheets multilayer film as we have seen different layers together as in case of envelopes medical packaging food packaging. So, different types of products can be made using the extrusion process where the plastics are involved should I tell you that extrusion is also a process which is used by the same name in case of metals also.

But the 2 processes are entirely different for plastics the control variables are different the applications are different the raw materials are different and even the process mechanisms are different. So, we can see that these are the major application areas of the extrusion process. Now what are the advantages and limitations as or by now you may a this is our second session on extrusion you may have been able to appreciate that it is a continuous process it is a large volume process the relatively low costs as compared to the other moulding processes.

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Advantages	Limitations
<ul style="list-style-type: none"><li>• High production volume</li><li>• Relatively low cost as compared with other molding process</li><li>• Design flexibility</li><li>• Short lead times</li><li>• Coating of wire can be done</li><li>• Continuous part can be produced</li></ul>	<ul style="list-style-type: none"><li>• Limited complexity of parts</li><li>• Uniform cross section can only be produced</li></ul>

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There is a design flexibility you can change the design of the die and you can get a different products from same machine.

So, therefore, there is design flexibility the lead times are short coating on the wire can be done and continuous part and also be produce as I have already told continuous parts can be produced similarly the lim, but there are certain limitations also limited complexity of part usually you have seen that the contains parts with uniform cross section can only be made if there is large variations in the cross section those type of parts cannot be made using the extrusion process similarly uniform cross section can only be produced that I have already explained. So, with this we come to the end of today's session that is extrusion 2. So, if on extrusion process we have already engaged 2 session in the next class we will move to a new process which will be used for processing of polymers.

Thank you.