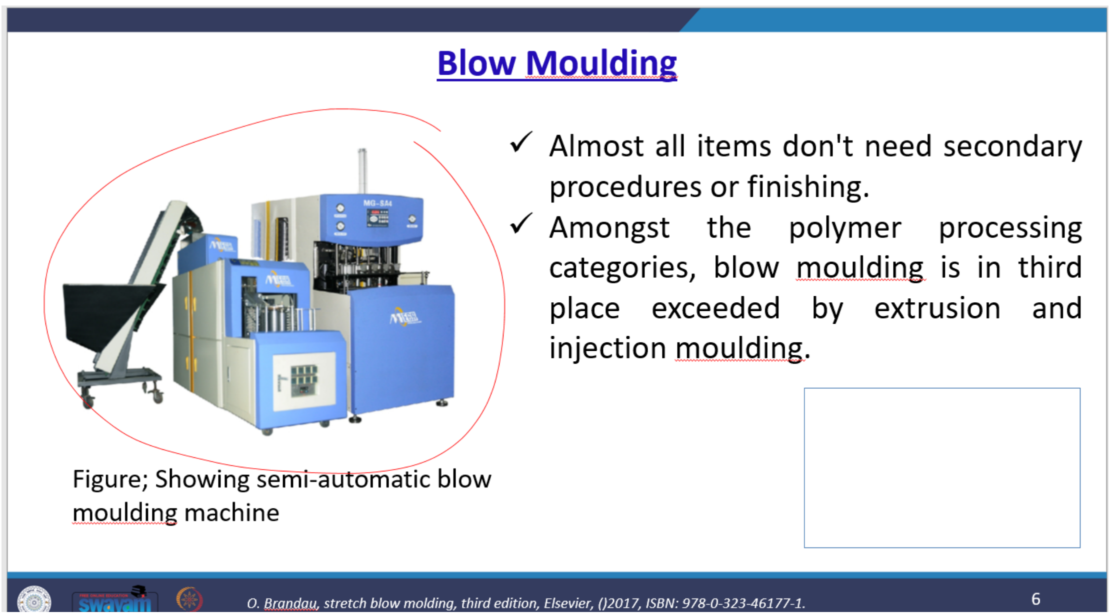
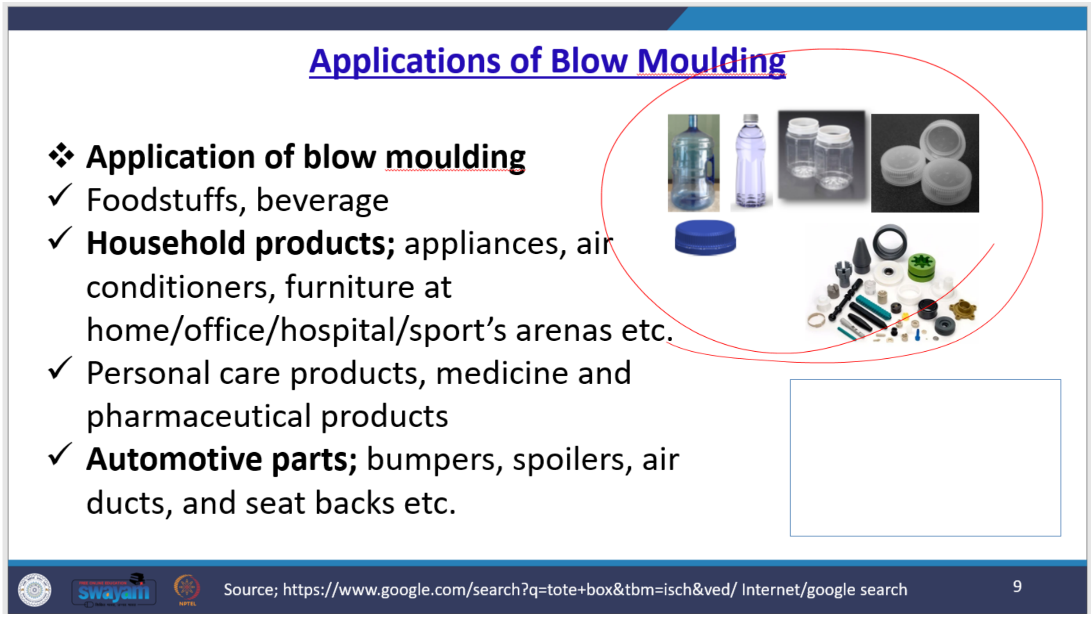
Lecture 34- Blow Molding

Hello friends, welcome to another interesting segment of polymer processing. and that is called blow molding. Blow molding is again one of the important operations of polymer process engineering for producing various products for the day-to-day affairs of various engineering or specialized purposes. Now, before we start to discuss the blow molding, let us have a brief outlook on what we discussed in the previous segment. We discussed the extrusion and we covered both the single screw extrusion process and the twin extrusion process. We discussed the various zones or regimes involved in the extrusion process with all kinds of nitty-gritty like solid conveying or the feed zone, transition, plasticizing or plasticating zone, and then the melt and metering zones.



We discussed the geometrical aspect of extruders because there are a variety of combinations available as of date and the geometry of these extruders plays a very vital role in different types of parameters of the process. So, we discussed all those things, we discussed the frictional behavior, and we discussed the heat generation through this frictional behavior. All these things we discussed. Now, in this particular segment, we are going to discuss the integral part of blow molding.

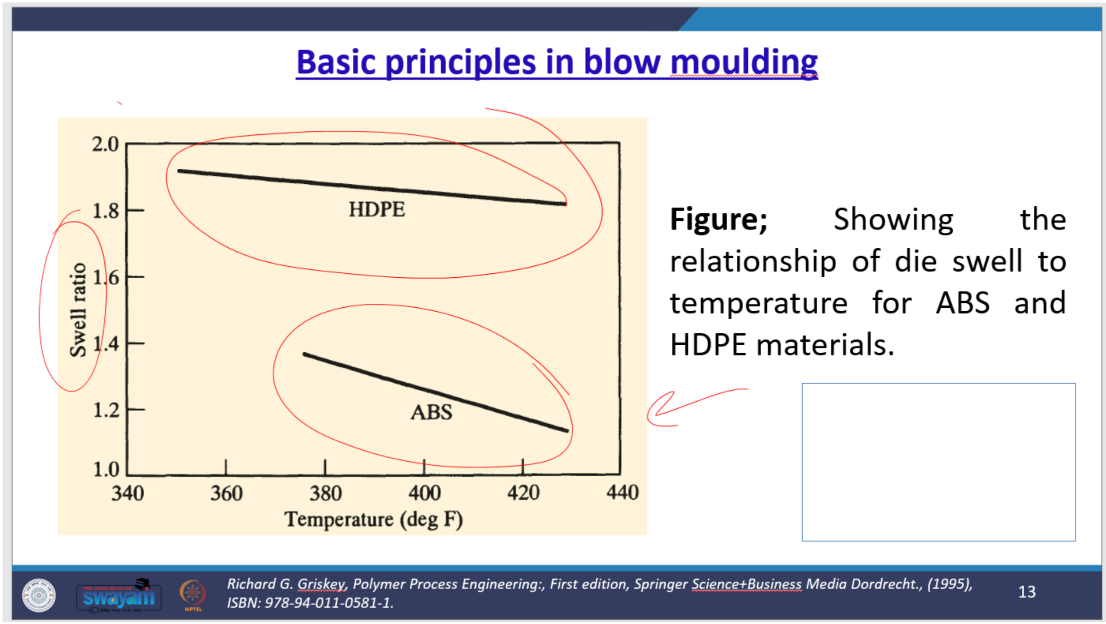


What are the different applications of blow molding? What is the basic principle involved in this type of molding operation? What are the advantages and disadvantages associated with blow molding? Then we will classify the blow molding operation into different segments like extrusion blow molding, injection blow molding, stretch blow molding, and rotation blow molding. So, let us start with the basic concept of blow molding.

Blow molding, a widely employed technique, serves the purpose of creating hollow items with diverse shapes using thermoplastic material. This method is particularly effective in consolidating various functions into a single product, allowing for the creation of items with simple, complex, or refined shapes. Unlike continuous processes, such as extrusion, blow molding is a discontinuous or batch-wise method, involving a series of procedures that lead to the production of a molded item.

In the blow molding process, a softened hollow shape is inflated against the cold cavity surface of a closed, cold female mold. This surface can be textured, engraved, smooth, or tailored to meet specific customer preferences. The mold cavity, where this inflation occurs, plays a crucial role in determining the final shape and surface properties of the molded item. In many cases, the molded products do not require secondary procedures or finishing, highlighting the efficiency and completeness of the blow molding process.

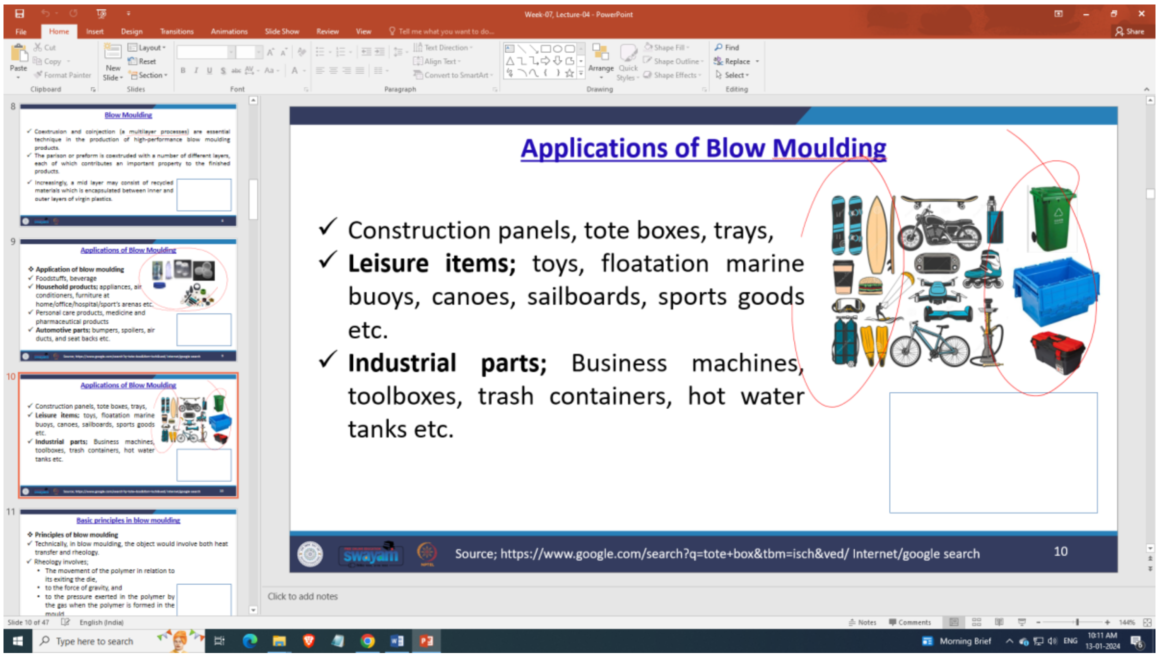
Within the realm of polymer processing, blow molding ranks third in popularity, following extrusion and injection molding. The significance of blow molding is underscored by its consumption of approximately 10 percent of all plastic materials. Notably, PET bottles, widely used for water and other beverages, are prime examples of products manufactured through blow molding operations. In the subsequent sections, we will delve into the intricacies of semi-automatic blow molding machines, providing a more comprehensive understanding of this versatile and widely utilized manufacturing process.



Polyethylene terephthalate (PET) finds extensive use in the manufacturing of beverage bottles, motor oil containers, and various auto and marine fluids containers. Its popularity stems from its frequent utilization in producing containers due to its lightweight nature. On the other hand, high-density polyethylene (HDPE) bottles offer cost efficiency and enhanced chemical resistance, making them a preferred choice. PVC, or polyvinyl chloride, is employed in industrial packaging, as well as automotive and marine fluid bottles. The use of PVC is attributed to its hydrocarbon resistance and barrier properties, which untreated HDPE cannot provide.

Advanced technologies, such as co-extrusion and co-injection, are integral to the blow molding process, often referred to as multi-layer processes. These techniques enable the combination of PET with other plastics for packaging various products, especially foods. The versatility of blow molding is evident in its ability to produce a wide spectrum of products, catering to diverse industry needs.

Co-extrusion and co-injection, considered multi-layer processes, play a pivotal role in the production of high-performance blow molding products. The parison or preform, the starting point of blow molding, is typically co-extruded with multiple layers, each contributing crucial properties to the final product. In some cases, a mid-layer may incorporate recycled material, encapsulated between the inner and outer layers of virgin plastic. Before delving into the anatomy of blow molding, this overview provides a glimpse into the varied applications and complexities of the blow molding process within the realm of polymer processing.



Blow molding, a versatile manufacturing process, finds applications across various industries. Some key areas include:

1. **Foodstuff and Beverages:** Production of bottles and containers for food and beverage packaging.
2. **Household Products:** Manufacturing of items used in households, such as containers and storage solutions.
3. **Appliances:** Creating components for appliances, including air conditioners.
4. **Furniture:** Crafting furniture for use in homes, offices, hospitals, sports arenas, and other settings.
5. **Personal Care Products:** Production of containers for personal care items.
6. **Medicine and Pharmaceutical Products:** Manufacturing containers and components for medical and pharmaceutical purposes.

7. **Automotive Parts:** Crafting automotive components such as bumpers, spoilers, air ducts, and seat backs.
8. **Construction Panels:** Producing construction-related items like tote boxes and trays.
9. **Leisure Items:** Creating items for leisure activities, including toys, flotation devices, and marine equipment like boats and sailboats.
10. **Industrial Parts:** Crafting components for industrial machinery and equipment.
11. **Business Machines:** Manufacturing components for various business machines.
12. **Tool Boxes:** Production of toolboxes for storage and transportation.
13. **Trash Containers:** Crafting containers for waste disposal.
14. **Hot Water Tanks:** Manufacturing components for hot water storage.

The broad spectrum of applications showcases the versatility of blow molding in meeting diverse manufacturing needs. Now, let's delve into the principles behind blow molding. The process involves intricate interactions of heat transfer, rheology, and various material parameters such as flow behavior, melting temperature, glass transition temperature, and pressure. Rheology, in particular, encompasses the movement of polymer within the mold, responding to gravity and pressure exerted by the gas during molding. Phenomena like dye swell, jet swell, and extruder swell further add complexity to the process, emphasizing the intricate nature of molding molten or thermally softened polymer.

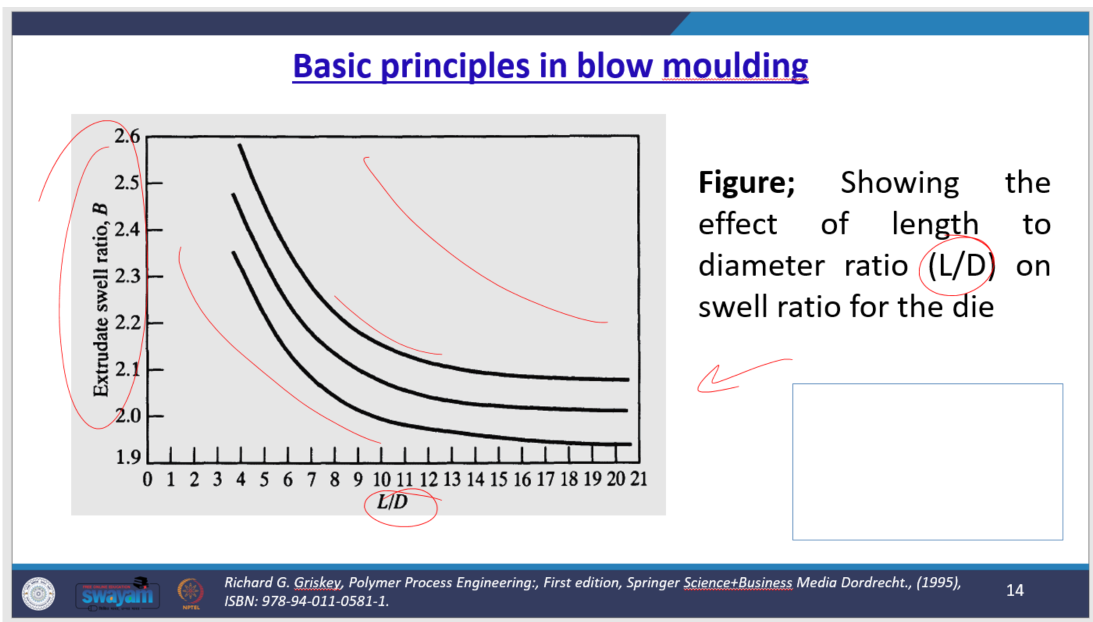
The phenomenon of dye swell in blow molding is influenced by several parameters, each playing a distinct role in the operation. These factors include:

1. **Velocity Rearrangement:** The rearrangement of material velocity within the dye during the molding process.
2. **Elasticity Recovery:** The ability of the material to recover its original shape and dimensions after deformation.
3. **Gravitational Effects:** The impact of gravity on the material, affecting its behavior during the molding operation.
4. **Surface Tension Effects:** The influence of surface tension on the material's response within the dye.
5. **Normal Stresses:** Stresses acting perpendicular to the surface of the material.

Dye swell is considered a function of at least two, and possibly up to four, of the mentioned factors. The relationship between these parameters determines the extent of dye swell in the blow molding process.

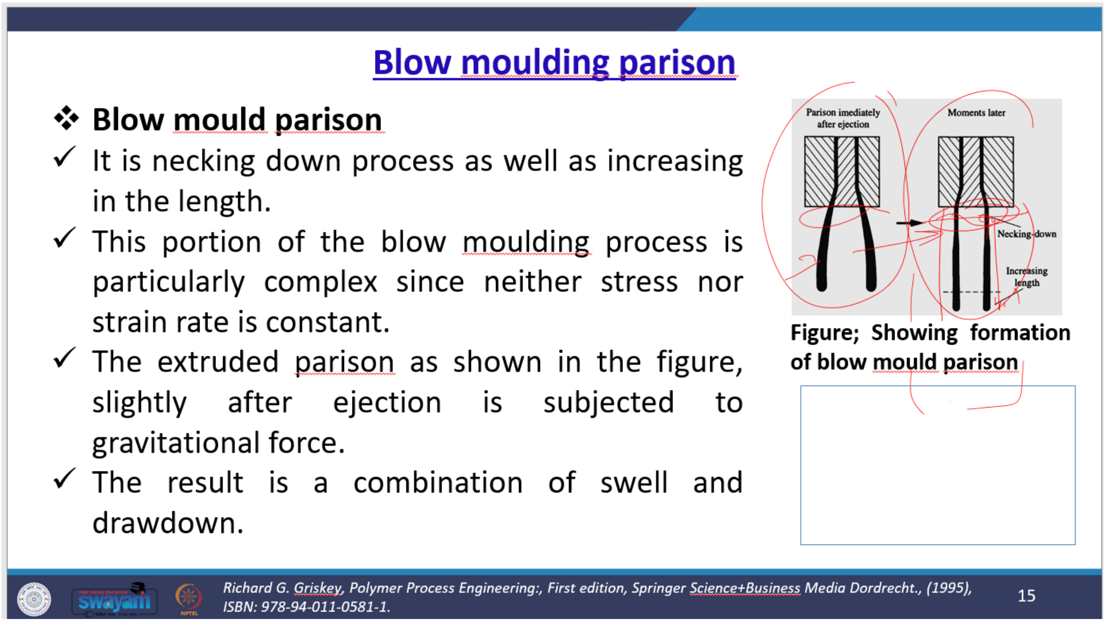
In the context of material characteristics, a figure illustrates the relationship between dye swell and temperature for ABS (Acrylonitrile Butadiene Styrene) and HDPE (High-Density Polyethylene). The swell ratio for ABS decreases more sharply than that of HDPE as temperature increases. This information provides insights into the temperature sensitivity of different materials and guides the blow molding process accordingly.

Another figure demonstrates the impact of the length-to-diameter ratio (L/D ratio) on the swell ratio for the dye. The L/D ratio is a critical parameter influencing the dye swelling operation, and understanding this relationship aids in optimizing the blow molding process for different materials and product specifications.



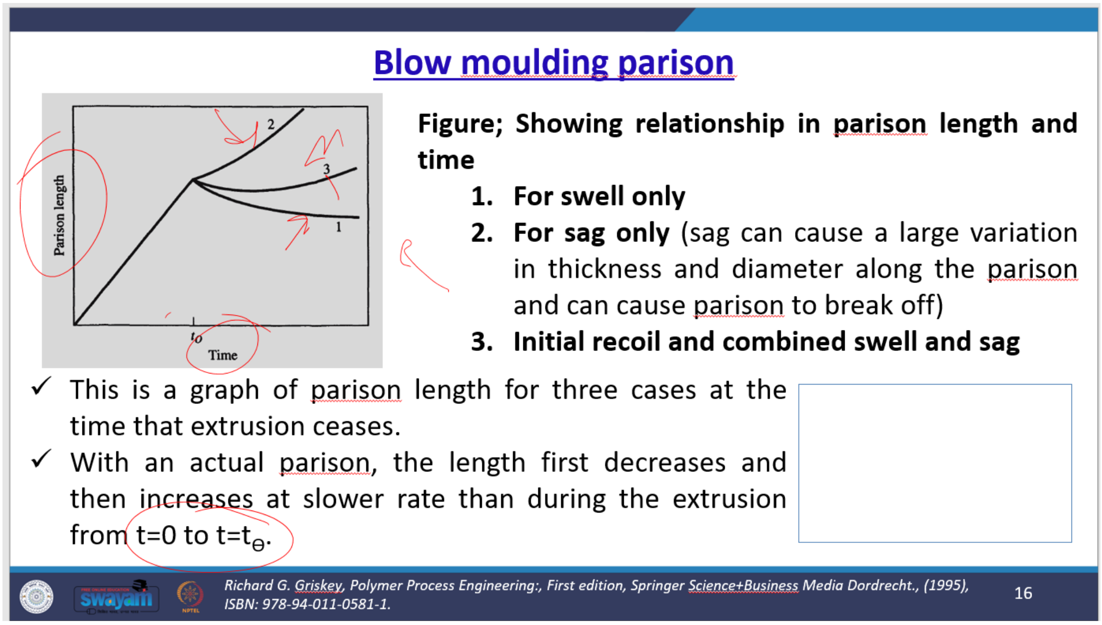
In the blow molding process, the parison holds a significant role as the precursor to the final molded object. The parison is the melted polymer part that enters the blow molding operation just before the molding process begins. During this stage, the parison undergoes a necking-down process accompanied by an increase in length. This phase of the blow molding process is notably complex, characterized by dynamic changes in both stress and strain rate.

The complexity arises from the fact that, immediately after ejection, the parison experiences transformations in its dimensions. The necking-down phenomenon is observed as the material narrows, preparing for the subsequent stages of the blow molding operation. This intermediate stage is critical in shaping the final product, and understanding the dynamic changes in stress and strain rate during the parison formation is essential for achieving optimal blow molding results.



The timing of cutting the extruded parison in the blow molding process is crucial to the overall success of the operation. This stage of the process remains complex, as the stress and strain experienced by the extruded parison are not constant. The extruded parison, just after ejection, is influenced by gravitational forces, leading to a decrease in diameter. The combination of factors during this phase results in both swell and drawdown, contributing to the shaping of the parison as it progresses through the blow molding process.

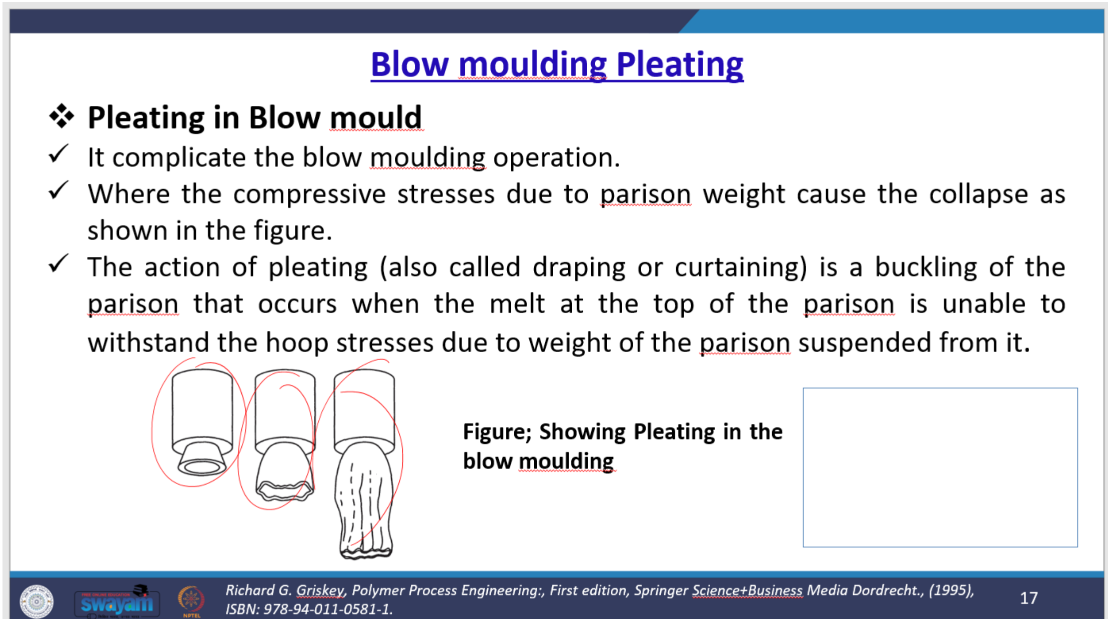
Efficiently managing the cut-off timing from the extruder is essential to control the dimensions and characteristics of the parison, ultimately influencing the final product's quality. The dynamic interplay of forces and dimensions during this stage requires careful consideration and optimization to achieve desired outcomes in the blow molding operation.



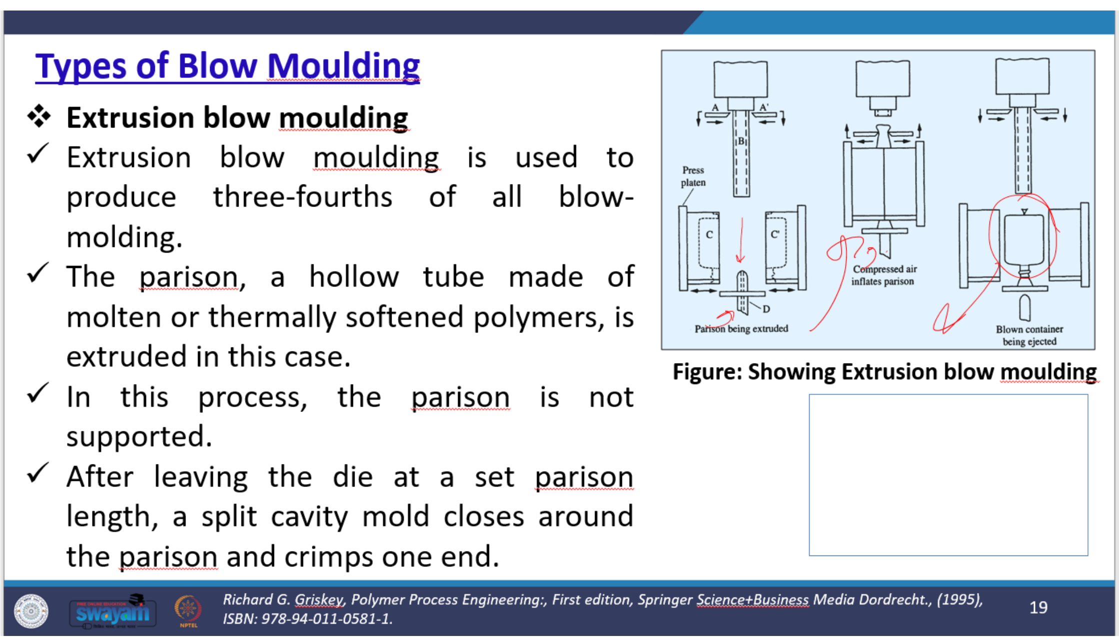
The figure illustrates the relationship between parison length and time during various stages of the blow molding process. Three distinct cases are considered: swell only, sag only, and the combination of initial recoil and combined swell. The graph depicts the behavior of parison length for these cases at the moment extrusion ceases.

In the actual parison scenario, the length initially decreases, followed by a slower increase during the extrusion from time t=0 to t=θ. This dynamic behavior is crucial in understanding the shaping of the parison during the blow molding operation.

However, the introduction of pleating into the blow mold adds complexity to the process. Pleating involves the compression of the parison under its weight, leading to collapse, as depicted in the figure. This pleating, also referred to as draping or ascertaining, involves buckling of the parison. It occurs when the melt at the top of the parison is unable to withstand the hoop stresses due to the weight of the parison suspended from it, along with simultaneous necking effects.



There are three main types of blow molding operations: extrusion blow molding, injection blow molding, and stretch blow molding. Let's delve into extrusion blow molding, where the parison is inserted into the mold, and compressed air is introduced to inflate the parison, resulting in the formation of the final object, which is then ejected from the mold.

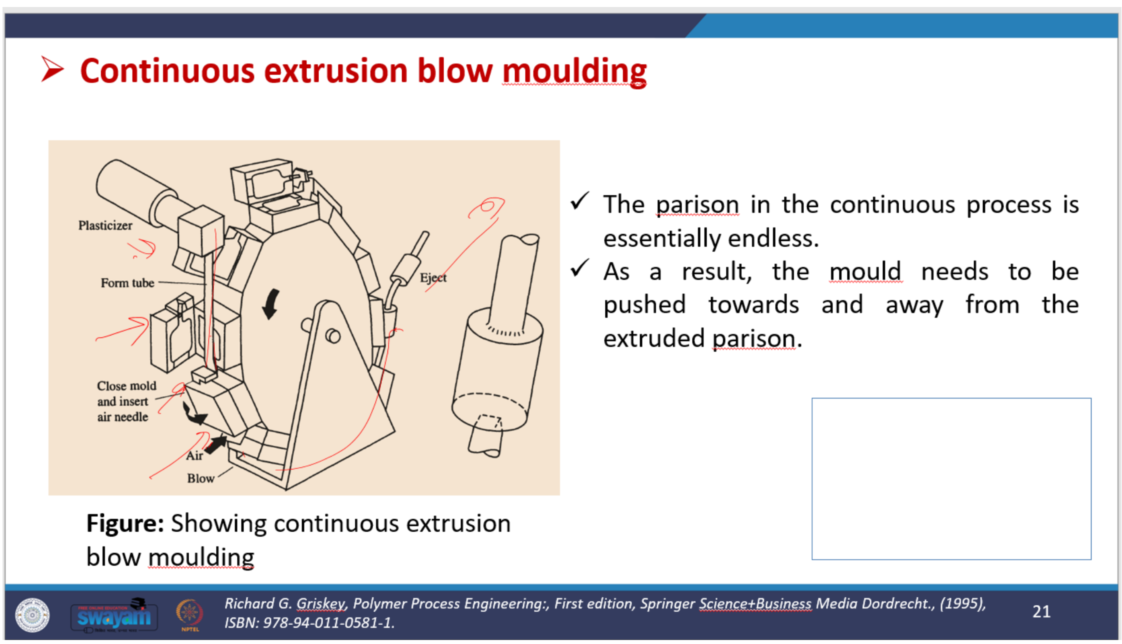


Extrusion blow molding is a predominant method, accounting for three-fourths of all blow molding operations, producing approximately 75 percent of blow-molded products.

In this process, a parison, which is a hollow tube made of molten or thermally softened polymer, is extruded. The parison is then enclosed by a split cavity mold that closes around it and crimps one end.

To shape the parison, compressed air is injected using a tool known as the blow pin, positioned next to the crimped or closed end. As the polymer contacts the cooler mold surface, it cools and solidifies, taking the shape of the mold. Extrusion blow molding can be carried out continuously or intermittently.

In continuous extrusion blow molding, the parison is essentially endless in the continuous process. Consequently, the mold must move towards and away from the extruded parison continuously. The process involves blowing air into the closed mold, with a plasticizer, continuous parison, and ejection of the final product.



On the other hand, intermittent extrusion blow molding utilizes a reciprocating screw, similar to that found in the injection molding process. This is known as short extrusion. Intermittent extrusion blow molding is faster than the continuous operation. The process involves a hopper for resin supply, divided into three zones similar to those in injection molding: the feed zone, the transition zone, and the metering zone, all equipped with electrical heaters. This comprehensive approach ensures precise control over the extrusion process, enabling the production of high-quality blow-molded products.

➢ Intermittent extrusion blow moulding

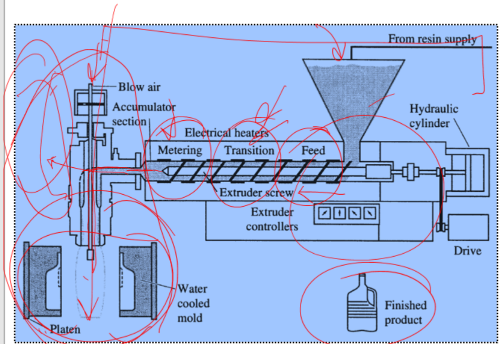
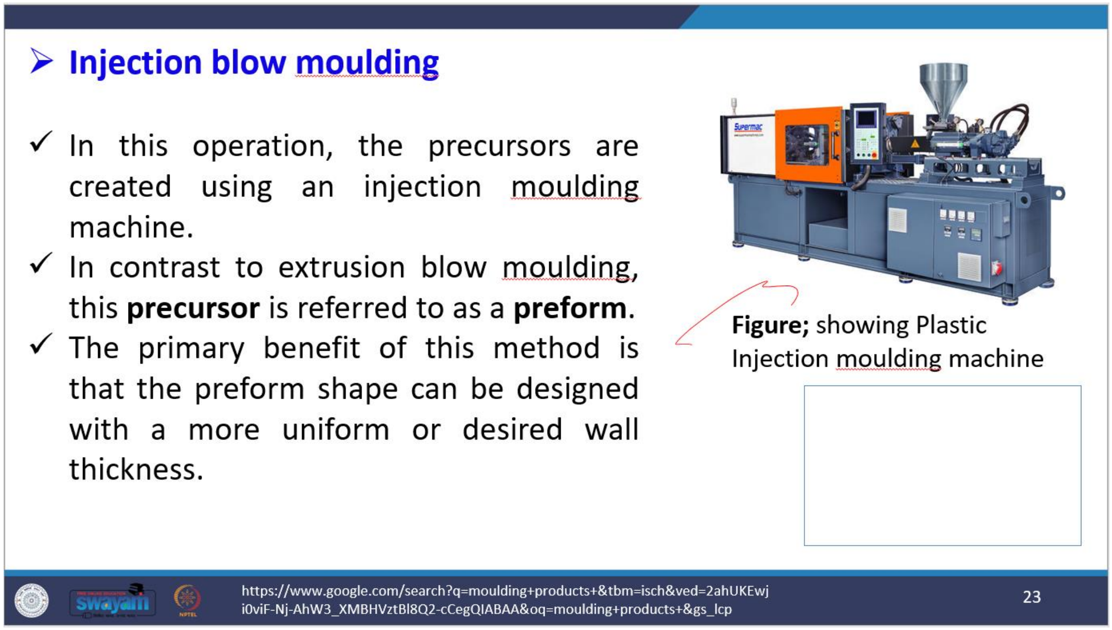


Figure: Showing Intermittent extrusion blow moulding

- ✓ A reciprocating screw with the same design as those used in injection moulding processes is utilised in the intermittent method, also known as short extrusion.
- ✓ Intermittent extrusion blow moulding is quicker than continuous extrusion.

So when the feed is subjected to the motion with the help of a barrel and a screw then it moves in the forward direction it starts heating there and there is a melting zone or the plasticating zone and through this nozzle there in the injection molding you are having a mold over here where this injects to the mold cavity and you get the desired product but here the things are bit different. Here you are having this mold is over here and the blow air is subjected from this port. So all the material melted material comes out from this particular zone and is inserted in this then these molds water-cooled molds are crimped together and then blown air is subjected and you get the finished product after cooling. So the thing is that this particular part is the same as in the injection molding and the difference is that here you are having the mold in the injection molding but here you are having the mold and subjected to the blow air, air blowing. Now in this operation, the precursors are created using injection molding it is quite obvious and the contrast to the extrusion blow molding the precursor is referred to as the preform the primary benefit of this method is that the preform shape can be designed with a more uniform or desired wall thickness.



Now this is the plastic injection molding machine. A molten thermoplastic is blown against the interior of the surface of a female mold cavity during the entire process and then the material is chilled until it solidifies into the stiff object. The injection molding machine has the integral injection unit which we discussed and the multi-impression mold assembly in which the mold cores are usually mounted on a rotary table. So this is how you can say the front view different molds cavities are mounted. So once it is filled it moves in there and the empty mold takes place to the parison entry.

The cores double the blowing planes index and 120-degree steps between the basic injection blowing and ejection stations. Now here you see the three-station injection blow molding operation. The things are the same as this is the hopper all three zones are there, feed zone, transition zone, and melting zone. Now here you are having this through the nozzle the preform can pass through this one there this is the direction. Now here this is the blow molding neck ring blow molded this is the blow air passage blown container and this is the mold.

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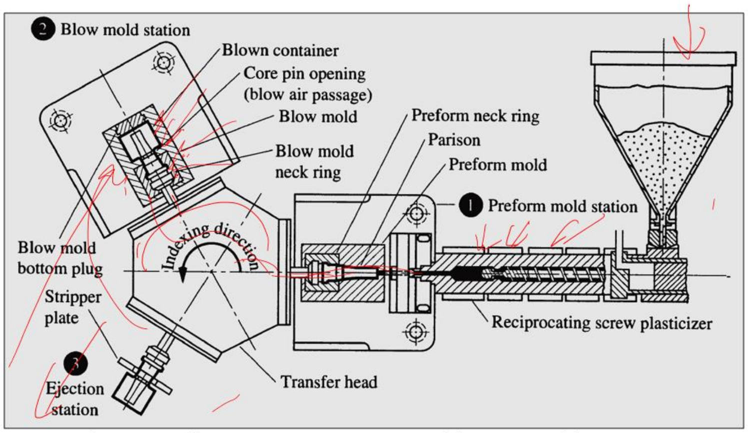

Figure; Showing three station injection blow-moulding operation

Richard G. Griskey, Polymer Process Engineering:, First edition, Springer Science+Business Media Dordrecht., (1995), ISBN: 978-94-011-0581-1.

So this is the ejection station. So it is moving like this once it is filled it gives us proper retention time for cooling down and then the ejection station removes the finished product. The injection blow molding injects molten or thermally softened polymers into one or more heated preform cavities around a given core pin. Now the preform mold is usually opened and the heated polymer is then moved by using the core pin to the blow molded station where it is inflated and then ejected. Now this is again the injection preform blow molding and ejection. Here you see that this is the ejection preform goes like this and this is the blow molding blow molded product being coming out.

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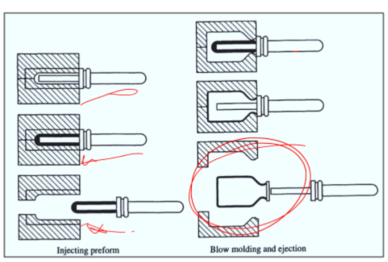
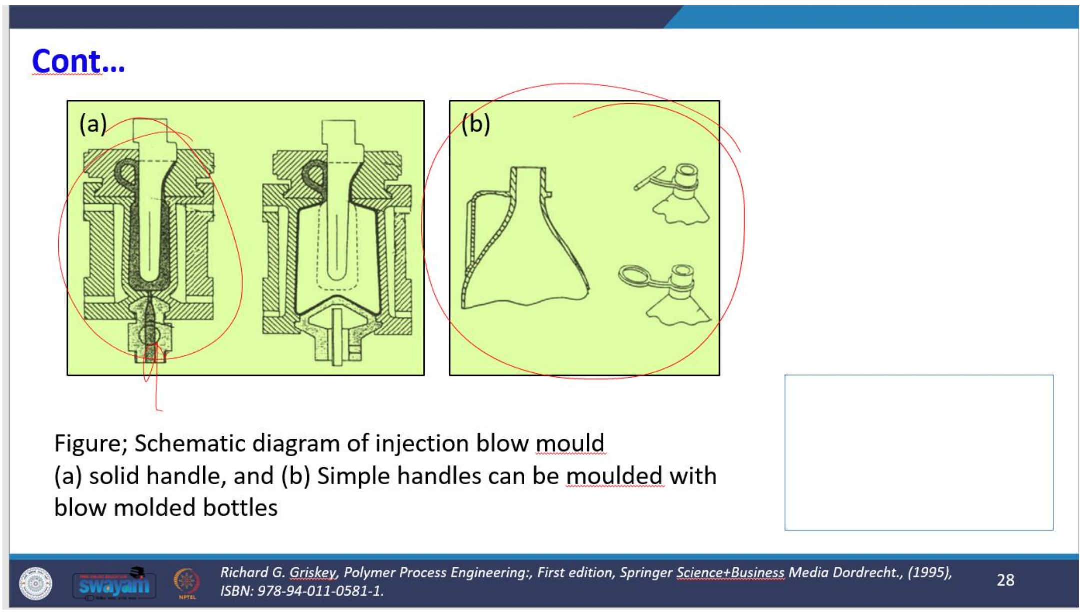
- ✓ Injection blow molding injects molten or thermally softened polymers into one or more heated preform cavities around a given core pin.
- ✓ The preform mold is then opened.
- ✓ Heated polymer is then moved by using the core pin to the blow-mold station, where it is inflated and then ejected.



Figure; Showing injection preform, blow moulding and ejection

Richard G. Griskey, Polymer Process Engineering:, First edition, Springer Science+Business Media Dordrecht., (1995), ISBN: 978-94-011-0581-1.

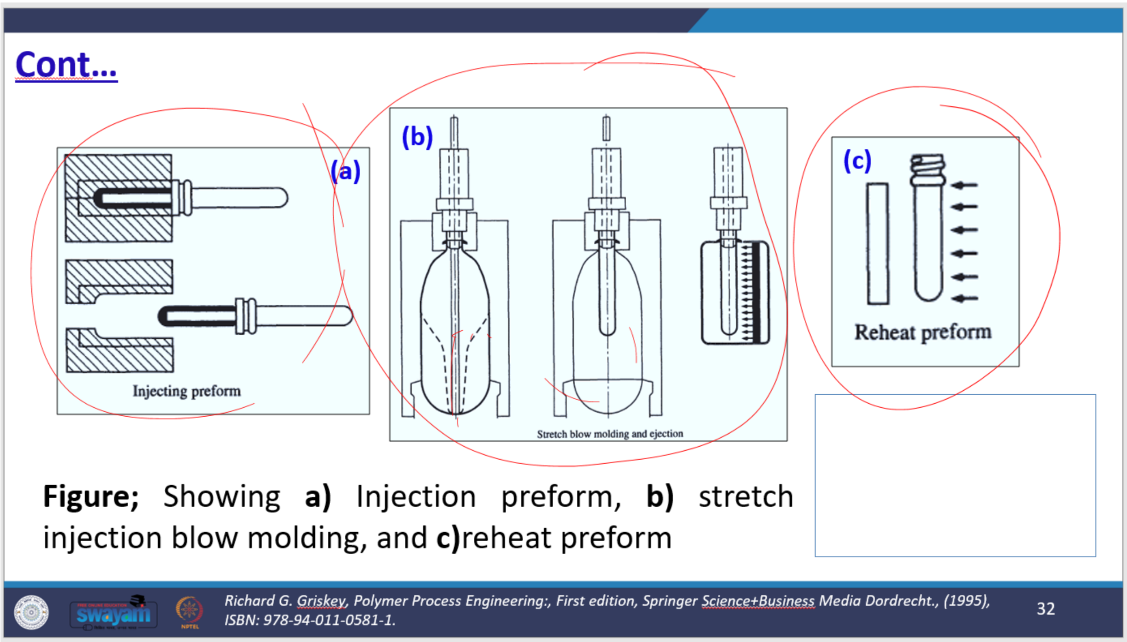
The preform resembles a test tube these are the shapes of preform resembles a test tube since it has the hemispherical closed end. The open bore on the opposite end was created by the core pin and the preform is enclosed within the blow mold which also introduces blowing air via the core pin followed by cooling. So when blow molds are opened finished goods are rotated to an ejection station where they are mechanically and air-tightly stripped off. Now here this is you see the schematic diagram of injection blow mold this is the solid handle now this is you see the solid handle and this one is a simple handless that can be molded with the blow molding bottles.



So this is for the bottles. Let us talk about the stretch blow molding. Now stretch blow molding can be carried out using either an extrusion or an injection molding process. Now it produced biaxial orientation in the blown article. Now due to the expansion of the parison into the mold cavity when it enters the mold cavity blown air is passed so there is an expansion of the parison. The traditional blow molding imparts a certain degree of circumferential orientation.

Now it provides axial orientation by stretching the preform or parison axially before or during the blowing. Now to do this a stretch rod usually that is advanced axially into the preform or parison at a regulated rate can be used. Now it offers a considerable cost and performance-related benefits. It will offer improved transparency and gloss, reduced permeability, greater strength and stiffness, and increased resistance to burst pressure. So saving on chemicals like impact modifiers may be possible as a result of improved strength.

Injection stretch blow molding is again a modified version of this stretch blow molding. Now the preform injection molding step is integrated in this particular aspect with the stretch blow molding machinery in a single-stage injection stretch blowing process. So the machines are generally arranged for rotary operation. Performs pass directly from the injection molding station to a thermal conditioning station and the stretch blow molding. Now here you see the injection preform this is a stretched blow molding and this is the reheat preform.



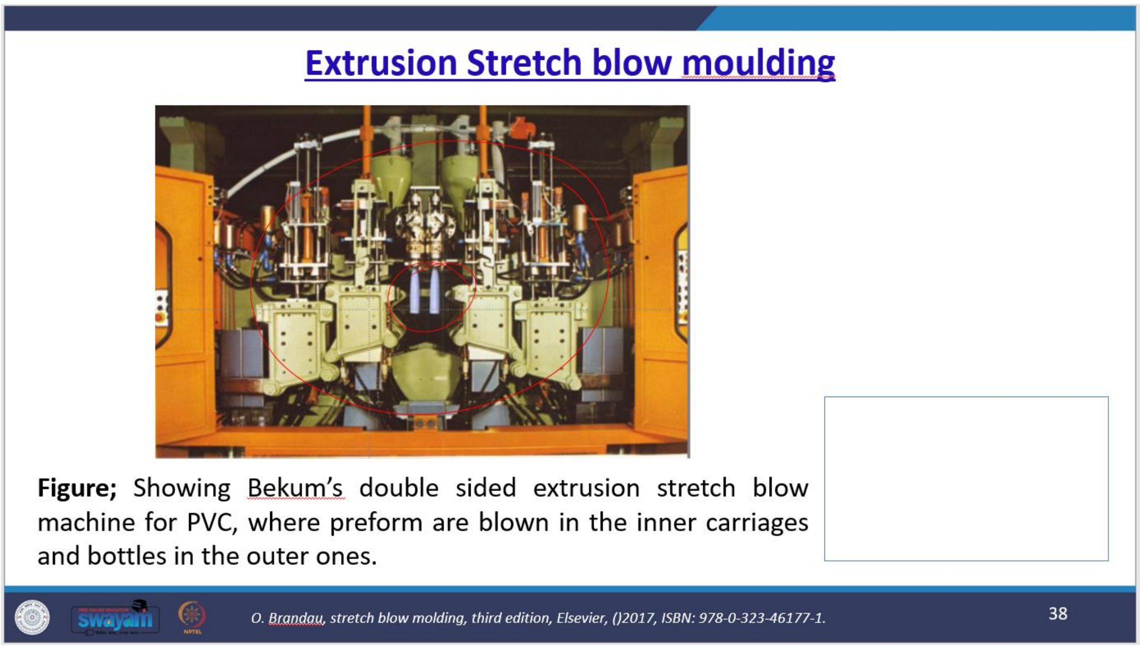
So here you see that the stretching because of the flow of air stretching takes place. Now the parison is usually passed to the correct orientation profile temperature from end to end once it has been produced either by injection or extrusion. Due to the use of a single machine, the process can move from raw material to finished goods. The range of temperature for ideal stretch blow molding can vary small starting at roughly 10 degree Celsius. So uniform heating in the order of say plus or minus 1 degree Celsius is very important.

So up to 36 separately controlled heat zones are included in the thermal conditioning stations which commonly combine hot air for inside heating with infrared radiant outdoor heaters. So the thermally conditioned preform gets transferred to a blow mold and the mechanical grip stretching or an internal stretch rod is used to stretch and align axially. So either just before or at the same time as the blowing process leading to radial stretch and orientation. So the blowing pressure ranges up to about say 40 bar. Now to reduce the bottle strain the blow mold is heated to a relatively high temperature of 35 to 65 degrees Celsius.

The major determining factors for the degree of orientation for a particular bottle size are the Parisian length and diameter. So stretch ratios are relatively high. Now the ratio may be as high as 15 :1 in the bottle body wall thickness or axial stretch ranges from 4 : 1

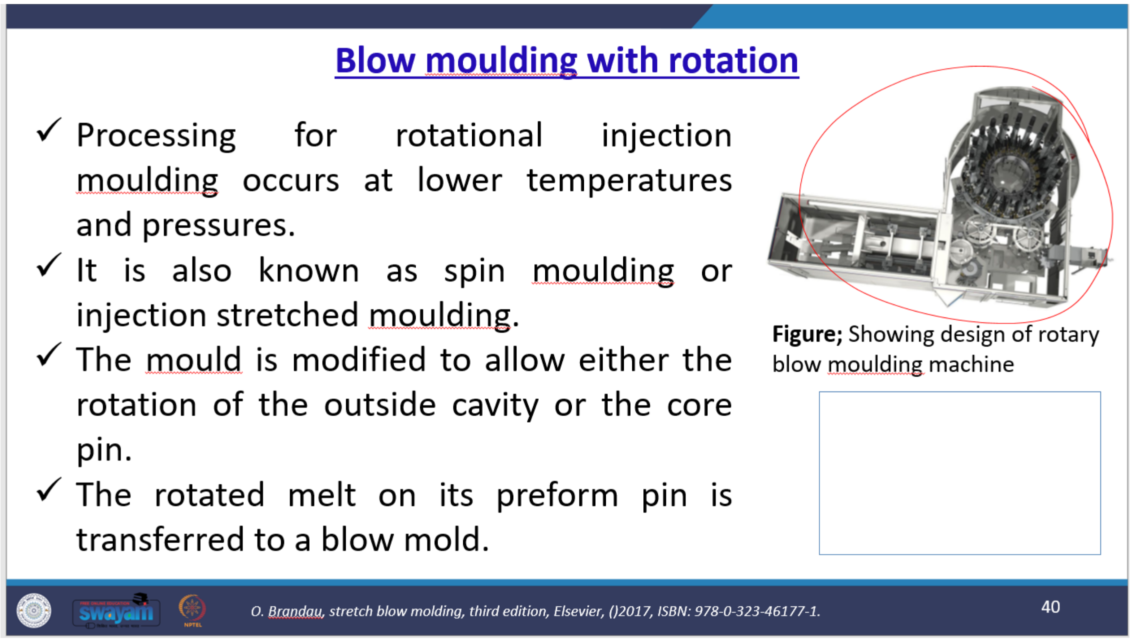
to 3.5 : 1 while diametrically stretches 4 : 1. Now let us talk about the streusel stretch blow molding sometimes referred to as ESBM.

It is a 1-stage or a 2-stage process using 2 mold mandrel sets where one is for pre-blow and the other for the final blow. Now to create the close and perform an extruded Parisian is first pinch off and conventionally blown in a small pre-blow mold. Now here you see the BACOM double-side extrusion stretch blow molding machine for PVC where preform are blown in the inner carriage and bottle in the outer one. So here you see this one. Now the preform is usually transferred to the final blow mold.

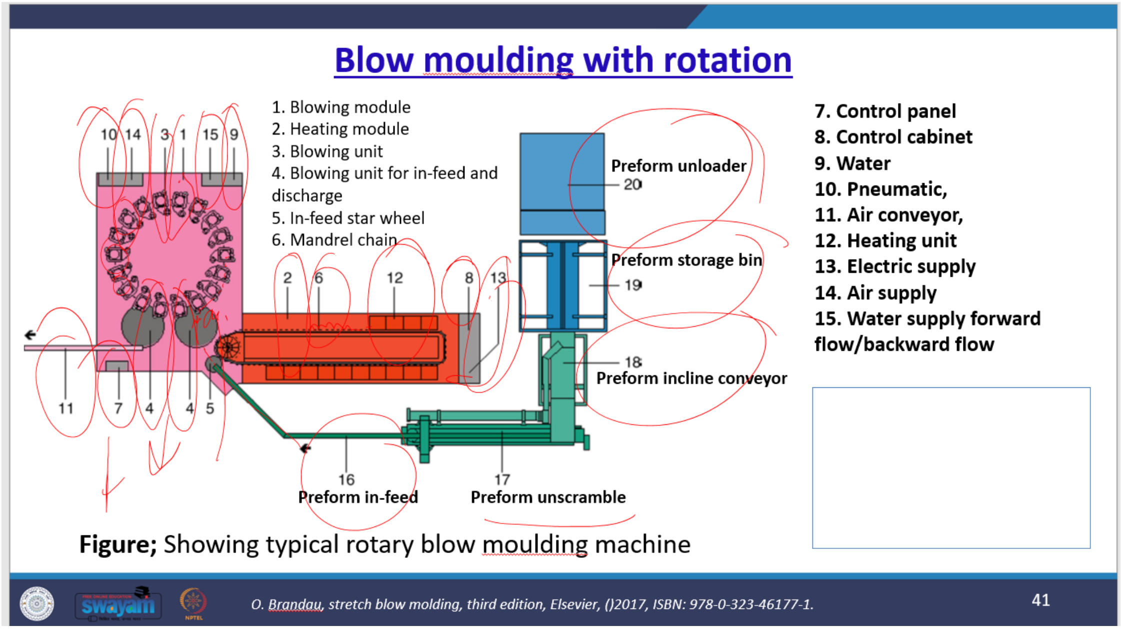


Now when stretching axially the closed preform is typically pressed again by an extending stretch rod inside the blowing mandrel. So the stretch preform is then blown to impart circumferential stretch and the process is almost or process is most often used for the PVC bottles. Let us talk about the blow molding with rotation. Now this processing for the rotational injection molding occurs at a low temperature and pressure. It is also known as a spin molding or injection stretched molding.

Now the mold is modified to allow either the rotation of the outside cavity or core pin and the rotated melt on its preform pin is transferred to a blow mold. Here you see that this is the design of a typical photograph of a rotary blow molding machine and the internal anatomy of this rotary blow molding machine. Now these are some of the segments of blow molding rotations. Now here you see that different parts are mentioned of different this blow molding machine. Now this is the blowing module you see different types of molds there.



Then this is the heating module. Now this one is the blowing unit and the important part is that the blowing unit is in feed and discharge which is where you see the discharge is here. Then in the feed star wheel, you will find the mandrel chain you see these dotted lines the controlling panel, and control cabinets all these things are housed here. There should be a regular water supply for the cooling so it is there. Then the pneumatic things which are controlling over here apart from this are the air conveyor and these are the heating units. And here you see the electrical supply and apart from this because it is a blow molding you need the air supply so this is mentioned over here and the water supply which is mentioned over here.



So you see that there are different segments like this is in a scramble the preform in the feed so preform is being fed here you can see here these are the different molds this can be inserted there is a regular supply of air where it can be inserted in form and then there is the ejection. And apart from this, this is the preform unloader storage bins and all these things so these are the rotational blow molding operation. This particular aspect is most effective when employed with articles like having the polar axis of symmetry having reasonably uniform wall thickness and whose dimensional specification and part-to-part trueness are very important. Now during the fabrication using this particular process, two forces act on the plastic injection longitudinal and a rotational hoop. The targeted balanced orientation is a result of these forces the additional high magnitude cross laminated orientation this develops as the product wall cools and is frozen in and throughout the wall thickness.

Injection on molecular planes occurs as each layer cools after injection, and depending on the wall thickness, this orientation may change in both direction and magnitude. This particular process involves a vast number of microscopic layers, each of which has a controlled orientation. The amplitude, direction of the orientation, and strength qualities can be changed and controlled throughout the wall thickness by using appropriate processing conditions.

Now, at the outset, there are numerous advantages and disadvantages associated with blow molding. Let's delve into one specific operation – extrusion blow molding. It offers advantages such as a high production rate, low tooling cost, and a wide selection of equipment. However, it comes with simultaneous disadvantages, including a large amount of scrap, limitations on wall thickness, and the need for trim and facilities.

Moving on to injection blow molding, a notable advantage is the absence of scrap. It excels in thickness control, accurate neck finishes, and producing outstanding surfaces. Additionally, it can handle low-volume production. Despite these advantages, there are drawbacks attributed to high tooling costs and the impracticality of producing large objects using this method.

Next, let's explore stretch blow molding, which stands out for its economic viability, enhanced properties, and precise control of wall thickness. This method allows for reduced weight without compromising structural integrity. In this particular segment, we've delved into the blow molding operation, a process closely intertwined with our day-to-day affairs and the production of a variety of products.

For your convenience, we have provided a list of references that you can utilize for further study or to delve deeper into the subject. We appreciate your attention and thank you very much for engaging in this discussion.