



# Extrusion blow moulding

## Shaping hollowed products such as bottles

- \* The production line uses an annulus die attached to the end of a reciprocating screw extruder.
- \* A molten polymer is vertically extruded through the die and placed and clamped in between two halves of a cold mould, the shape of the mould usually being the shape of the desired product.
- \* The extrudate from the die called “parison” is cut off from the die using a hot knife and is then inflated with compressed air and the product solidified as the inflation continues.

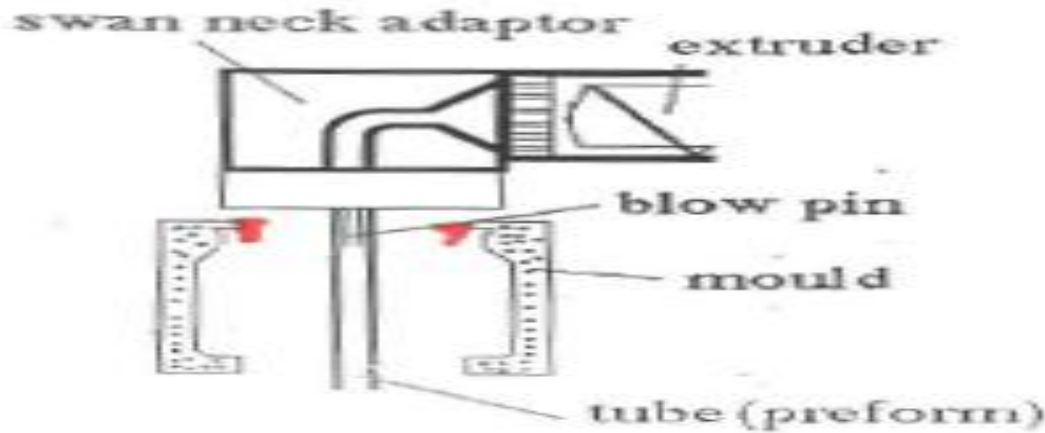


# Extrusion blow moulding

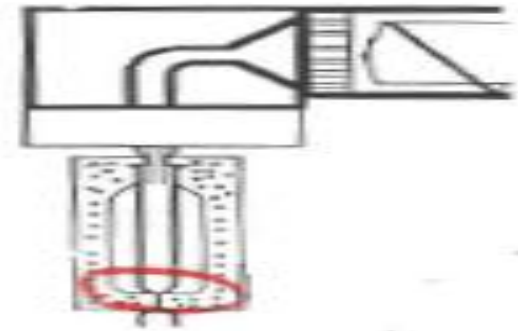
- \* **By opening the mould, the finished product is ejected.**
- \* **The process can be discontinuous and continuous. In the continuous process, second parison is extruded through the die whilst the first one is being inflated with air. In the discontinuous process, second parison is extruded through the die whilst the first one is being inflated with air.**

**Note: Stretch extrusion blow moulding is also available.**

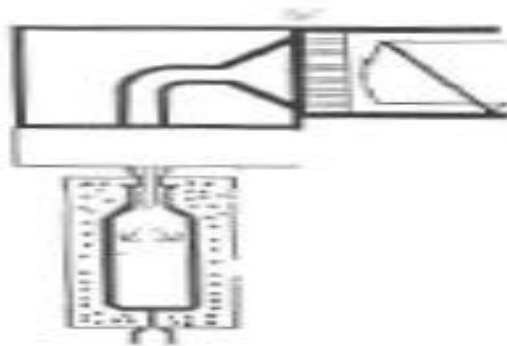
# EXTRUSION BLOW MOULDING



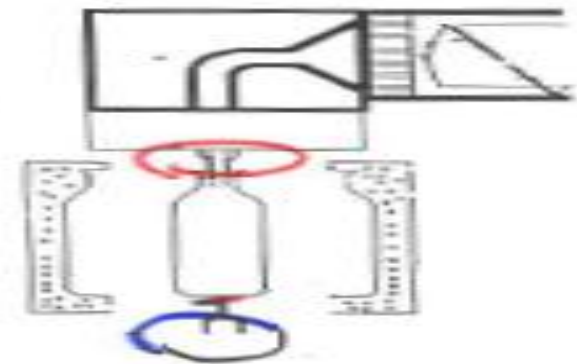
(i) extrude tube -  
moulds open



(ii) close mould

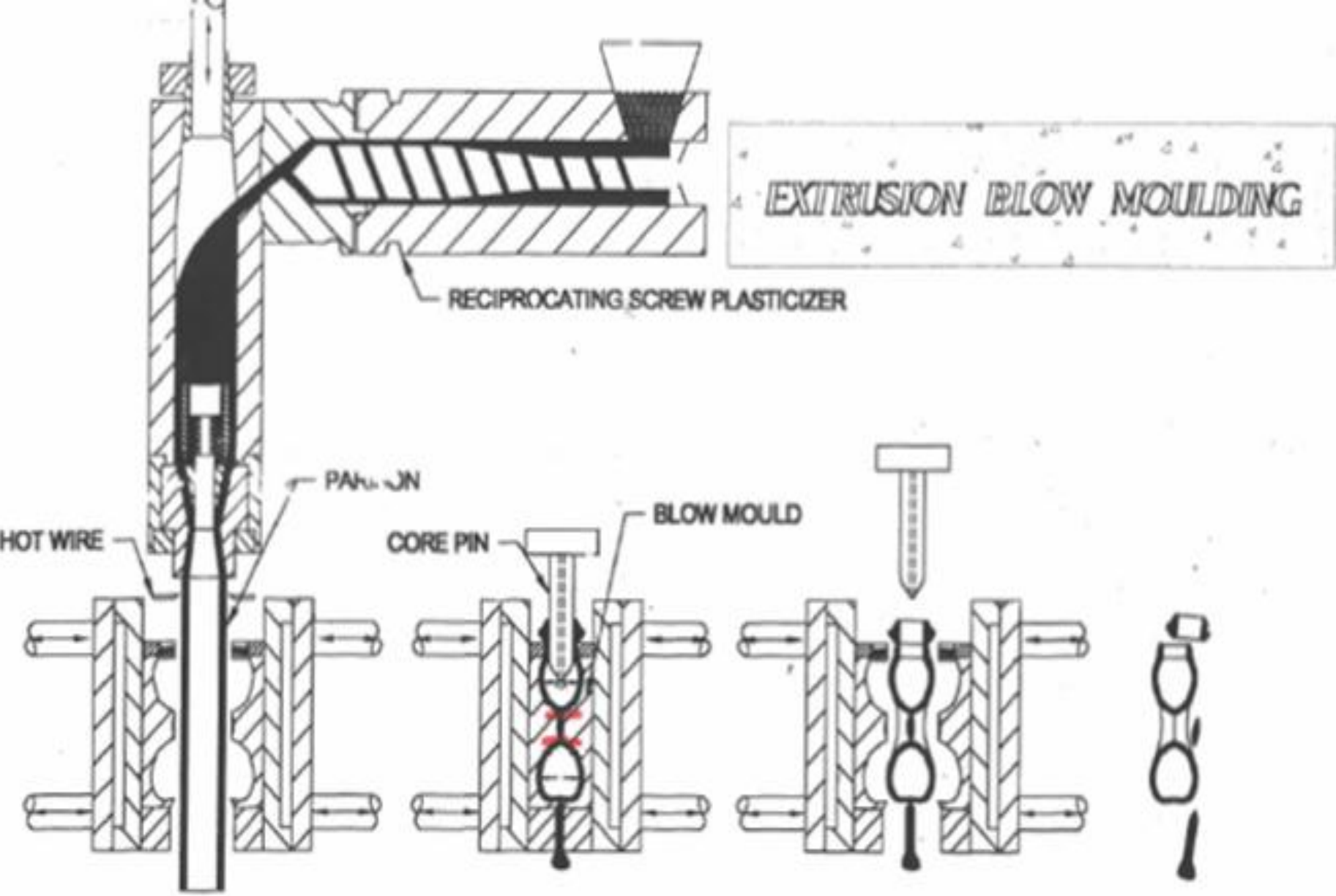


(iii) inflate tube and cool



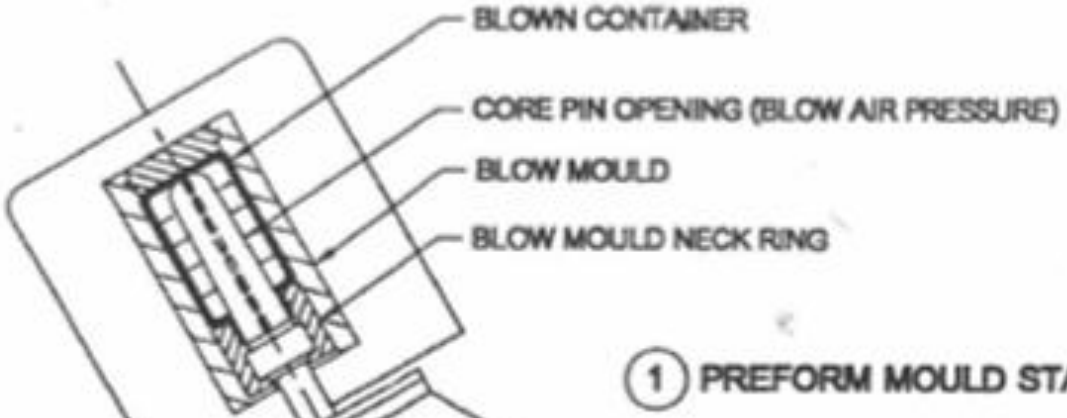
(iv) open mould  
repeat cycle

# EXTRUSION BLOW MOULDING

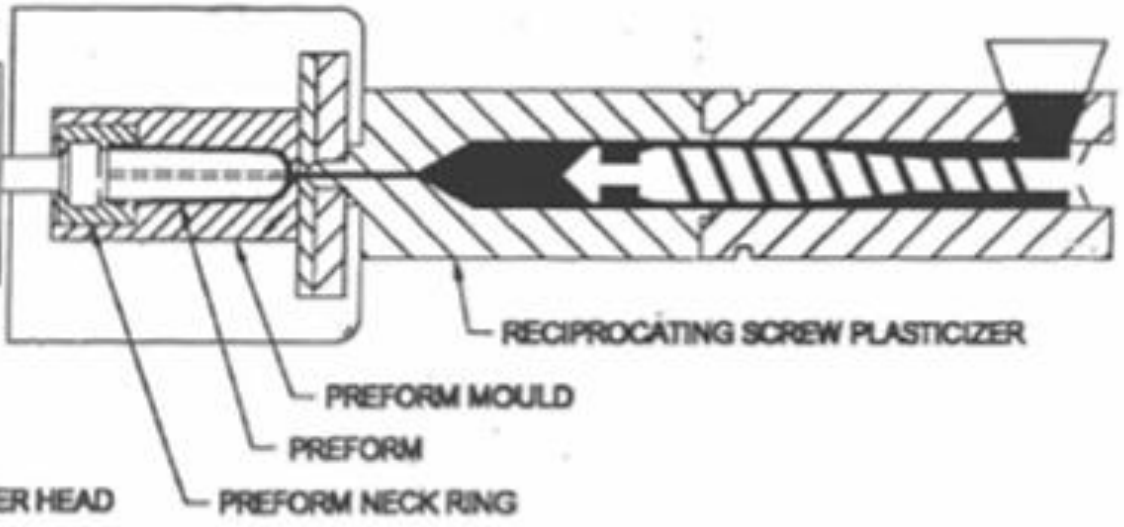


- 1. EXTRUDE PARISON
- 2. BLOW STATION
- 3. DEMOULD
- 4. TRIMMING

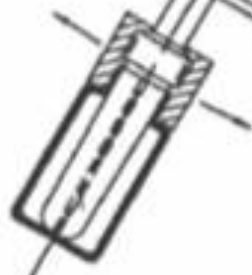
2 BLOW MOULD STATION



1 PREFORM MOULD STATION



3 EJECTION STATION



*em.*

INJECTION BLOW MOULDING



# Flow related effects in extrusion blow moulding

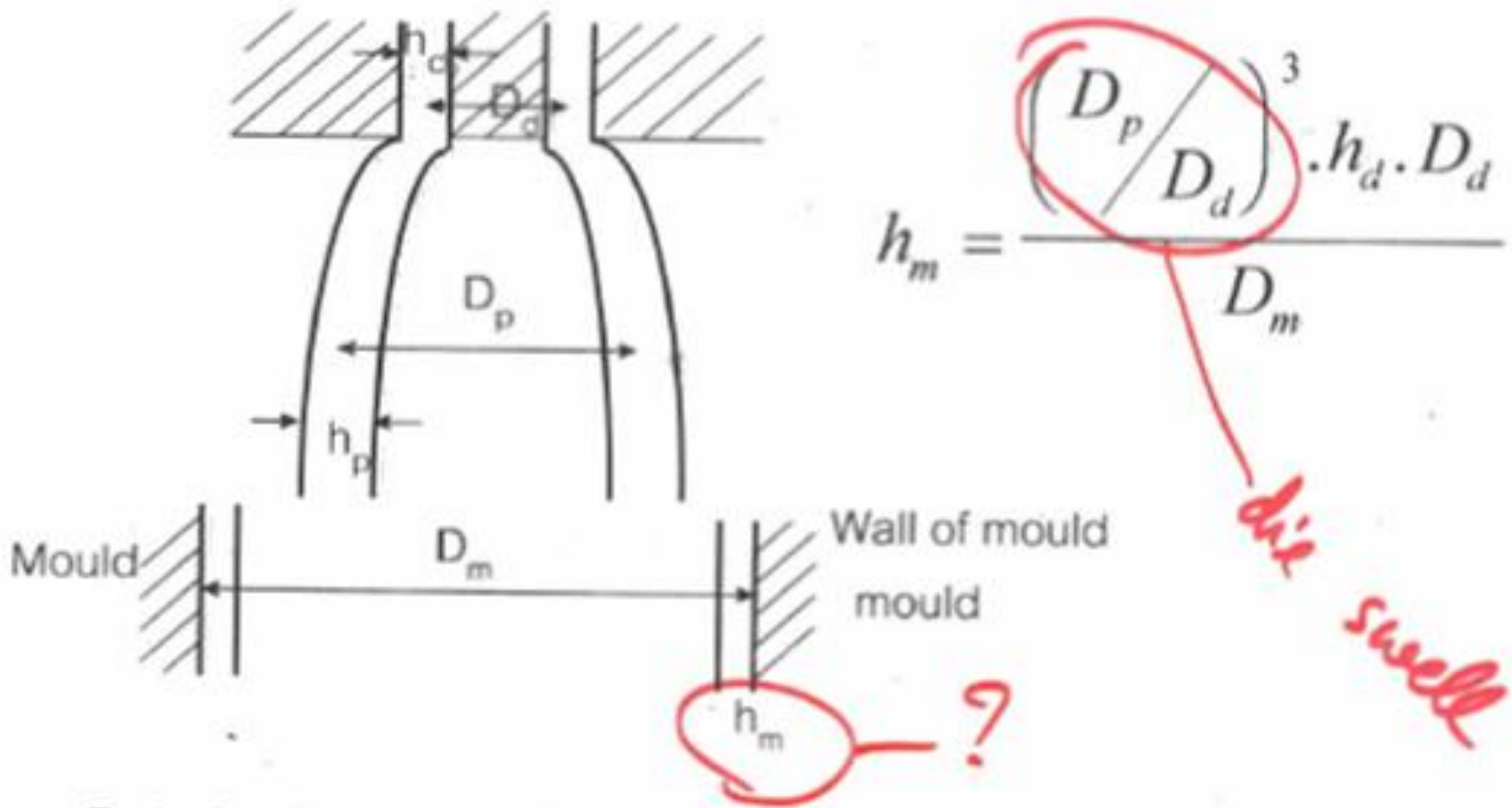
- \* **There are two flow related problems occurring in extrusion blow moulding, these being:**
  1. **Parison sag - This causes a decrease in thickness of parison as it is being extruded.**
  2. **Die swell - This causes an increase in thickness of parison as it is being extruded.**
- \* **These two parameters influence the thickness and general properties of the moulding.**
- \* **Thicker section is found at the bottom of the bottle, the thinner section being on the body of the bottle.**



# Flow related effects in extrusion blow moulding

- \* The thickness distribution of the bottle can be estimated using the following equation.

$$h_m = \frac{\left(\frac{D_p}{D_d}\right)^3 \cdot h_d \cdot D_d}{D_m}$$



$D_d$  is the die diameter (mean)

$h_d$  is the die annulus width

$D_p$  is the parison diameter

$h_p$  is the parison thickness

$D_m$  is the mould diameter

$h_m$  is the moulding wall thickness





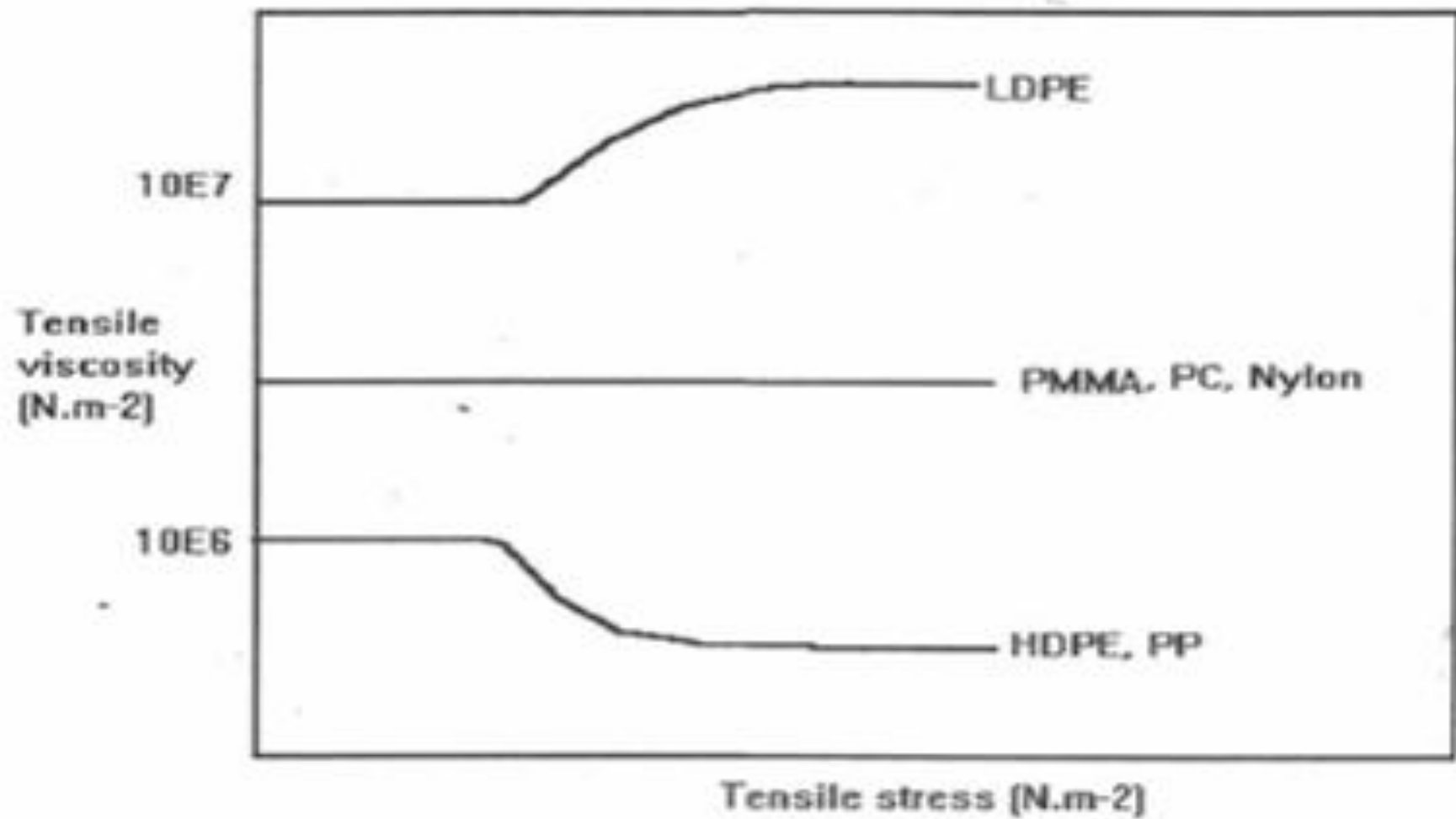
# General comments on the processing of a bottle by extrusion blow moulding

- \* **There are scraps both at the bottom and top of the bottle.**
- \* **Pinch-off and trimming are required.**
- \* **One of the economical ways to minimise the scrap is by designing for sealing screwed-cap.**
- \* **Stiffnesses and rigidities of the bottle are required, these being rather important than its appearances such as glossiness and smoothness.**



# General comments on the processing of a bottle by extrusion blow moulding

- \* **Mechanical properties are strongly dependent on the crystallinity and density of the product. For example, HDPE and LDPE are more considered to be used in making bottles due to the fact that they have higher crystallinity and density than PP and PET. This is also the reason for obtaining a light weight of bottles.**
- \* **PP is not usually used to produce bottles by extrusion blow moulding because the strength at the molten state is lower than that of LDPE and HDPE melts. Therefore, it is usually required for injection blow moulding, in which the cooling process of the parison is employed before inflated.**



Tensile viscosity of polymer melts



# Comparison between extrusion and injection blow mouldings

There are some differences between the two blow moulding processes, these being tabulated as follows:

Extrusion blow moulding	Injection blow moulding
Simpler operation and more versatile	More complicated operation and less versatile
More wastes of plastics	Less wastes of plastics
Large moulding possible	Limitation in size
Shorter cycle time	Longer cycle time



# Comparison between extrusion and injection blow mouldings

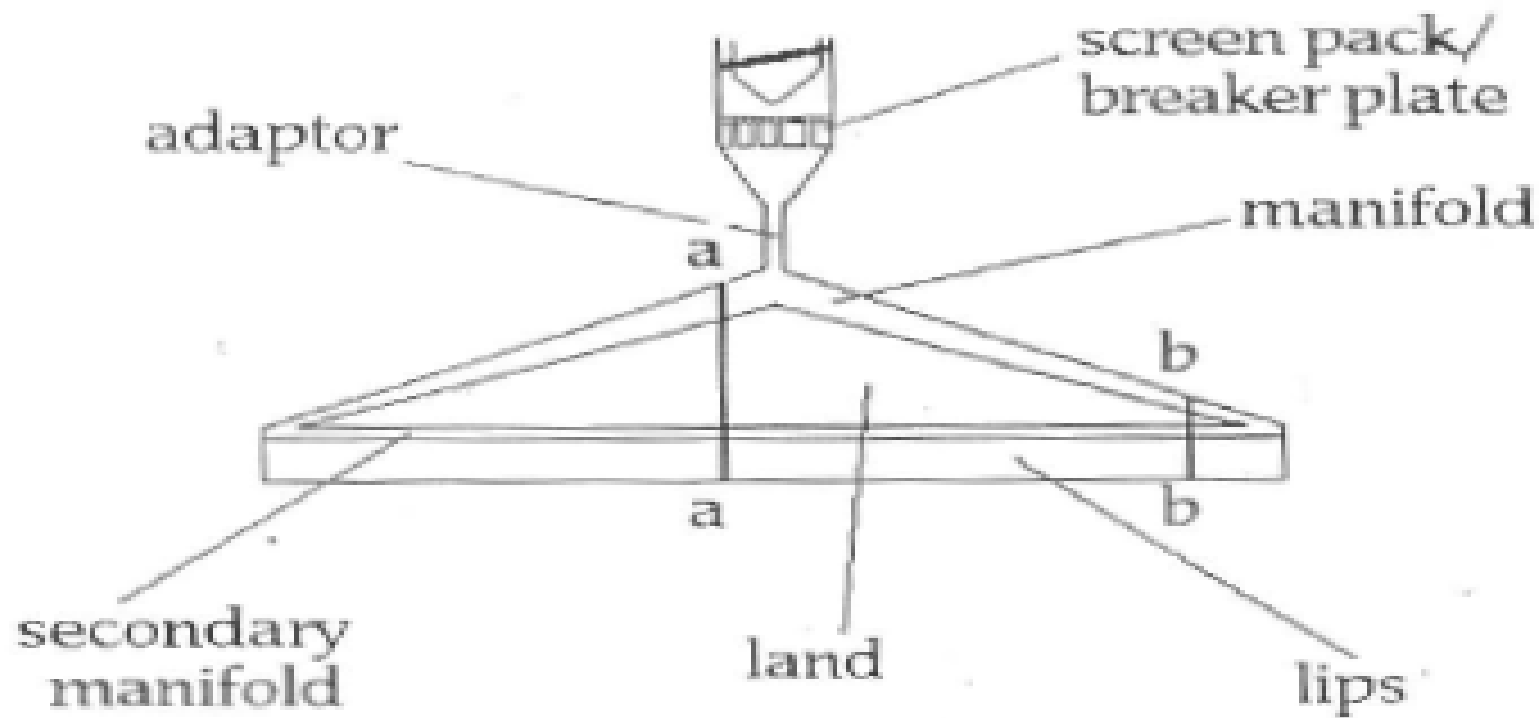
Extrusion blow moulding	Injection blow moulding
Less uniform thickness of moulding	More uniform thickness of moulding
Good for high strength of the extrudate	Good for low strength of the extrudate
Suitable for polymers having high degree of crystallisation	Suitable for polymers having low degree of crystallisation



# Sheet manufacture

- \* The extruder pumps the polymer through a slit die to give a polymer sheet.
- \* A typical thickness is greater than 0.25 mm, lower thickness being referred to as film.
- \* The main materials are polyethylene and polypropylene.
- \* The most commonly used die from this process is *coathanger* geometry, this being very expensive die because it gives uniform melt stream and melt temperature distribution.

# Coathanger die



section a-a



section b-b

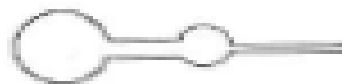
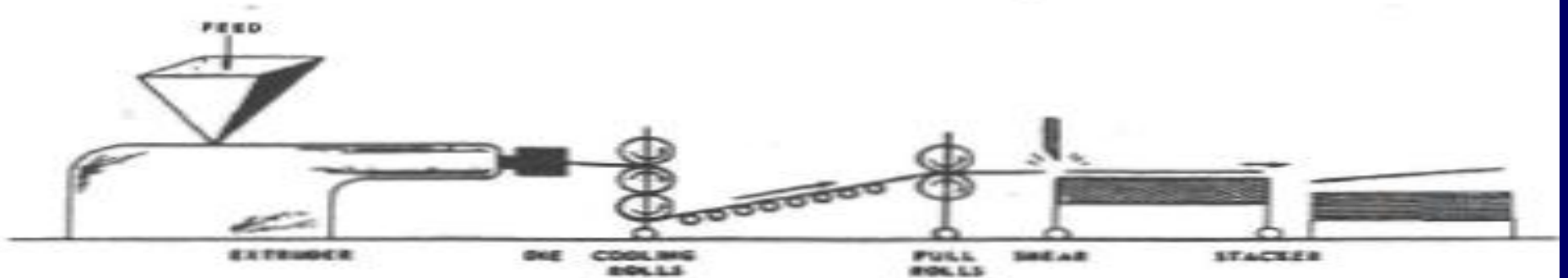
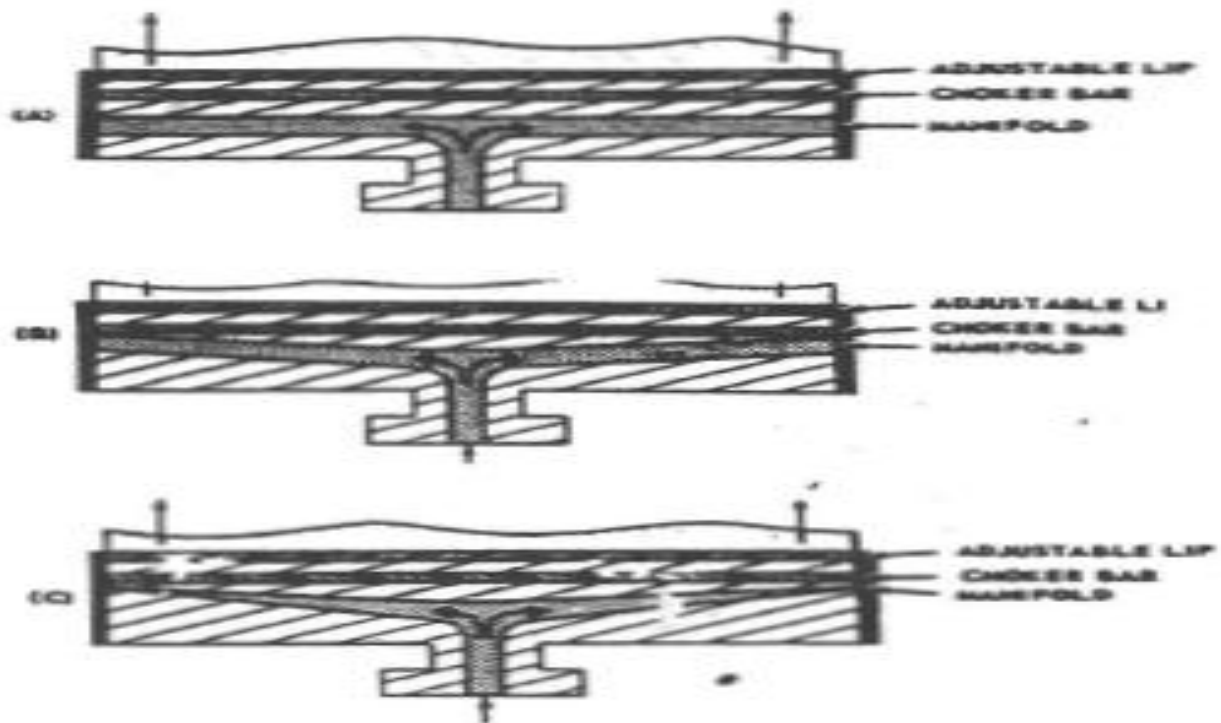


Figure 1.4

## 8 - Sheet Extrusion Line



## 9 - Sheet Dies







# Sheet manufacture

- \* Die lip can be adjusted using a spreader (choke) bar to alter the thickness of the sheet produced, the movement being about 1.5 mm.



# Details in sheet extrusion

In sheet manufacture, the molten polymer extruded from the die is then passed onto:

1. **A casting unit.** This is used with thermoplastics, the unit consisting of a cooled roll, this resulting in the solidification of the extrudate.
2. **Chill-roll stack (sheet line).** This is used with thermoplastics, the unit consisting of three cooled rolls used to cool the extrudate and to polish the surface of the extrudate in order to produce a controlled surface finish.



# Details in sheet extrusion

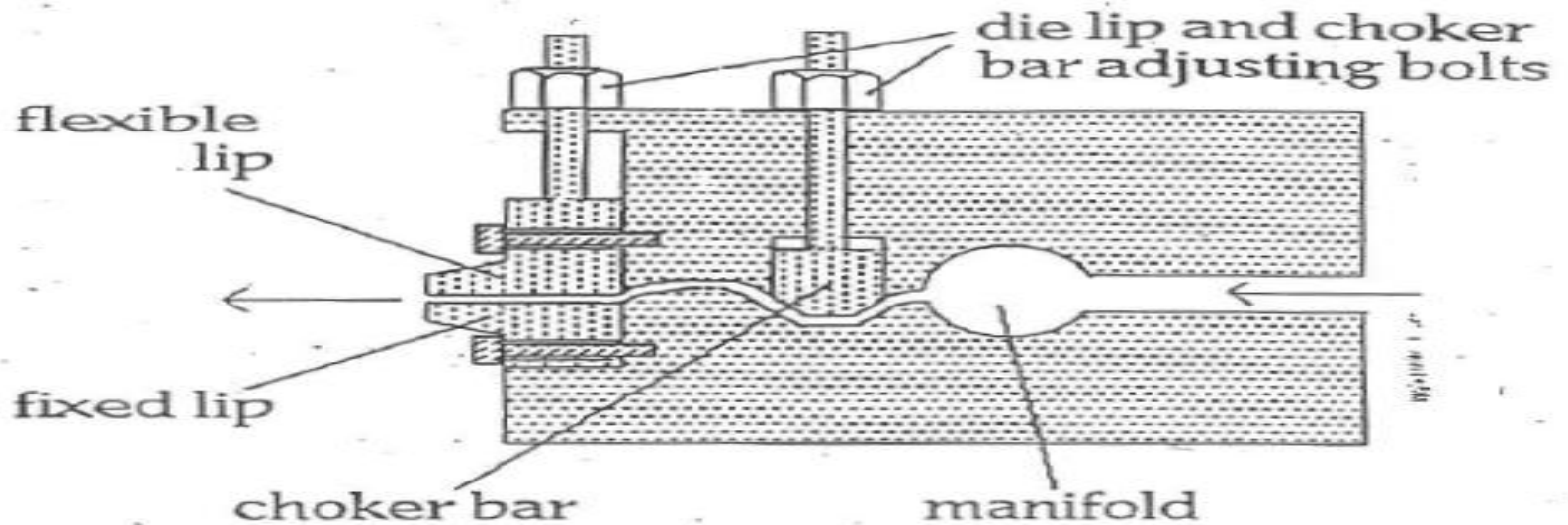
3. **Calender/calenderette.** This is used for both thermoplastics and elastomer compounds. These devices are designed to control the thickness of the product, the rolls being operated at or above the melting point. The extruder is used solely as a supply of molten polymer, the gap (nip) between the rolls setting the gauge (thickness) of the product.



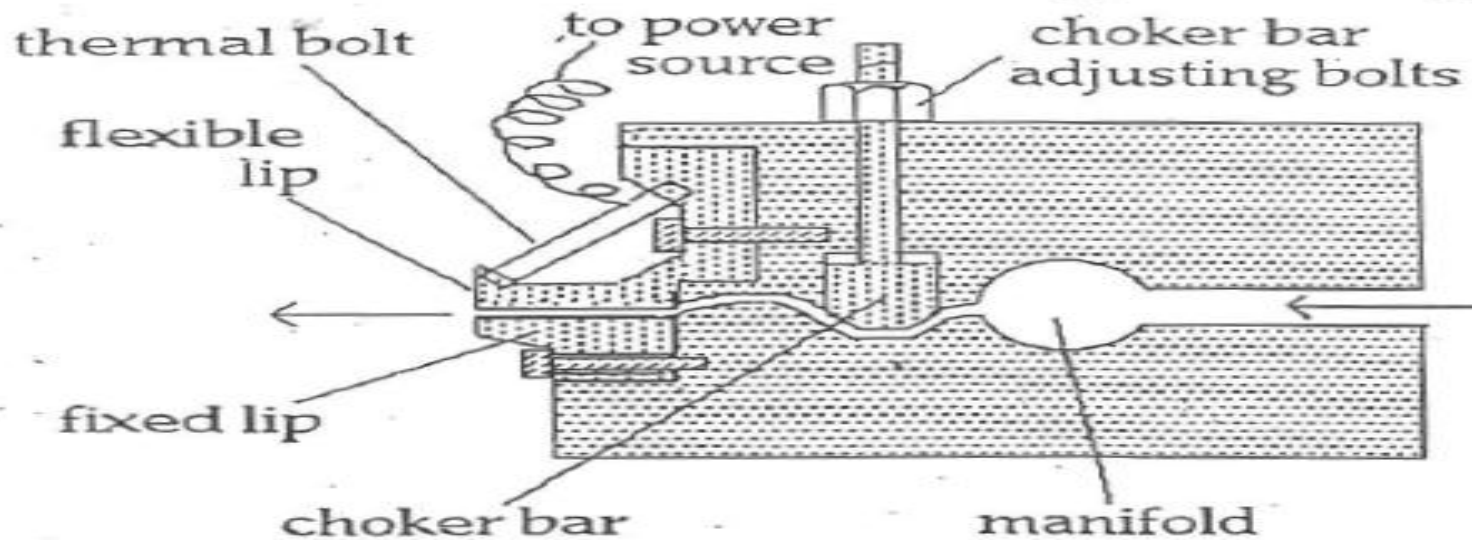
# Film manufacture

- \* The process is very similar to sheet extrusion.
- \* An extruded product is called a film if its thickness is less than 0.25 mm, greater than this being called a sheet.
- \* The main materials are polyethylene and polypropylene.
- \* The process includes two main types, these being:
- \* **Chill-cast film extrusion** - The film is extruded from a film die and passed directly onto rollers which control cooling and surface quality of the film.

### Manifold/restrictor bar T-die

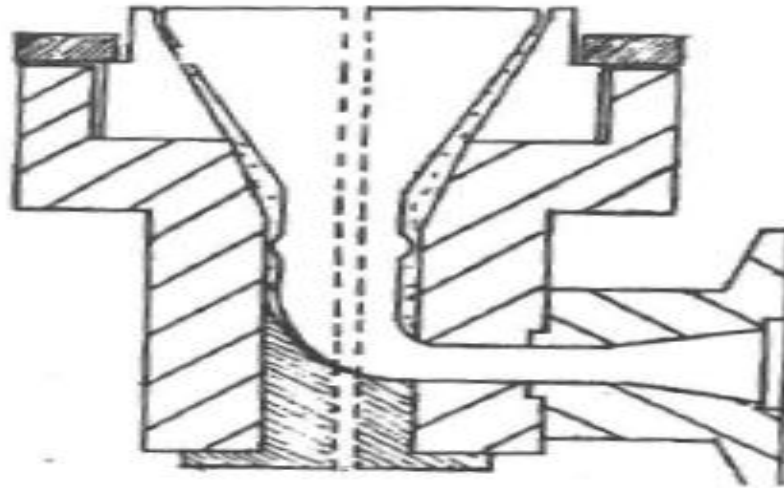


### Automatic thickness profile adjustment



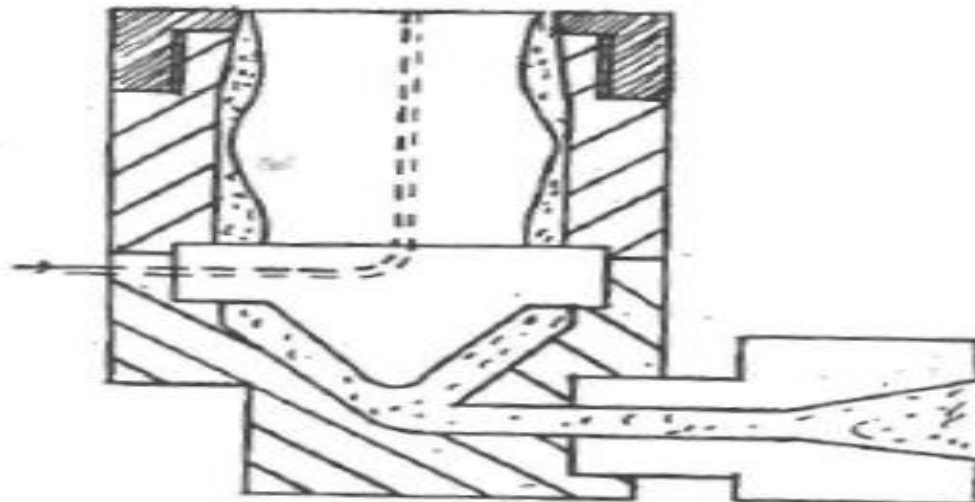
11a

Side Fed Die



11b

Bottom Fed Die





# Film manufacture

- \* **Cast-quench extrusion** - The film is extruded from a film die and immersed into a chilled water before being passed onto nip rollers to adjust final thickness.
- \* **Extrusion coating** - The film emerging from the die contacts the substrate to be coated in a nip, this resulting in a coating or lamination.

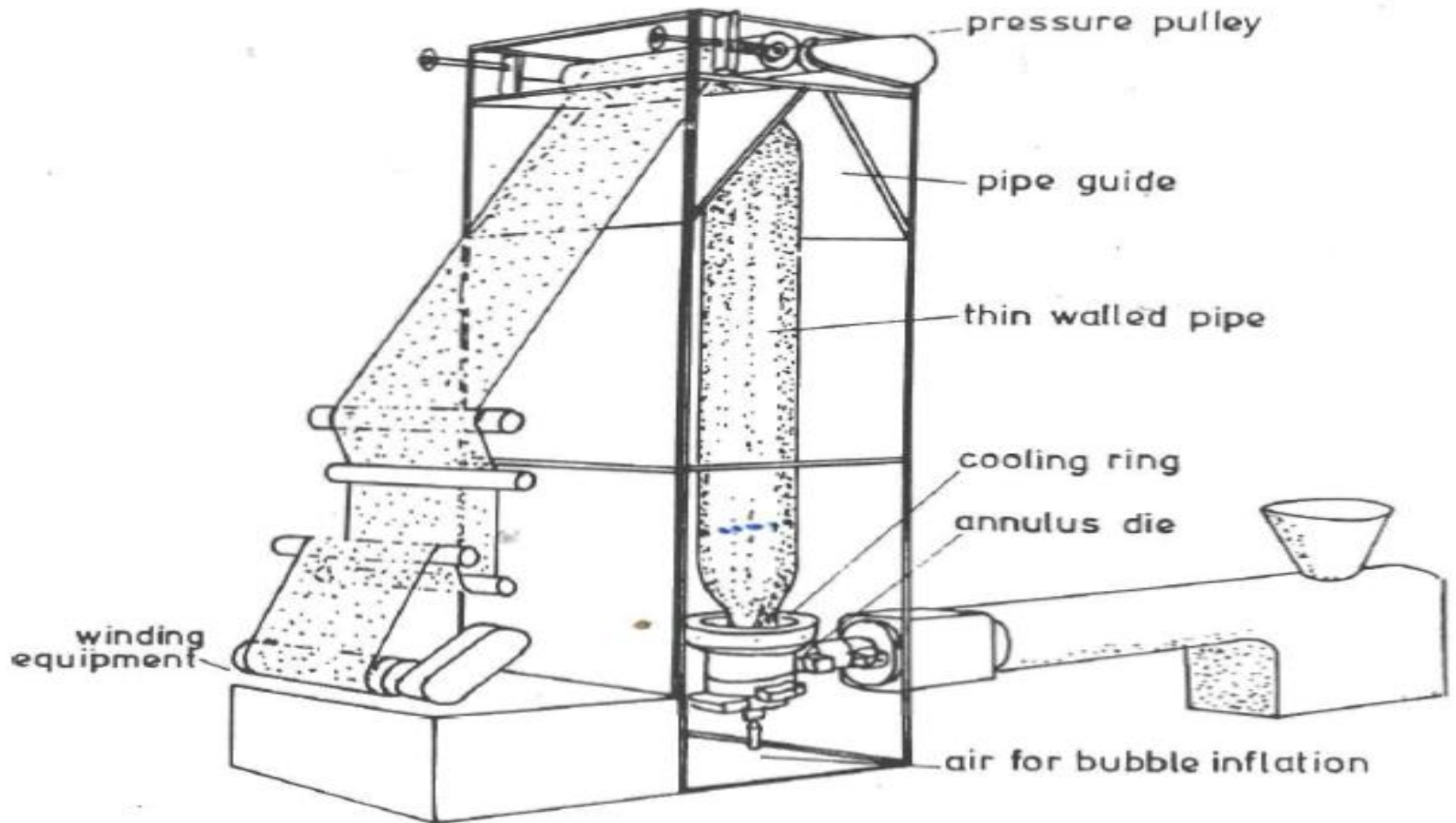


# Blown film extrusion

- \* The fundamental components of a blown film line include:
  1. The extruder - To generate a melt
  2. The die - To produce and shape an extrudate
  3. Nip rollers - To transport the film
  4. Cooling system - To cool the extrudate
  5. Collapsing frame - To enclose the film
  6. Surface Treatment Station - To treat the surface of the film
  7. Winding - To collect the film



## 10 - Lay Flat Film





# Blown film extrusion

- \* In the case of a film line the nip rollers at the top of the tower need to be aligned *vertically upwards* over the centre of the die and the die surface and the nip rollers need to be horizontal.
- \* Blow ratio is defined as the ratio of bubble diameter to die diameter.
- \* The main material processed by this technique is polyethylene.



# Technical details in blown film extrusion

- \* **Viscous and elastic responses - Molten state is responded by viscous whereas crystallising state is by elastic response.**
- \* **The stabilisations (shape and size) of the bubble (film) is dependent on freeze line or frost line.**
- \* **Biaxial orientation - increased mechanical strength due to stress induced crystallisation.**



# Technical details in blown film extrusion

- \* The bubble doesnot burst due to tension stiffening of materials (the melt strength decreasing with tensile stress) such as LDPE). HDPE and PP are tension thinning, the melt strength decreasing with tensile stress.
- \* **The thinner the film thickness the greater the stress.**



# Blown film extrusion of PP

- \* PP is also tension thinning, but it is widely known that PP is produced from blown film extrusion with some modification. Applications are used in packaging such as crisp packets and tobacco packets
- \* Since PP is tension thinning, the bubble produced may be unstable and causes collapses of the film. Modifications of the process are then required, these being:
  1. The process is operated vertically downwards.
  2. The melt emerging from the die is quenched by chilled water.
  3. The melt is reheated before blowing.



# Comparison between blown film extrusion and film extrusion

1. **The advantages of the blown film process over film extrusion**
  - \* **Superior mechanical properties of the film due to biaxial orientation.**
  - \* **The width of the production is easily controlled.**
  - \* **The product is more readily converted into bags.**
  - \* **The production machinery is generally cheaper.**



# Comparison between blown film extrusion and film extrusion

## 2. The disadvantages of the blown film process

- \* Lower outputs due to the cooling limitations.
- \* Poorer optical properties of the film are due to lower cooling rate.
- \* The film thicknesses are more limited.



# Multi-layer films

- \* Very often the desired properties cannot be obtained from one type of polymer alone.
- \* In packaging manufacture, film production is very important.
- \* For example, polyolefin films are relatively cheaper and have better heat sealing and transparency than PVC and some other copolymers, but they have too high oxygen permeability. Therefore some modifications are required. The olefin films nowadays are coated with a thin layer of oxygen barrier polymer. This results in the necessity to use a multi-layer product, this product being generated by a process of either coating, lamination or coextrusion.





# Co-extrusion

Coextrusion is a process where one or more melt streams are fed into one die, the extrudate from the die having a layered cross-section.

- \* Coextrusion offers advantages over the other techniques as a result of:
- \* Although the equipment is more expensive, the product is made in a one-stage process.



# Co-extrusion

- \* There is a reduced tendency for the products to delaminate.
- \* The process allows products to have different properties on each side.

## Materials used include:

- \* LLDPE/EVAL/LLDPE - 3 or 5-layer system.
- \* Uncoloured/coloured layers
- \* Foam/solid/foam



# Importances in co-extrusion

- Various combinations of layer structure are possible but it is normally three layer or five layer.
- Ideally the reins used should have similar rheological characteristics and similar shrinkages on cooling otherwise the film will tend to curl.
- The melt streams of each layer are brought together either inside or outside the die.



# Importances in co-extrusion

- In the case where the *rheological characteristics* (shear viscosity) do not match very closely, it is better that the lower viscosity material is used to generate the outer layers of the film.
- Adhesion of adjacent layers has to be good.
- Layers do not mix because the flow of polymer melts is usually laminar, not turbulent.



# Importances in co-extrusion

- \* Environmentally, coextruded films do result in the problem that the scrap and used packaging *cannot easily be recycled*, particularly where it consists of materials that have distinctly different characteristics such as polyethylene and polyamide.
- \* Rheology of polymer melts is significant, involving extrudate swelling.



# Wire and cable manufactures

Many thermoplastics can be used for coating onto copper and aluminium wire, the wire being insulated with the plastics.



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# Materials and applications

Many thermoplastic materials are used for the wire coating applications such as *polyvinyl chloride (PVC), polyethylenes and nylon.*

The selection of the materials is usually dependent on the temperature in service. In very high temperature application, silicon coated wires are preferably used.



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# Materials and applications

**Relatively important thing to bear in mind is sharkskin, the perpendicular marks or defects to the flow direction. This is used to control the product rate and the product quality. Sharkskin is very complex phenomenon that may lead to melt fracture, but can be understood by knowledge of polymer melt rheology.**





# Process procedure in wire coating

1. The process begins when the wire is pre-heated to above the glass transition temperature, or the melting temperature because in this temperature, the wire will adhere to a polymer.
2. The wire is pulled through a die. As the wire flows through the die, the polymer melt is being extruded around the wire inside the die.
3. The wire circumferentially coated with the polymer is then drawn through a water bath, the cooling process allowing thermal contraction of the melt and thus the wire being tightly coated with the polymer.



# Process procedure in wire coating

4. The wire is usually wound around the large diameter wheels several times, the speed of the wheels depending on the size of the wire.
5. In the case of very large diameter of the wire is produced, the wheels will need a belt roller to ease the winding process.



# Processing of pipes and tubes

- \* A molten polymer is extruded through a tubing/pipe die, the melt being in the form of annular.
- \* The melt is then drawn into a water bath. In this state, the size of the annulus is determined by a provision of air injection.
- \* At the other end of the extrusion line, the cooled pipe/tubing is received by haul-off, reeling and cutting systems.



# Processing of pipes and tubes

- \* The thickness of the pipe/tube can be controlled by haul-off speed and cooling system. Sizing of pipes and tubes can be controlled using internal sizing mandrel or external sizing evacuator.
- \* More complicated phenomena in terms of extrudate size involve die swell, sharkskin and melt fracture.



# Profile extrusion

This involves other shape of cross-section of products that have not been mentioned, the cross-sectional profiles being determined by the die shape. The cross-sections are rather complex and the process is usually aided by using a mandrel or torpedo. Examples include:

- \* **UPVC window frames**
- \* **PPVC seals**
- \* **Hoses**
- \* **Curtail frames**
- \* **Car window wipers**



# Profile extrusion

- \* UPVC door frames
- \* Shaped pipes and tubes
- \* PC and PMMA lighting equipment.

There are two main factors having to take into consideration when designing profiled extrusion products, these being:

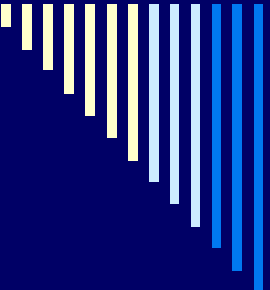
- \* Elastic & viscous effects such as Deborah number.
- \* Rheology of polymer melts such as die swell.
- \* Processing variables such as temperature, pressure and flowrate.



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# Twin screw extrusion

- \* This usually involves using two screw to process a polymer.
- \* Heat sensitive polymers like PVC can easily be processed without any significant degradation.
- \* Twin screw extruders are more used for compounding materials.



# Advantages of twin screw extruders over single screw extruders

- \* Less work is required for processing.
- \* Positive pumping is obtained.
- \* **Less friction occurs.**
- \* They are good for sensitive materials.
- \* L/D ratio is not important therefore no long metering zone is required.
- \* **Shear rate and temperature are more controllable, the values being relatively low.**
- \* Melting process is more complex.
- \* Mixing efficiency is excellent.





# Classifications of twin screw extruders

1. Non-intermeshing - These are sometimes referred to as *tangential twin screw extruders* consisting of two single screw extruders but with a single barrel. Theoretically they are treated as two single screw extruders.
2. Intermeshing - These can be further classified into the following:
  - \* Co-rotating and counter-rotating twin screw extruders



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2. Intermeshing - These can be further classified into the following:
  - \* Co-rotating and counter-rotating twin screw extruders
  - \* Conjugated (highly intermeshing) and non-conjugated (loosely intermeshing)

Commercially, co-rotating and counter-rotating twin screw are known.



# Comparison between co- and counter-rotating twin screw extruders

Co-rotating twin screw	Counter-rotating screw
Two screws rotate in the same direction.	Two screws rotate in the different directions.
Self-wiping is possible	Self-wiping is possible
Overall, give better mixing and compounding	Overall, give less mixing efficiency
Screw geometry is less complex	Screw geometry is more complex



# Comparison between co- and counter-rotating twin screw extruders

Co-rotating twin screw	Counter-rotating screw
Trapezoidal screw flights are used	Rectangular screw flights are used
Materials transferred to the opposites screw	Materials forced into the gap between screws
Clearance between two screw is less critical	Clearance is important
Less wear	More wear



# Comparison between co- and counter-rotating twin screw extruders

Co-rotating twin screw	Counter-rotating screw
Pressure is constant	Pressure is not constant
Lower shear rate	Higher shear rate
Small shear heating	Large shear heating
Less variations in melt temperature	More variations in melt temperature

**Note that: More commercial extruders are co-rotating twin screw extruders.**



# General strategies in extrusion

1. **Changing processed materials**
2. **Cleaning an extruder**
3. **Changing machinery parts**
4. **Changing processing conditions**
5. **Starting up**
6. **Shutdown**
7. **Checking during the operation**
8. **Safety in extrusion**



# Some troubleshootings in extrusion

1. **Heater burnt-out**
2. **Bridged feeding**
3. **Poor appearances of the extrudate and product**
4. **Screw wear**
5. **Bobble brusting in blown film line**