POLYMERIZATION PROCESS

POLYMER

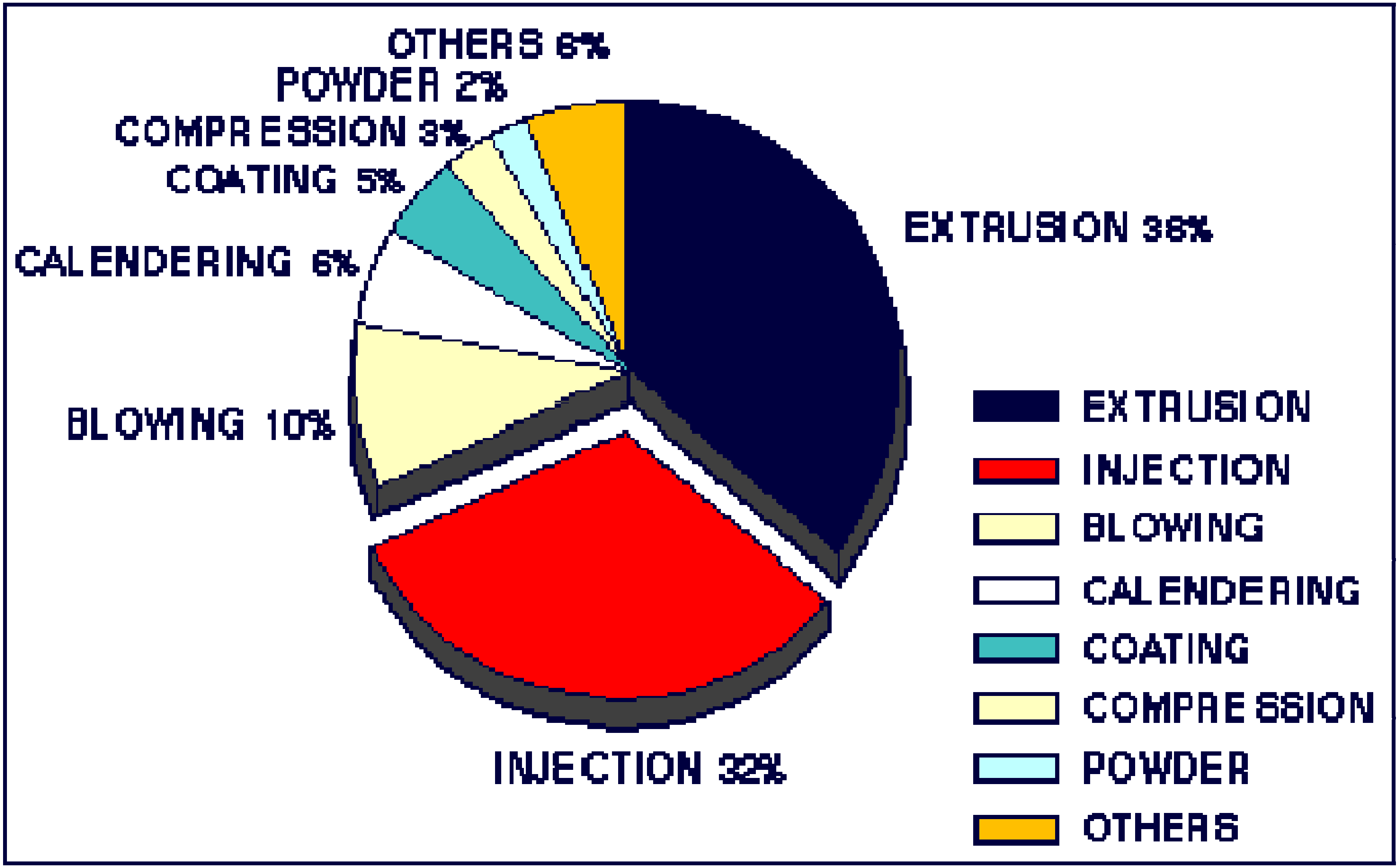
POLYMER PROCESSING

PRODUCT

Major Processes

- Extrusion
- Injection Molding
- Blow Molding
- Thermoforming
- Rotomolding

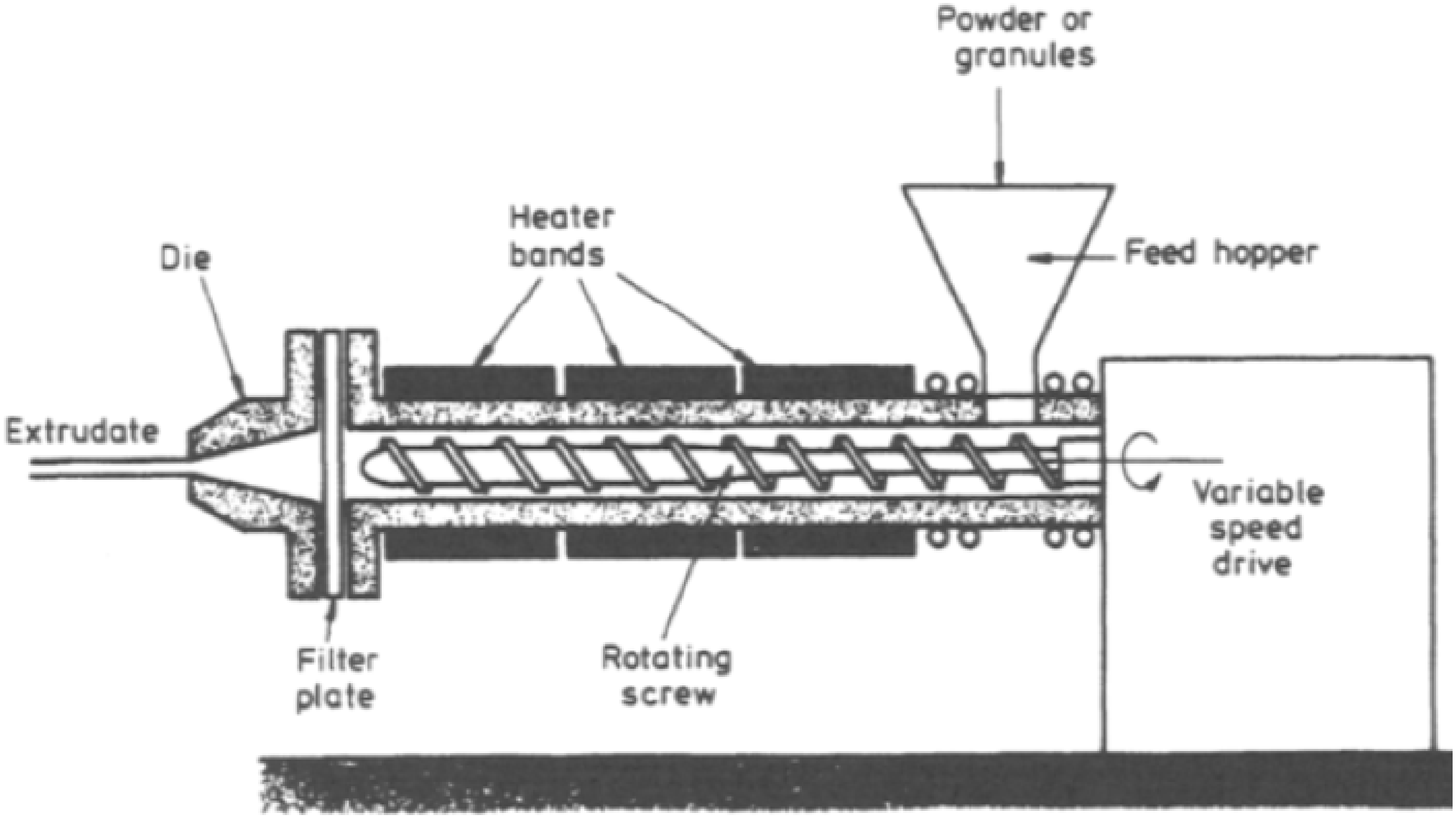
Polymer Processes



Applications of Extrusion Process

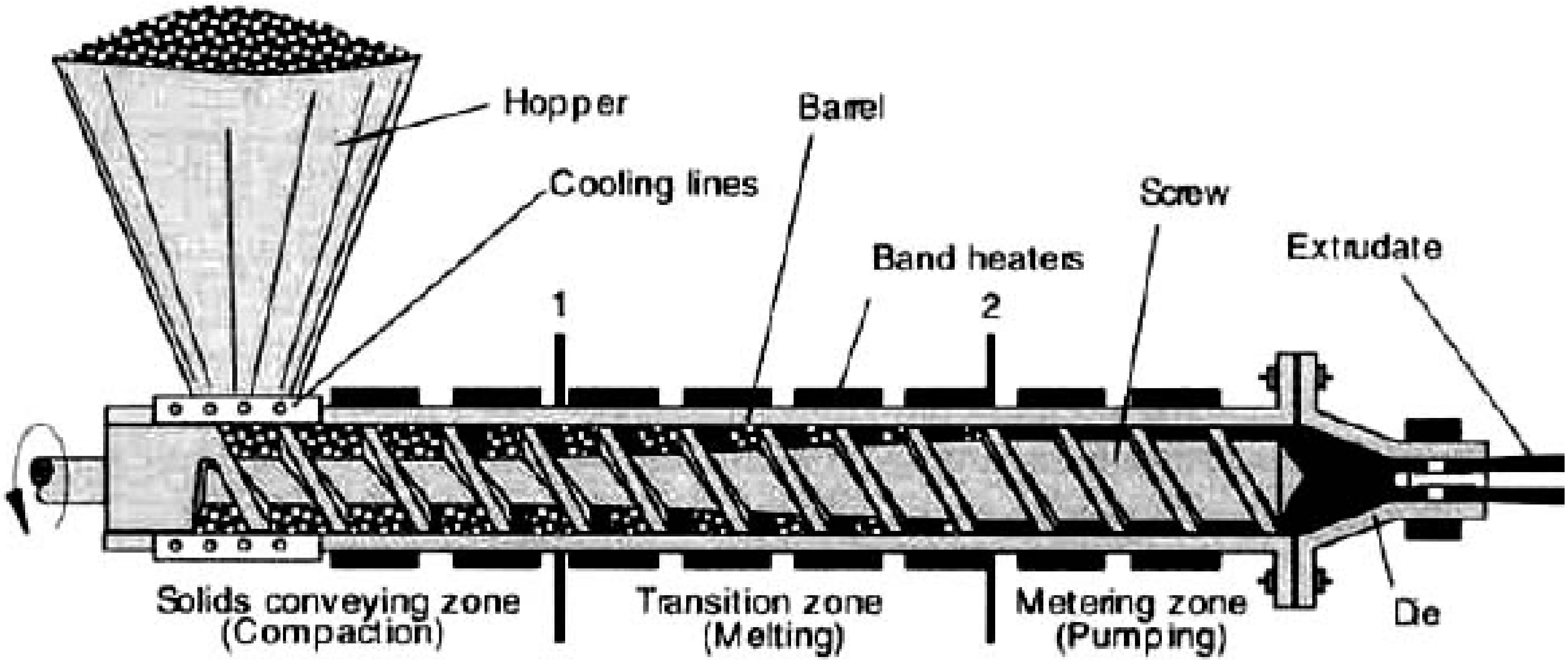
- ✓ Sheet Extrusion
- ✓ Profile Extrusion e.g. Window Frames
- ✓ Pipe/ Tubes extrusion
- ✓ Co-extrusion
- ✓ Blown Film Extrusion
- ✓ Cast Film Extrusion
- ✓ Foam Extrusion
- ✓ Pultrusion
- ✓ Calendering
- ✓ Insulated Wires
- ✓ Fibers

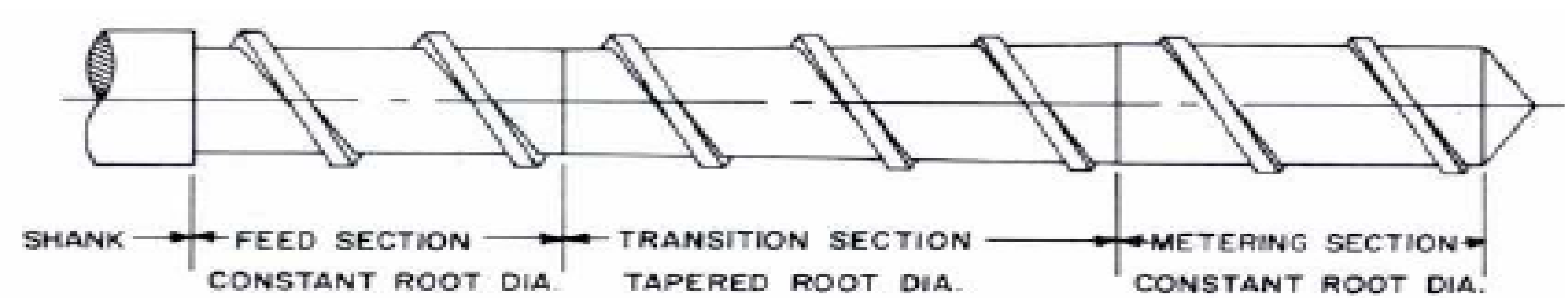
Extrusion



Powder or granules
Heater bands
Die
Feed hopper
Extrudate
Variable speed drive
Filter plate
Rotating screw

Extrusion


Hopper
Barrel
Cooling lines
Screw
Band heaters
Extrudate
1
2
Solids conveying zone
(Compaction)
Transition zone
(Melting)
Metering zone
(Pumping)
Die


SHANK
FEED SECTION
CONSTANT ROOT DIA.
TRANSITION SECTION
TAPERED ROOT DIA.
METERING SECTION
CONSTANT ROOT DIA.

Feed Zone

The function of this zone is to preheat the plastic and convey it to the subsequent zones. The design of this section is important since the constant screw depth must supply sufficient material to the metering zone so as not to starve it, but on the other hand not supply so much material that the metering zone is overrun. The optimum design is related to the nature and shape of the feedstock, the geometry of the screw and the frictional properties of the screw and barrel in relation to the plastic.

Compression Zone

In this zone the screw depth gradually decreases so as to compact the plastic. This compaction has the dual role of squeezing any trapped air pockets back into the feed zone and improving the heat transfer through the reduced thickness of material.

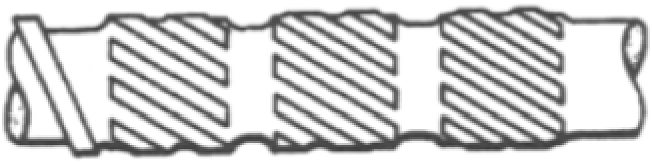
Metering zone

In this section the screw depth is again constant but much less than the feed zone. In the metering zone the melt is homogenised so as to supply at a constant rate, material of uniform temperature and pressure to the die.

ADDITIONAL ZONES

Mixing Zone

consisting of screw flights of reduced or reversed pitch. The purpose of this zone is to ensure uniformity of the melt and it is sited in the metering section.

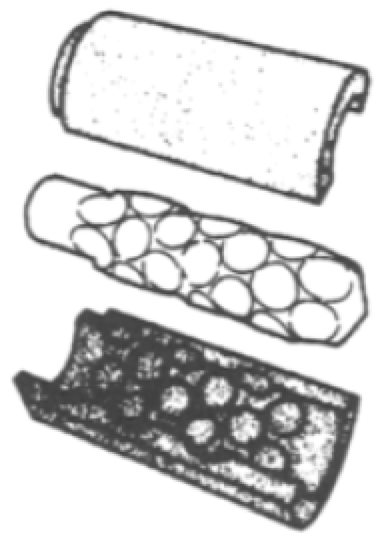


Parallel interrupted mixing flights

Undercut spiral barrier-type

Ring-type barrier mixer

Mixing pins



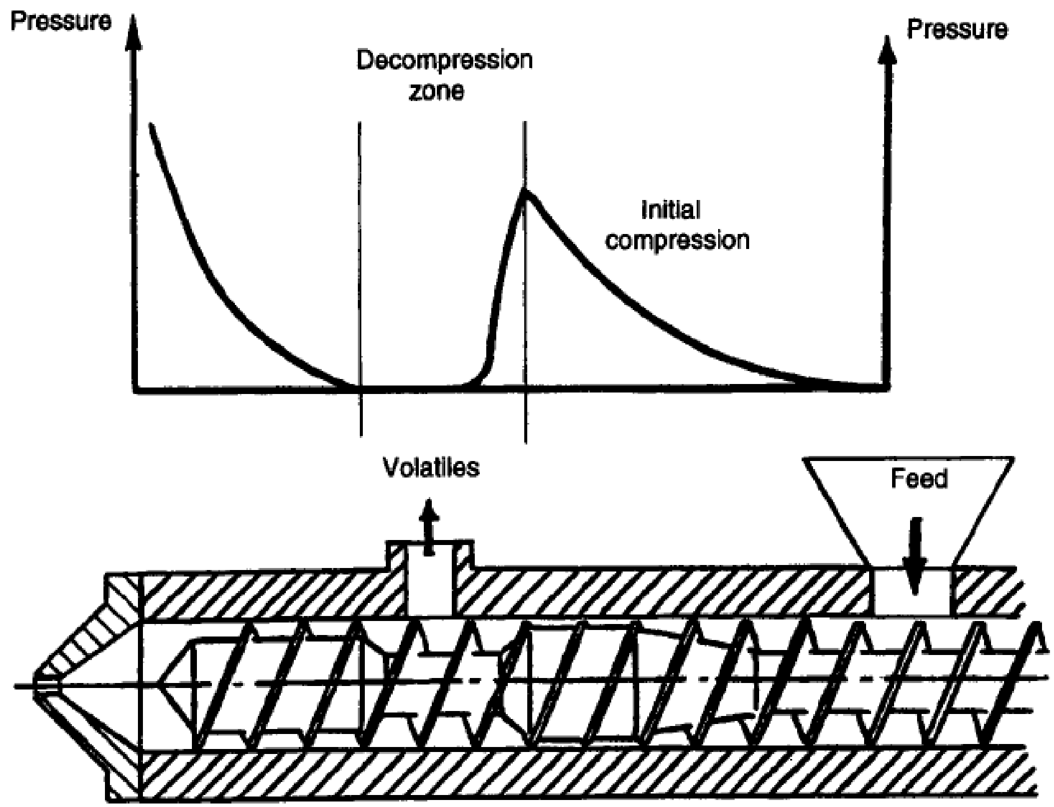
RAPRA cavity transfer mixer

ADDITIONAL ZONES

Venting Zone

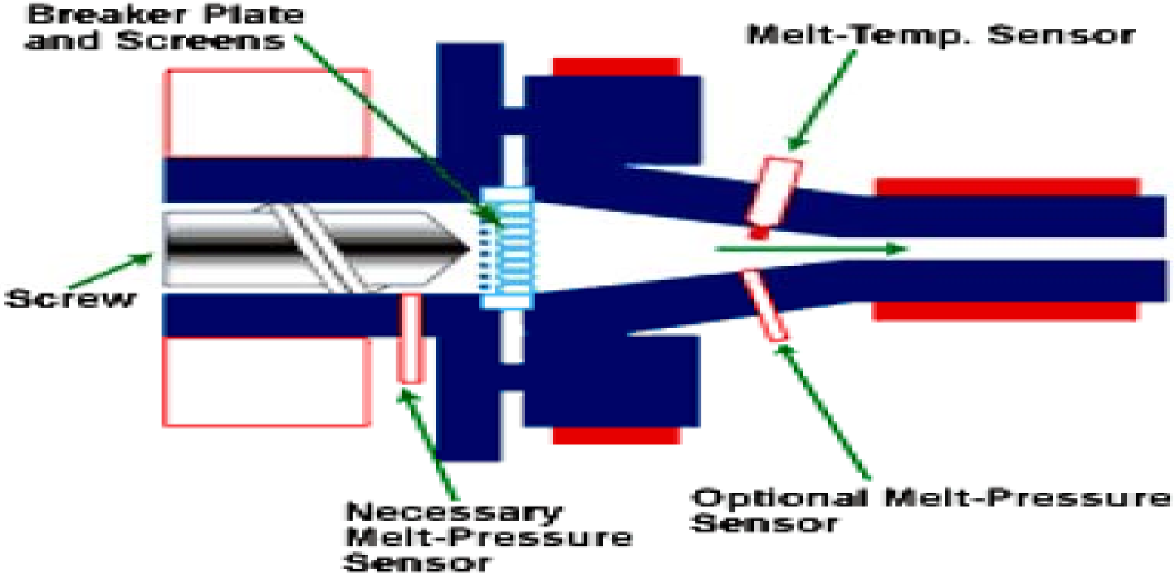
Specially for hygroscopic polymers

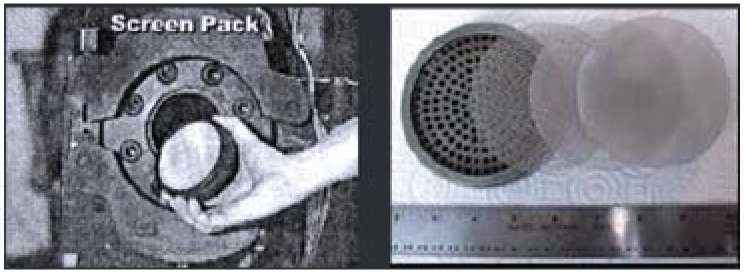
in the first part of the screw the granules are taken in and melted, compressed and homogenised in the usual way. The melt pressure is then reduced to atmospheric pressure in the decompression zone. This allows the volatiles to escape from the melt through a special port in the barrel. The melt is then conveyed along the barrel to a second compression zone which prevents air pockets from being trapped.



Zones on a vented extruder

Breaker Plate & Screen Packs





filters out any inhomogeneous material which might otherwise clog the die. These *screen packs as they are called, will* normally filter the melt to 120-150 µm.

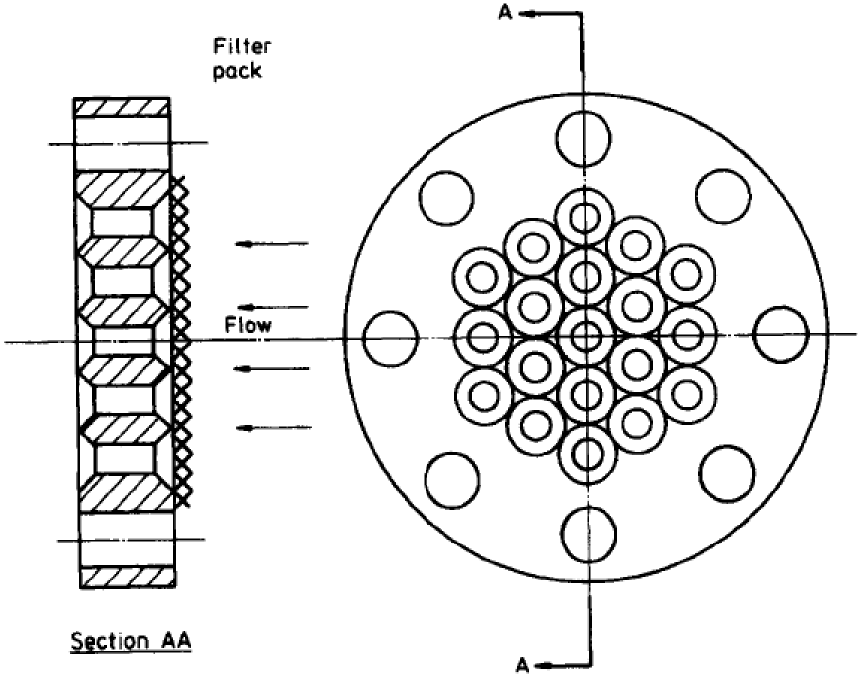
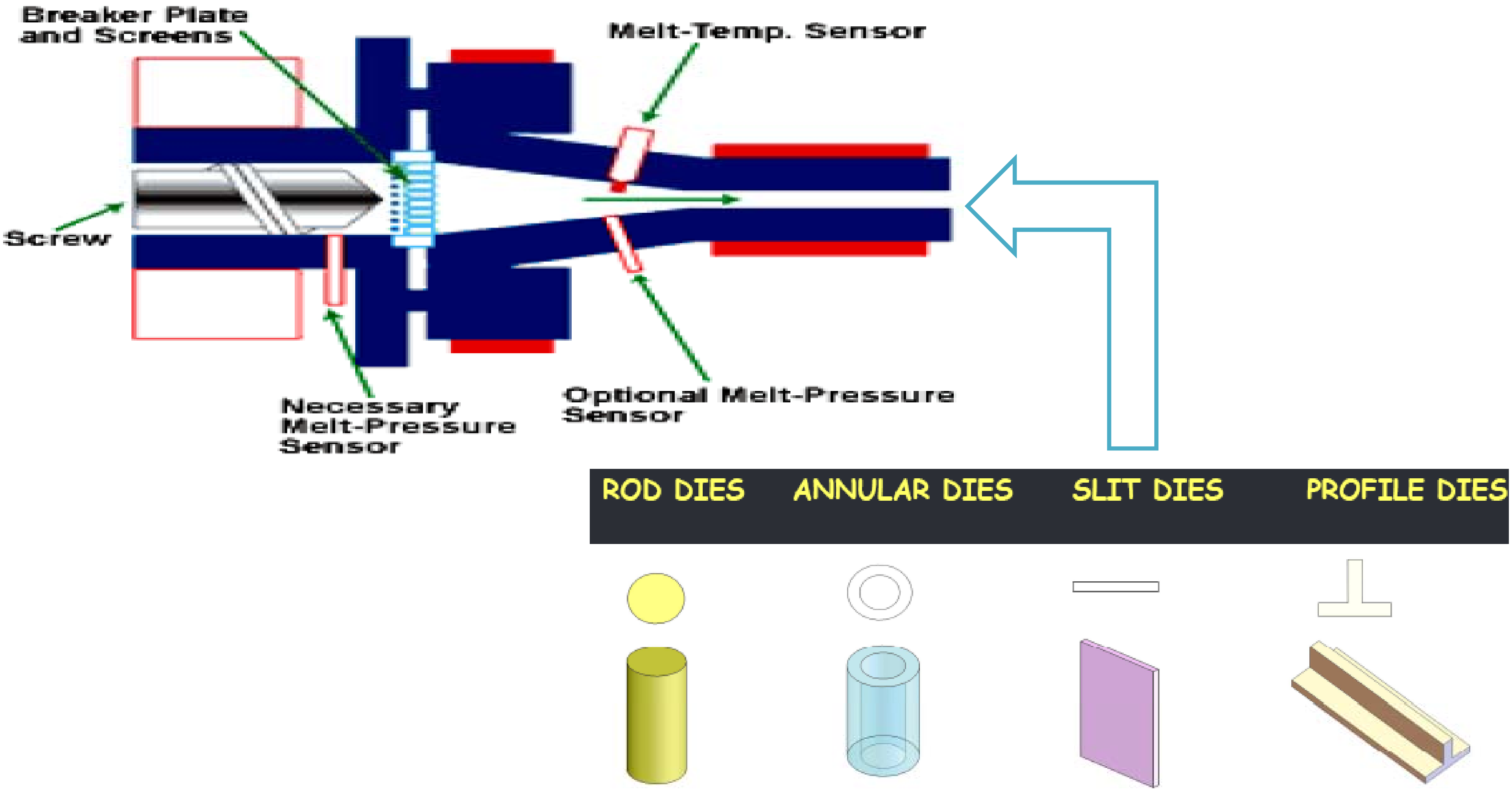


Fig. 4.6 Breaker plate with filter pack

Dies


Breaker Plate
and Screens
Melt-Temp. Sensor
Screw
Necessary
Melt-Pressure
Sensor
Optional Melt-Pressure
Sensor
ROD DIES
ANNULAR DIES
SLIT DIES
PROFILE DIES

Extruder Types

- Single screw
  - Most common
  - A screw rotates in a cylinder and creates a pumping action.
- Twin Screw
  - Twin screws have more positive pumping action than single screws and can be used for higher output.
  - Co-Rotating Twin Screw: popular for compounding
  - Counter- rotating Twin Screw Extruders

These machines permit a wider range of possibilities in terms of output rates, mixing efficiency, heat generation, etc compared with a single screw extruder.

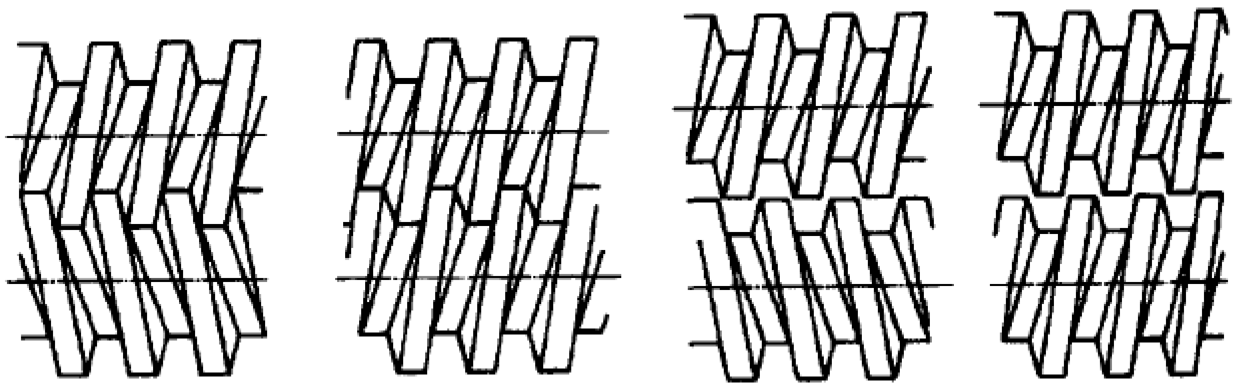
The output can be typically three times that of a single screw extruder of the same diameter and speed.

TYPES

a) counter-rotating b) co-rotating screws.

In addition the screws may be

a) Intermeshing b) Non-intermeshing

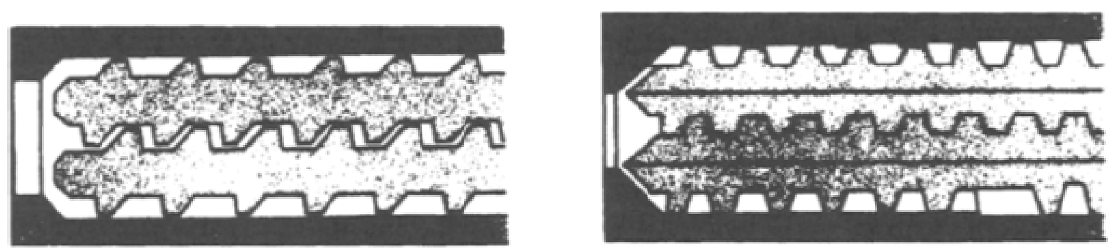


(a) Counter-rotating (intermeshing) (b) Co-rotating (intermeshing) (c) Counter-rotating (non-intermeshing) (d) Co-rotating (non-intermeshing)

It may also be

a) Conjugated

b) b) Non-conjugated



(a) Non-conjugated screws showing some passages around each screw (b) Conjugated screws showing closed passages around each screw

Comparison of single-screw, co-rotating and counter-rotating twin-screw extruders

Type	Single screw	Co-rotating screw: Low speed type	Co-rotating screw: High speed type	Counter-rotating twin screw
Principle	Friction between cylinder and materials and the same between material and screw	Mainly depend on the frictional action as in the case of single screw extruder		Forced mechanical conveyance based on gear pump principle
Conveying efficiency	Low	Medium		High
Mixing efficiency	Low	Medium/High		High
Shearing action	High	Medium	High	Low
Self-cleaning effect	Slight	Medium/High	High	Low
Energy efficiency	Low	Medium/High		High
Heat generation	High	Medium	High	Low
Temp distribution	Wide	Medium	Narrow	Narrow

GRANULES MANUFACTURING

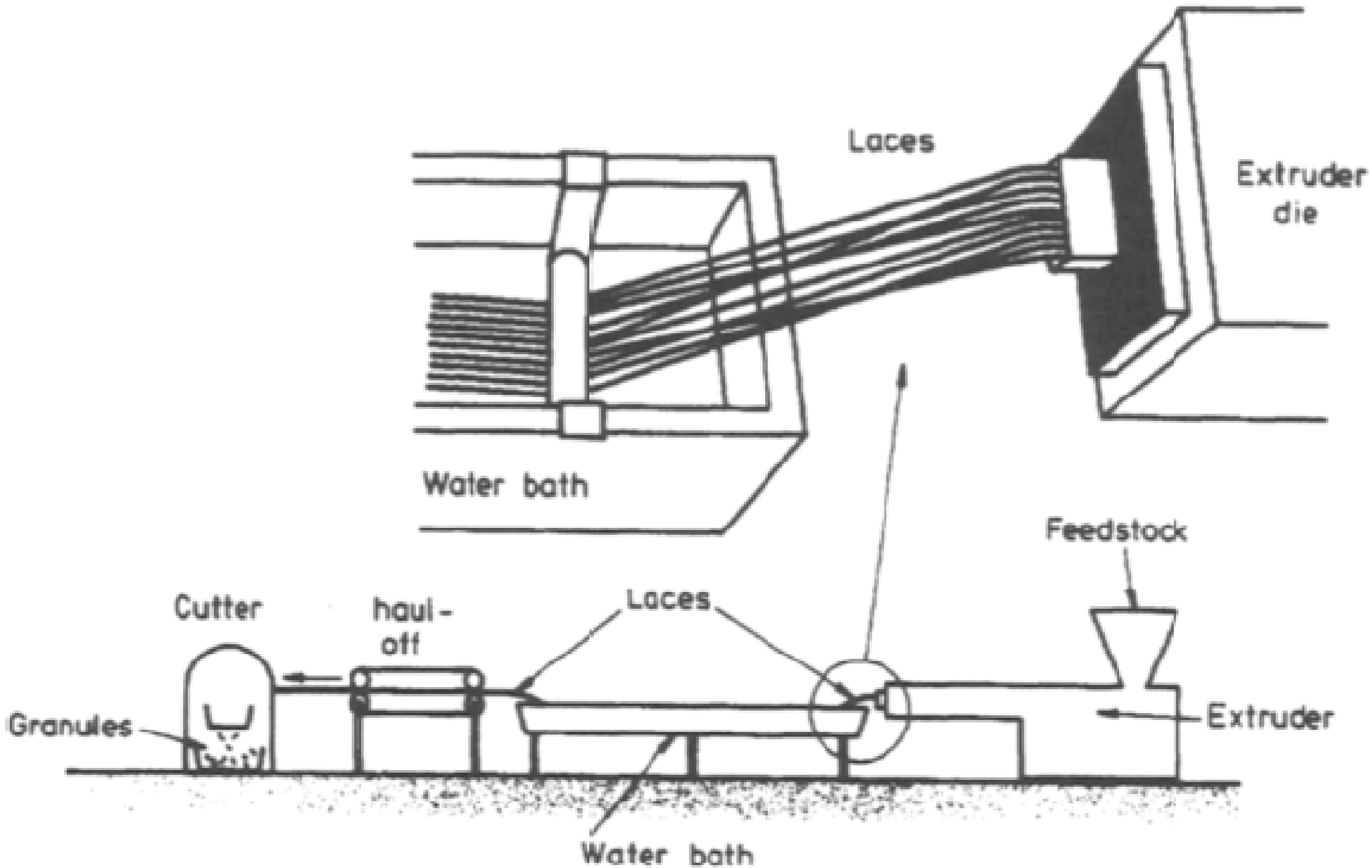
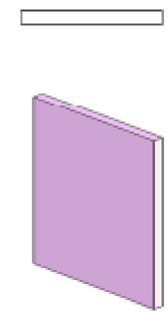


Fig. 4.17 Use of extruder to produce granules

SHEET MANUFACTURING

SLIT DIES



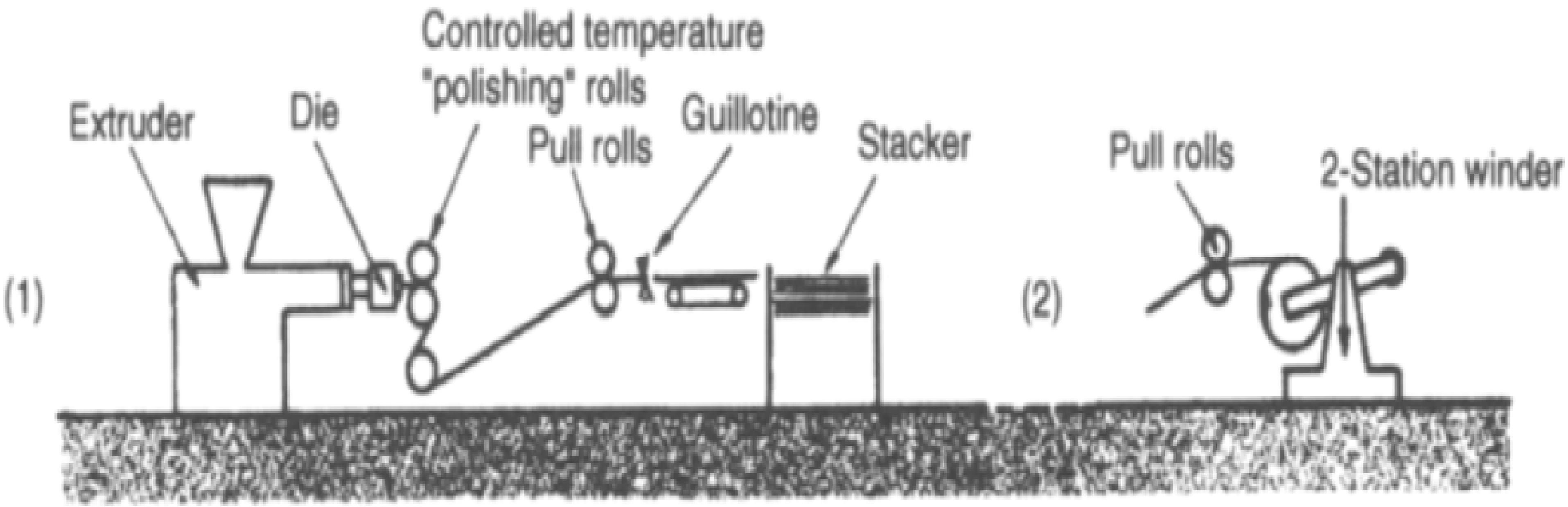
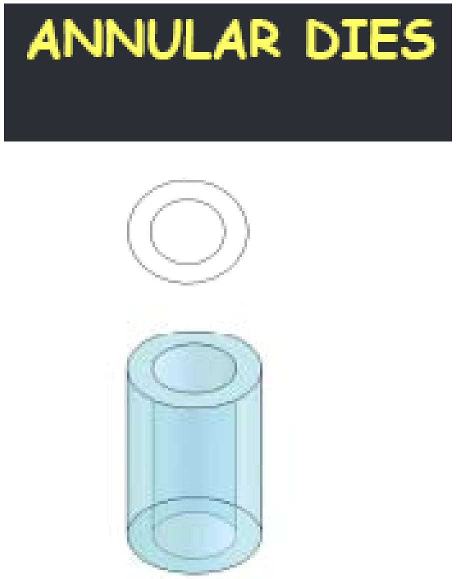


Fig. 4.19(a) Sheet extrusion (1) thick sheet (2) thin sheet

PIPE MANUFACTURING



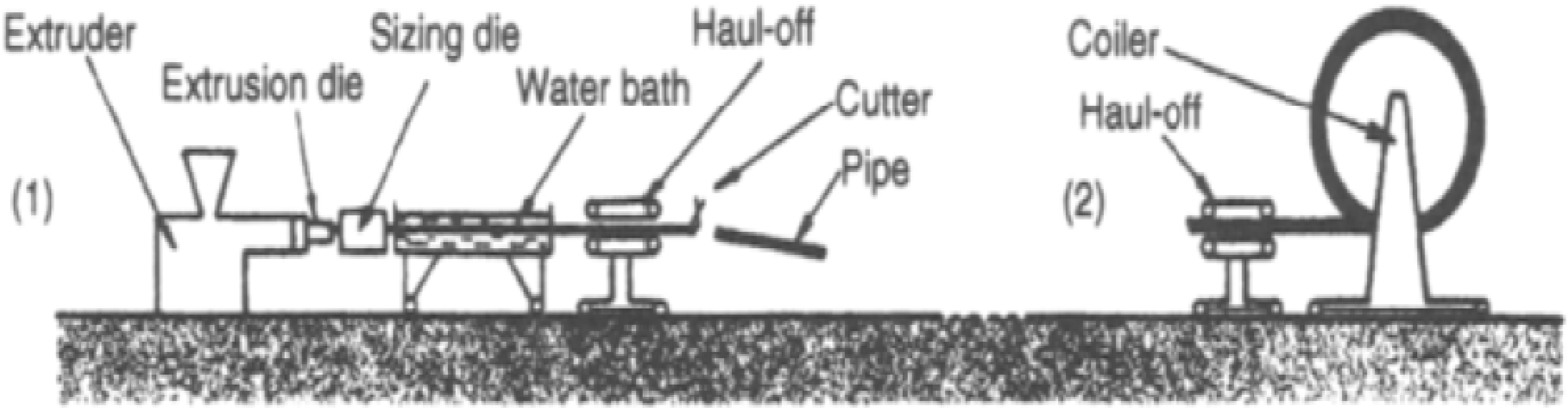
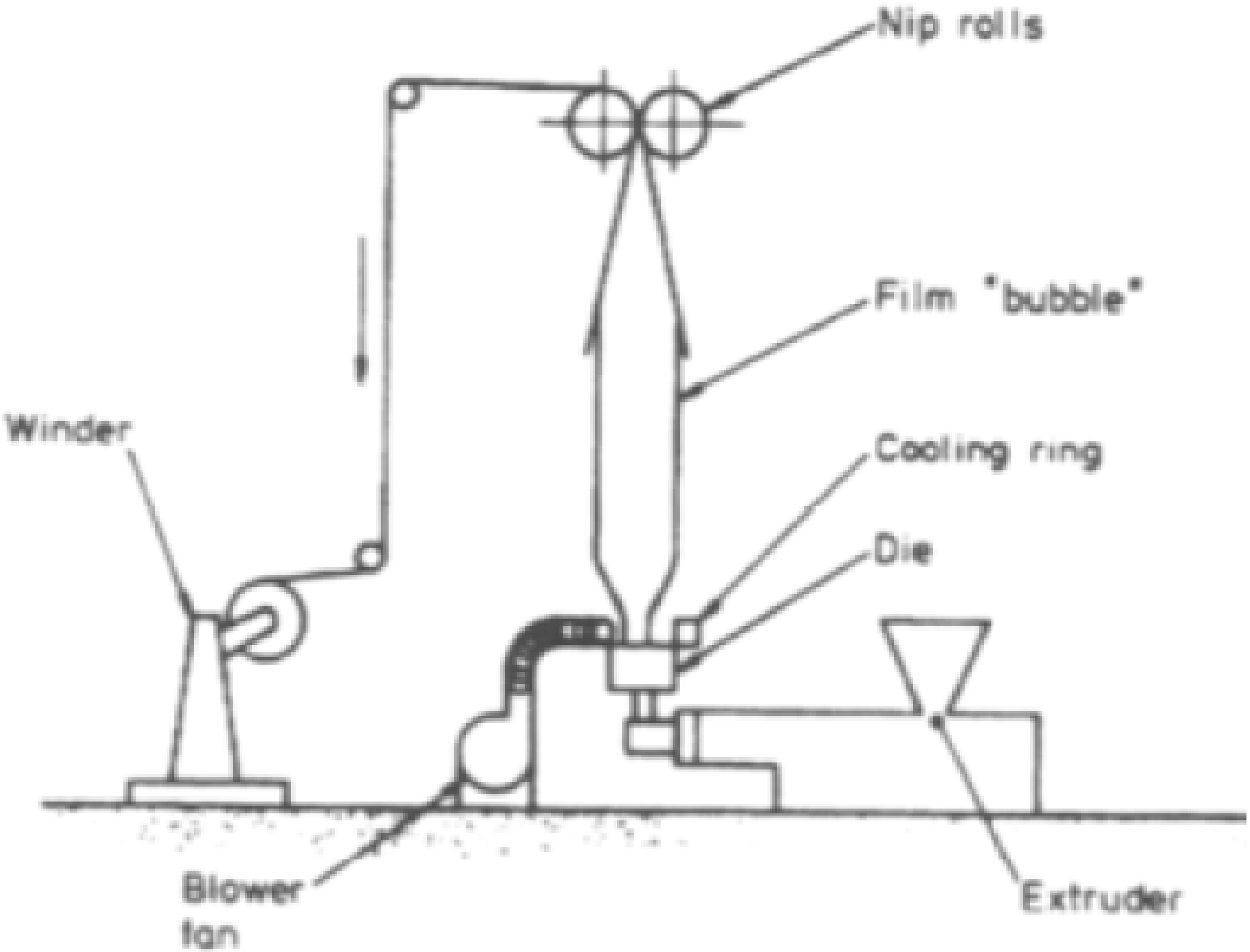
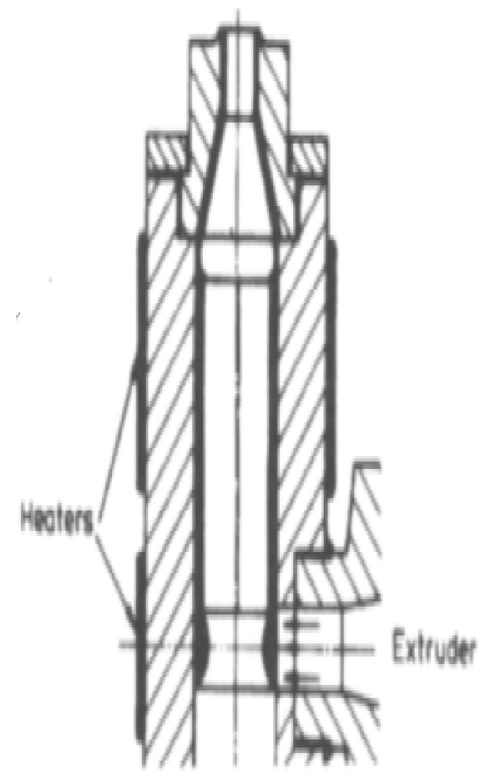


Fig. 4.19(b) Pipe extrusion (1) rigid pipe (2) flexible pipe

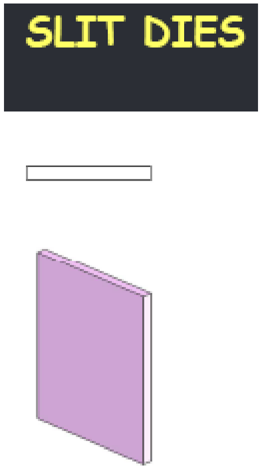
FILM MANUFACTURING



ANNULAR DIES



EXTRUSION COATING



A plastic coating on to paper or metal sheets and the extruder provides an ideal way of doing this. Normally a thin film of plastic is extruded from a slit die and is immediately brought into contact with the medium to be coated. The composite is then passed between rollers to ensure proper adhesion at the interface and to control the thickness of the coating

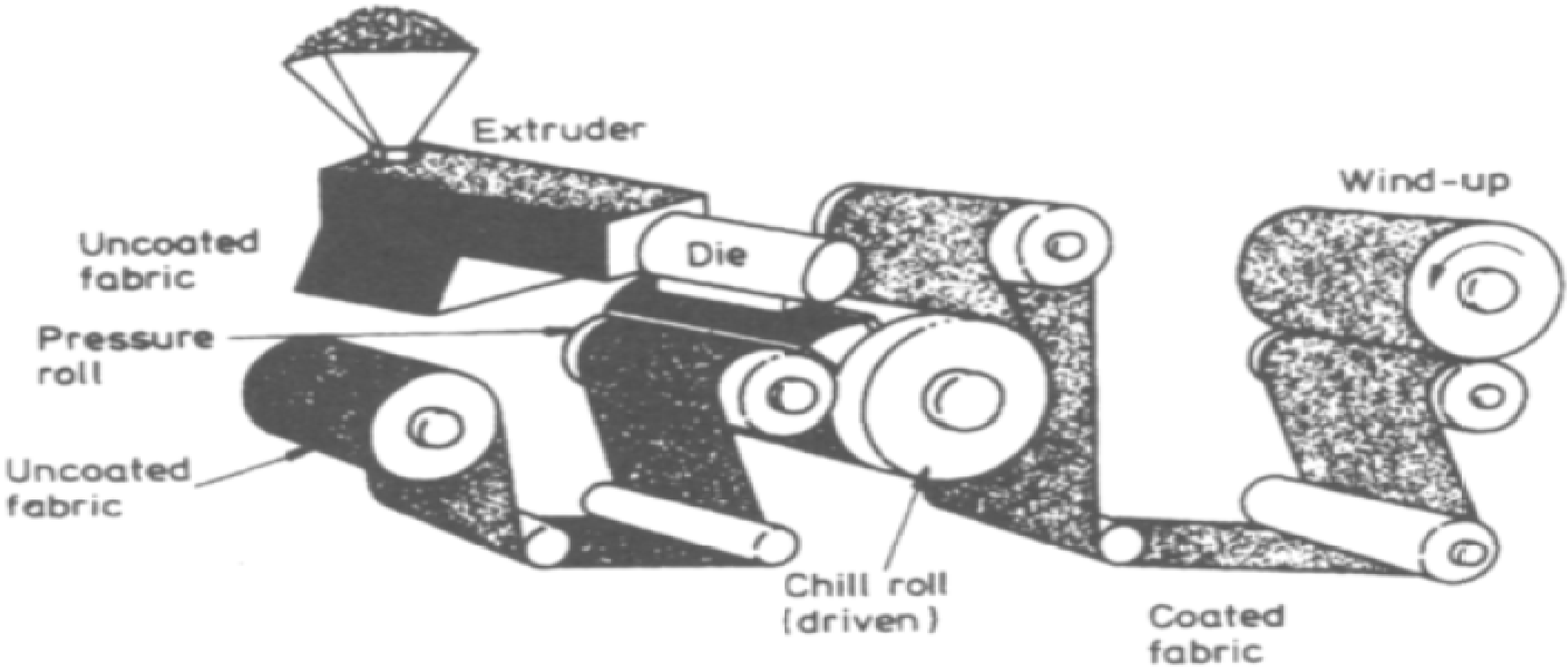


Fig. 4.26 Extrusion coating process

WIRE COATING PROCESS

ROD DIES

for insulated cables in the electrical industry

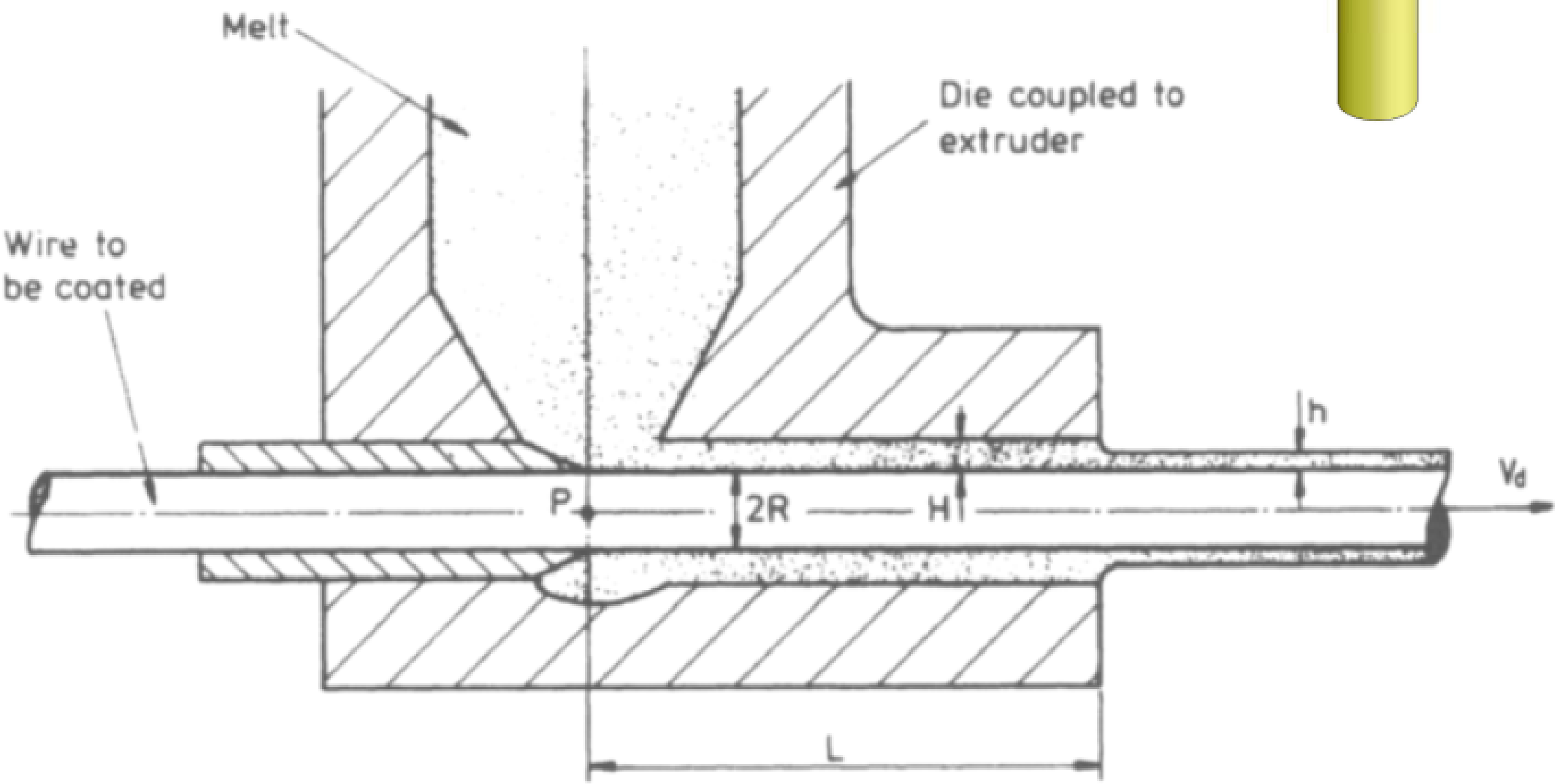
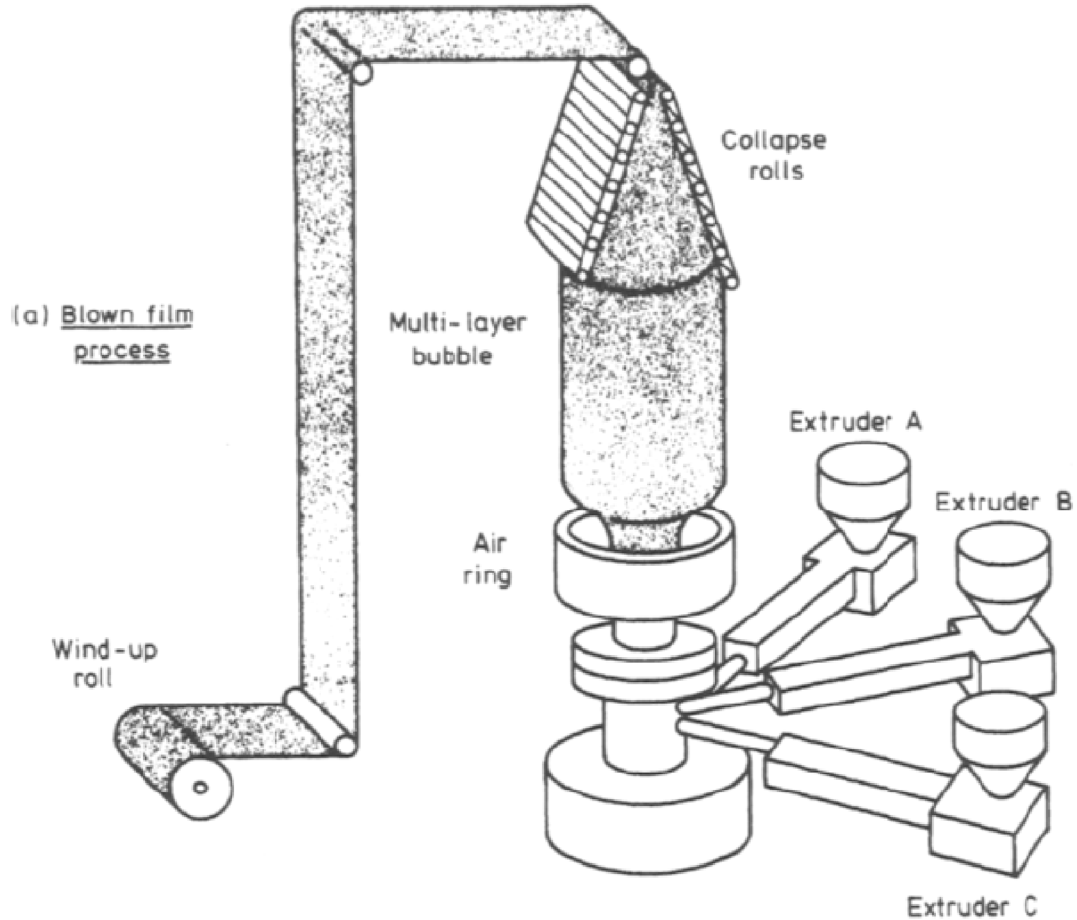


Fig. 4.27 Wire Covering Die

CO-EXTRUSION PROCESS

in many cases there is no individual plastic which has the correct combination of properties to satisfy a particular need. Therefore it is becoming very common in the manufacture of articles such as packaging film, yoghurt containers, refrigerator liners, gaskets and window frames that a multi-layer plastic composite will be used. This is particularly true for extruded film and thermoforming sheets.

In co-extrusion two or more polymers are combined in a single process to produce a multilayer film. These co-extruded films can either be produced by a blown film or a cast film process



The cast process using a slit die and chill roll to cool the film, produces a film with good clarity and high gloss. The film blowing process, however, produces a stronger film due to the transverse orientation which can be introduced and this process offers more flexibility in terms of film thickness.

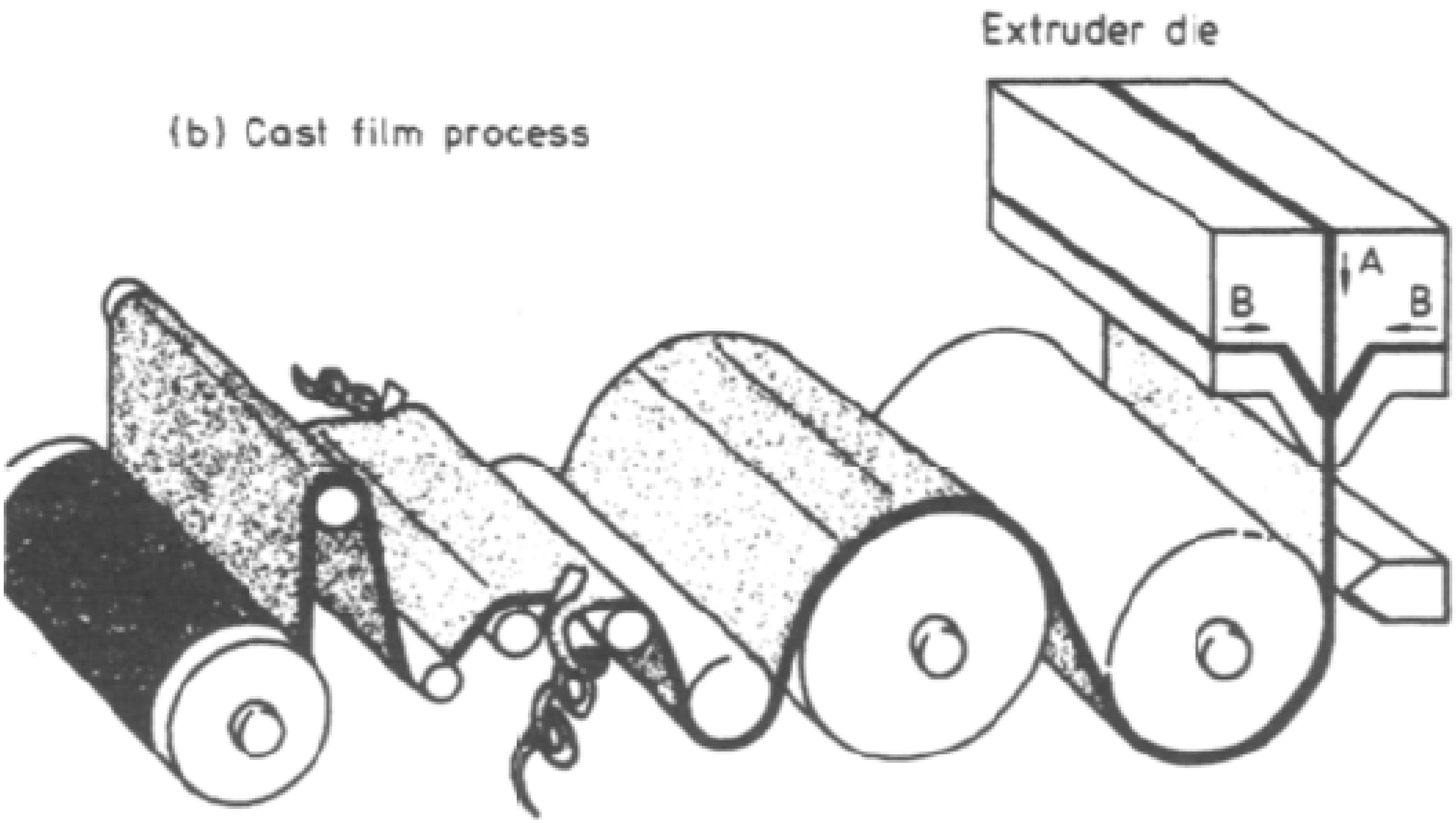
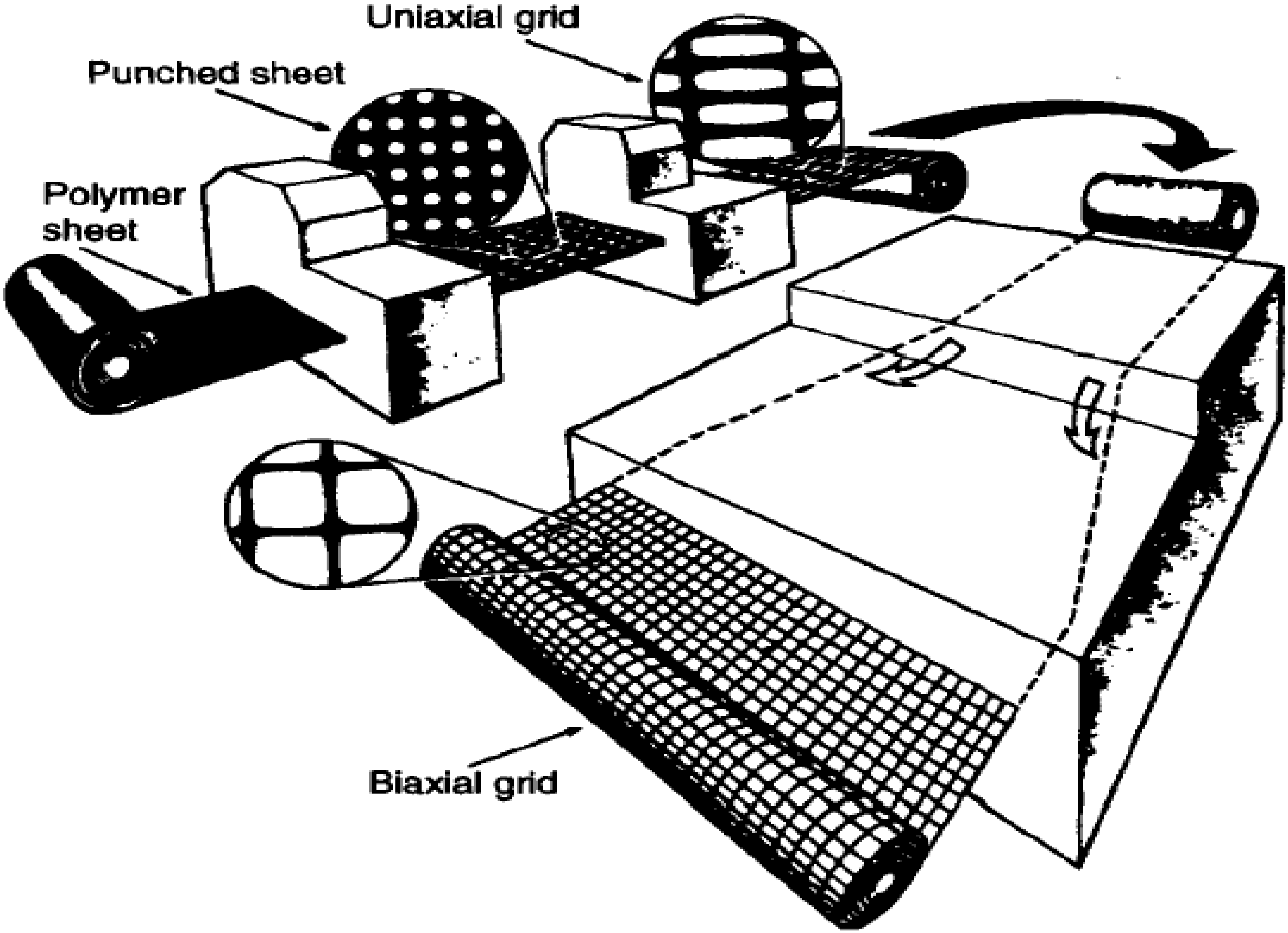
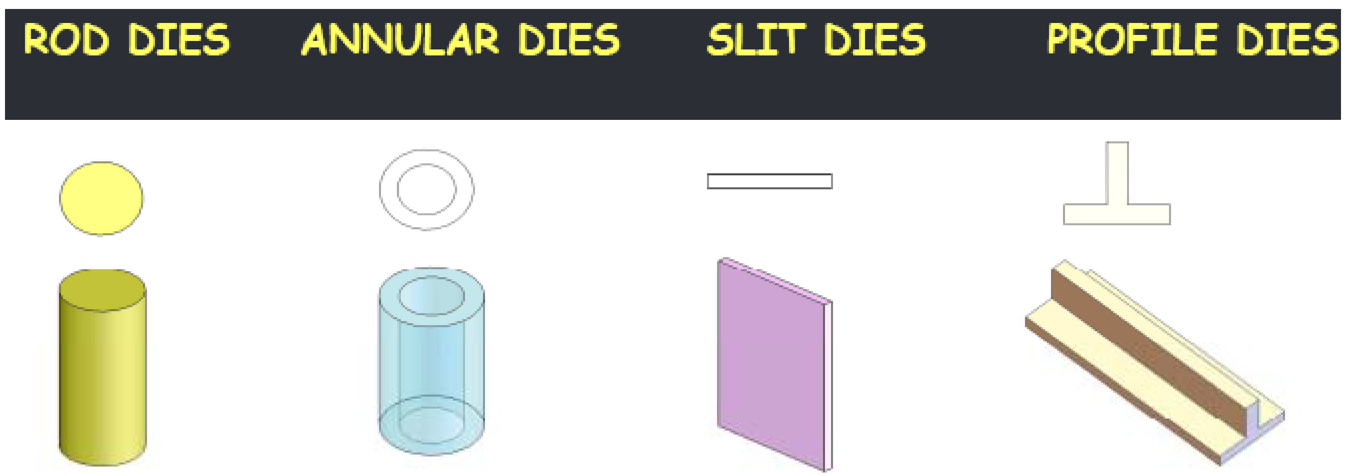


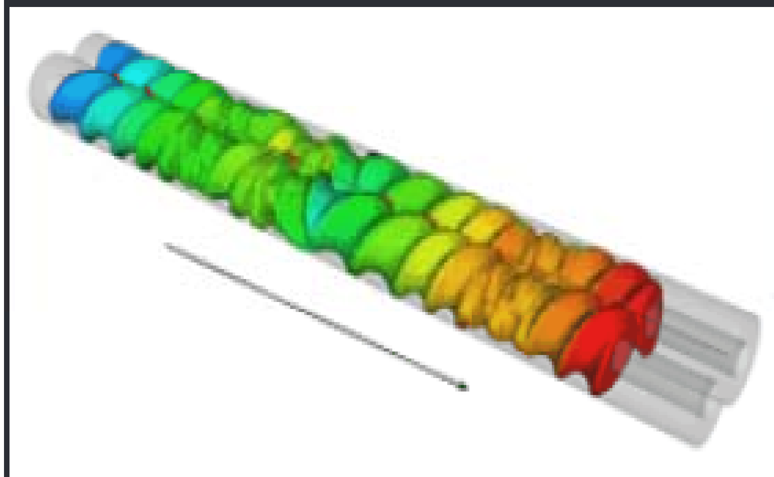
Fig. 4.28 Co-extrusion of plastic film

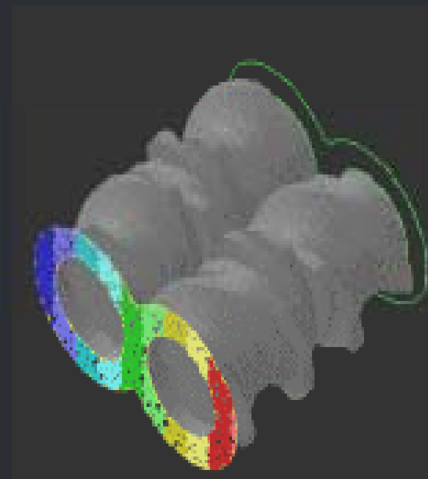
UNI-AXIAL & BI-AXIAL ORIENTATION PROCESS

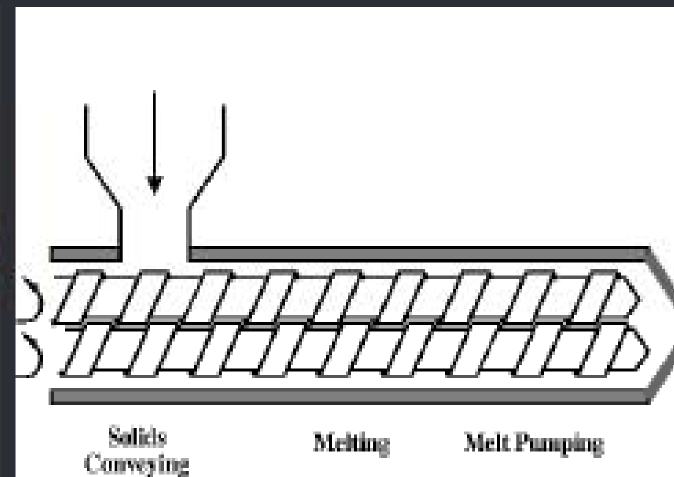



ROD DIES
ANNULAR DIES
SLIT DIES
PROFILE DIES

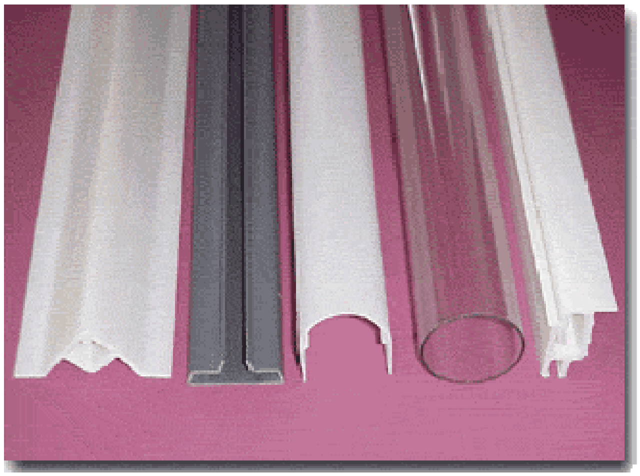
(TWIN SCREW EXTRUDER)

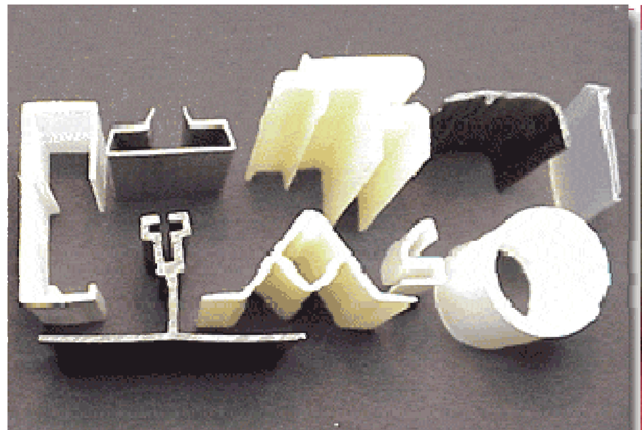


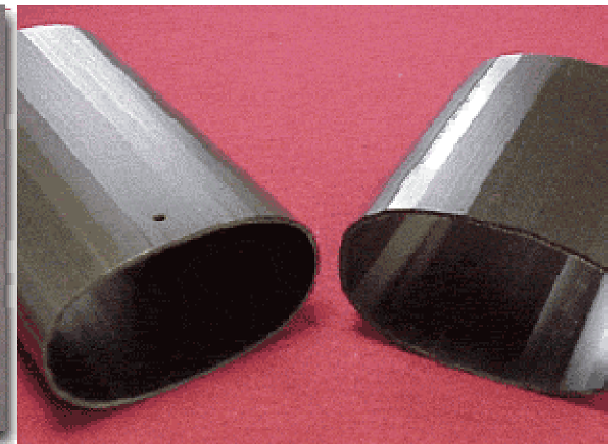


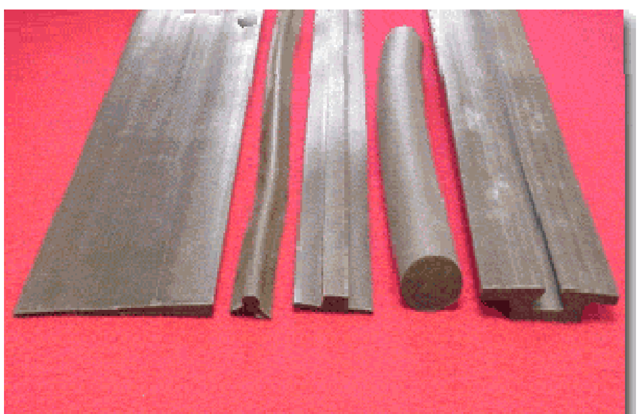


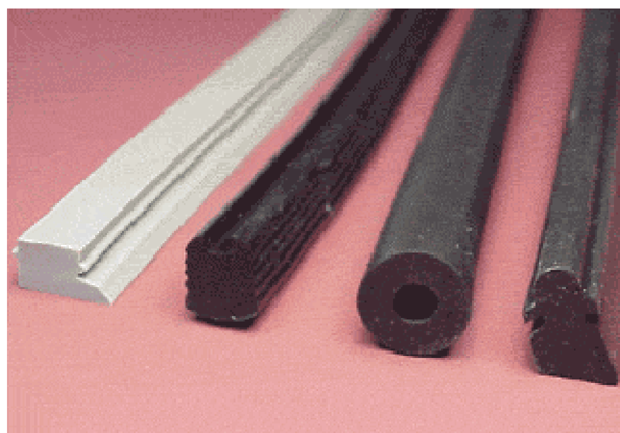
Extrusion Product Examples

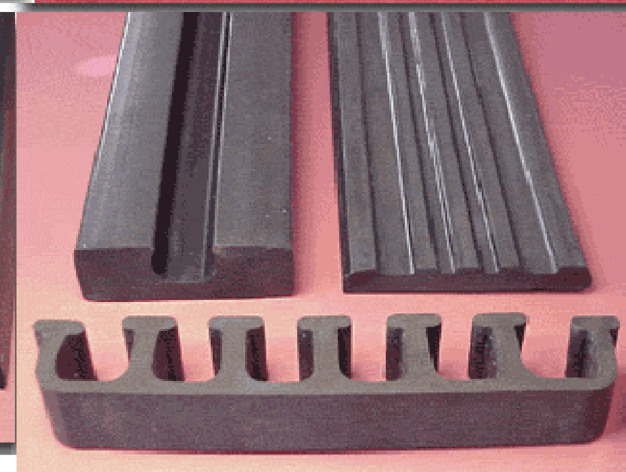












Calendering

Calendering is a method of producing plastic film and sheet by squeezing the plastic through the gap (or 'nip') between two counter-rotating cylinders. The art of forming a sheet in this way can be traced to the paper, textile and metal industries. The first development of the technique for polymeric materials was in the middle 19th century when it was used for mixing additives into rubber.

The subsequent application to plastics was not a complete success because the early machines did not have sufficient accuracy or control over such things as cylinder temperature and the gap between the rolls. Therefore acceptance of the technique as a viable production method was slow until the 1930s when special equipment was developed specifically for the new plastic materials. As well as being able to maintain accurately roll temperature in the region of 200°C these new machines had power assisted nip adjustment and the facility to adjust the rotational speed of each roll independently. These developments are still the main features of modem calendering equipment.

Calenders vary in respect of the number of rolls and of the arrangement of the rolls relative to one another. One typical arrangement is shown in Fig. 4.57- the inverted L-type. Although the calendering operation as illustrated here looks very straightforward it is not quite as simple as that. In the production plant a lot of ancillary equipment is needed in order to prepare the plastic material for the calender rolls and to handle the sheet after the calendaring operation. A typical sheet production unit would start with premixing of the polymer, plasticiser, pigment, etc in a ribbon mixer followed by gelation of the premix in a Banbury Mixer and/or a short screw extruder. At various stages, strainers and metal detectors are used to remove any foreign matter.

These preliminary operations result in a material with a dough-like consistency which is then supplied to the calender rolls for shaping into sheets.

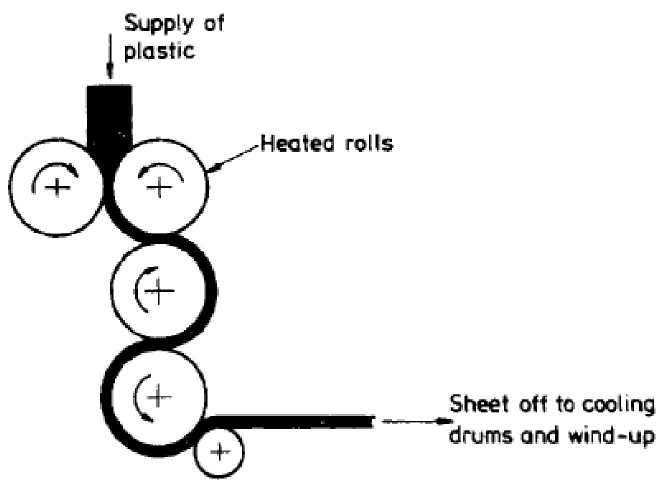


Fig. 4.57 Typical arrangement of calender rolls

However, even then the process is not complete. Since the hot plastic tends to cling to the calender rolls it is necessary to peel it off using a high speed roll of smaller diameter located as shown in Fig. 4.57. When the sheet leaves the calender it passes between embossing rolls and then on to cooling drums before being trimmed and stored on drums. For thin sheets the speed of the winding drum can be adjusted to control the drawdown. Outputs vary in the range 0.1-2 m/s depending on the sheet thickness. Calendering can achieve surprising accuracy on the thickness of a sheet.

Typically the tolerance is 4-0.005 mm but to achieve this it is essential to have very close control over roll temperatures, speeds and proximity. In addition, the dimensions of the rolls must be very precise. The production of the rolls is akin to the manufacture of an injection moulding tool in the sense that very high machining skills are required. The particular features of a calender roll are a uniform specified surface finish, minimal eccentricity and a special barrel profile ('crown') to compensate for roll deflection under the very high pressures developed between the rolls.

Since calendering is a method of producing sheet/film it must be considered to be in direct competition with extrusion based processes. In general, film blowing and die extrusion methods are preferred for materials such as polyethylene, polypropylene and polystyrene but calendering has the major advantage of causing very little thermal degradation and so it is widely used for heat sensitive materials such as PVC.

Material Specifications

The best polymers for calendering are thermoplastics. One reason for this is because they soften at a temperatures much lower than their melting temperature, giving a wide range of working temperatures. They also adhere well to the rollers, allowing them to continue through the chain well, but they don't adhere too well and get stuck on the roller. The last reason is that thermoplastic melts have a fairly low viscosity, but they are still strong enough to hold together and not run all over the place. Heat sensitive materials are also great for calenders because calenders put immense pressures on the materials to work them and therefore do not need as high of temperatures to process them limiting the chances of thermal degradation. This is why calendering is often the method of choice for processing PVC. Due to the nature of the process the polymers must have a shear and thermal history that is consistent across the width of the sheet.

Advantages

The best quality sheets of plastic today are produced by calenders; in fact, the only process that competes with the calender in sheet forming is extruding. The calender also is very good at handling polymers that are heat sensitive as it causes very little thermal degradation. Another advantage to calendering is that it is good at mixing polymers that contain high amounts of solid additives that don't get blended or fluxed in very well. This is true because compared to extrusion the calender produces a large rate of melt for the amount of mechanical energy that is put in. Due to this companies are able to add more filler product to their plastics and save money on raw materials. Calenders are very versatile machines meaning that it is very easy to change settings like the size of the roller gap.

Disadvantages

Although the calendering process produces a better product than the extruding process there are a couple of disadvantages. One disadvantage is that the process is more expensive to perform which is a major deterrent for many companies. The calendering process also is not as good at too high of gauges or too low of gauges. If the thickness is below 0.006 inches then there is a tendency for pinholes and voids to appear in the sheets[4]. If the thickness is greater than about 0.06 inches though there is a risk of air entrapment in the sheet[7]. Any desired thickness within that range though would turn out much better using a calender process.

Types

There are 3 main types of calender: the I type, L type and Z type

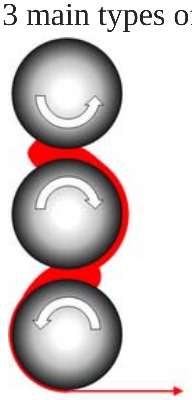


Fig 1: Roller setup in a typical 'I' type calender

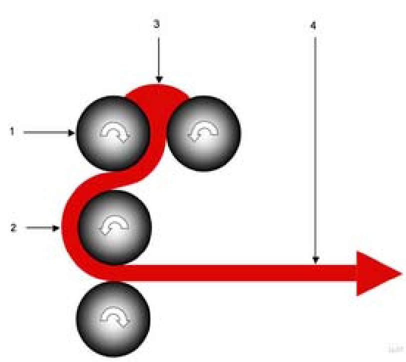


Fig 2: Roller setup in a typical inverted 'L' type calender

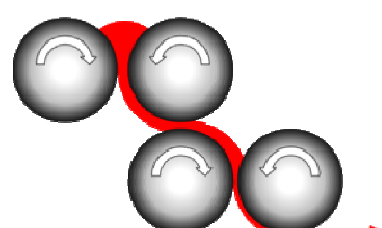


Fig 3: Roller setup in a typical 'Z' type calender

I Type

The I type, as seen in Figure 1, was for many years the standard calender used. It can also be built with one more roller in the stack. This design was not ideal though because at each nip there is an outward force that pushes the rollers away from the nip.

L Type

The L type is the same as seen in Figure 2 but mirrored vertically. Both these setups have become popular and because some rollers are at 90^o to others their roll separating forces have less effect on subsequent rollers. L type calenders are often used for processing rigid vinyls and inverted L type calenders are normally used for flexible vinyls.

Z Type

The Z-type calender places each pair of rollers at right angles to the next pair in the chain. This means that the roll separating forces that are on each roller individually will not effect any other rollers. Another feature of the Z-type calender is that is that they lose less heat in the sheet because as can be seen in Figure 3 the sheet travels only a quarter of the roller circumference to get between rollers. Most other types this is about half the circumference of the roller.

Analysis of Calendering

A detailed analysis of the flow of molten plastic between two rotating rolls is very complex but fortunately sufficient accuracy for many purposes can be achieved by using a simple Newtonian model. The assumptions made are that

(a) the flow is steady and laminar

(b) the flow is isothermal

(c) the fluid is incompressible

(d) there is no slip between the fluid and the rolls.

If the clearance between the rolls is small in relation to their radius then at any section x the problem may be analysed as the flow between parallel plates at a distance h apart. The velocity profile at any section is thus made up of a drag flow component and a pressure flow component.

For a fluid between two parallel plates, each moving at a velocity V_d, the drag flow velocity is equal to V_d. In the case of a calender with rolls of radius, R, rotating at a speed, N, the drag velocity will thus be given by $2\pi RN$.

The velocity component due to pressure flow between two parallel plates has already been determined in Section 4.2.3(b).

$$V_p = \frac{1}{2\eta}\frac{dP}{dx}(y^2 - (h/2)^2)$$

Therefore the total velocity at any section is given by

$$V = V_d + \frac{1}{2\eta}\frac{dP}{dx}[y^2 - (h/2)^2]$$

Considering unit width of the calender rolls the total throughput, Q, is given by

$$Q = 2\int_0^{h/2} V\,dy \quad \text{w}$$

$$= 2\int_0^{h/2} \left[V_d + \frac{1}{2\eta}\frac{dP}{dx}(y^2 - (h/2)^2)\right] dy \quad \text{w}$$

$$= h\left(V_d - \frac{h^2}{12\eta}\frac{dP}{dx}\right) \quad \text{w} \qquad (4.34)$$

Since the output is given by *VwdH, t*hen

$$V_d H = h\left(V_d - \frac{h^2}{12\eta}\frac{dP}{dx}\right) \qquad (4.35)$$

From this it may be seen that

$$\frac{dP}{dx} = 0 \text{ at } h = H.$$

To determine the shape of the pressure profile it is necessary to express h as a function of x. From the equation of a circle it may be seen that

$$h = H_0 + 2(R - (R^2 - x^2)^{1/2}) \qquad (4.36)$$

However, in the analysis of calendering this equation is found to be difficult to work with and a useful approximation is obtained by expanding $(R^2 - x^2)^{1/2}$ using the binomial series and retaining only the first two terms. This gives

$$h = H_0\left(1 + \frac{x^2}{H_0 R}\right) \qquad (4.37)$$

Substituting the value of *h*, we get the pressure profile as a function of direction *x* as

$$\frac{dP}{dx} = \frac{12\eta V_d\left(H_0 - H + \frac{x^2}{R}\right)}{\left(H_0 + \frac{x^2}{R}\right)^3} \qquad (4.39)$$

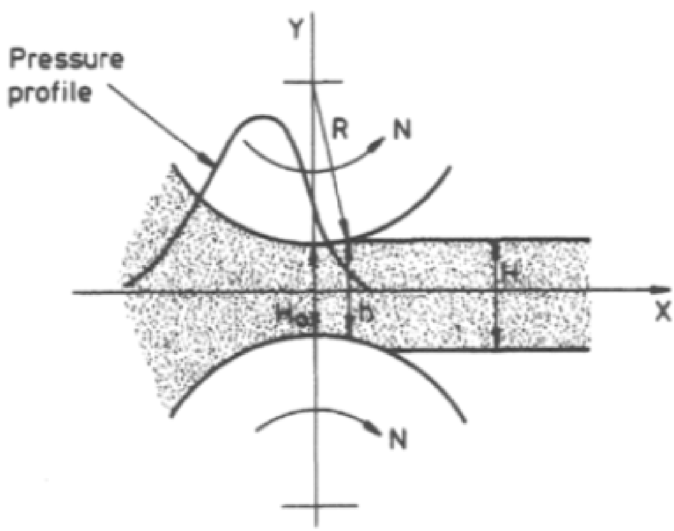


Fig. 4.58 Melt flow between calender rolls

For maximum or minimum pressure, *dP/dx* will be zero. Previously, it has been shown that at $h = H$, *dP/dx* is zero. Putting $h = H$ in equation 4.37, we get

$$H = H_0 \left(1 + \frac{x^2}{H_0 R}\right)$$

$$x = \pm\sqrt{(H - H_0)R'} \qquad (4.38)$$

If the equation 4.39 is integrated and the value of x from (4.38) substituted then the maximum pressure may be obtained as

$$P_{\max} = \frac{3\eta V_d}{H_0}\left(2\omega - \frac{(4H_0 - 3H)}{H_0}\left(\omega + \sqrt{\frac{R}{H_0}}\tan^{-1}\sqrt{\left(\frac{H - H_0}{H}\right)}\right)\right) \qquad (4.40)$$

Where

$$\omega = \frac{\sqrt{(H - H_0)R}}{H} \qquad (4.41)$$

Example 4.9 A calender having rolls of diameter 0.4 m produces plastic sheet 2 m wide at the rate of 1300 kg/hour. If the nip between rolls is 10 mm and the exit velocity of the sheet is 0.01 m/s, estimate the position and magnitude of the maximum pressure. The density of the material is 1400 kg/m^3 and its viscosity is 10^4 Ns/m^2.

Solution Flow rate, $Q = 1300$ kg/hour $= 0.258 \times 10^{-3}$ m^3/s

but $\quad Q = HWV_d$ where W = width of sheet

So $\quad H = \dfrac{0.258 \times 10^{-3}}{2 \times 0.01} = 12.9$ mm

The distance upstream of the nip at which the pressure is a maximum is given by equation (4.38)

$$x = \sqrt{(12.9 - 10)200} = 24.08 \text{ mm}$$

Also from (4.37)

$$P_{\max} = \frac{3 \times 10^4 \times 0.01}{10 \times 10^{-3}}\{(2 \times 1.865) - 0.13[1.865 + (4.45)(0.494)]\}$$

$$= 96 \text{ kN/m}^2$$

Blow Moulding

This process evolved originally from glass blowing technology. It was developed as a method for producing hollow plastic articles (such as bottles and barrels) and although this is still the largest application area for the process, nowadays a wide range of technical mouldings can also be made by this method e.g. rear spoilers on cars and videotape cassettes. There is also a number of variations on the original process but we will start by considering the conventional extrusion blow moulding process.

Extrusion Blow Moulding

Initially a molten tube of plastic called the *Parison* is extruded through an annular die. A mould then closes round the parison and a jet of gas inflates it to take up the shape of the mould. This is illustrated in Fig. 4.21(a). Although this process is principally used for the production of bottles (for washing up liquid, disinfectant, soft drinks, etc.) it is not restricted to small hollow articles. Domestic cold water storage tanks, large storage drums and 200 gallon containers have been blow-moulded. The main materials used are PVC,

polyethylene, polypropylene and PET.

The conventional extrusion blow moulding process may be continuous or intermittent. In the former method ~the extruder continuously supplies molten polymer through the annular die. In most cases the mould assembly moves relative to the die. When the mould has closed around the parison, a hot knife separates the latter from the extruder and the mould moves away for inflation, cooling and ejection of the moulding. Meanwhile the next parison will have been produced and this mould may move back to collect it or, in multi-mould systems, this would have been picked up by another mould. Alternatively in some machines the mould assembly is fixed and the required length of parison is cut off and transported to the mould by a robot arm.

In the intermittent processes, single or multiple parisons are extruded using a reciprocating screw or ram accumulator. In the former system the screw moves forward to extrude the parisons and then screws back to prepare the charge of molten plastic for the next shot. In the other system the screw extruder supplies a constant output to an accumulator. A ram then pushes melt from the accumulator to produce a parison as required.

Although it may appear straightforward, in fact the geometry of the parison is complex. In the first place its dimensions will be greater than those of the die due to the phenomenon of post extrusion swelling (see Chapter 5). Secondly there may be deformities (e.g. curtaining) due to flow defects. Thirdly, since most machines extrude the parison vertically downwards, during the delay between extrusion and inflation, the weight of the parison causes sagging or draw-down. This sagging limits the length of articles which can be produced from a free hanging parison. The complex combination of swelling and thinning makes it difficult to produce articles with a uniform wall thickness. This is particularly true when the cylindrical parison is inflated into an irregularly shaped mould because the uneven drawing causes additional thinning. In most cases therefore to blow mould successfully it is necessary to program the output

rate or die gap to produce a controlled non-uniform distribution of thickness in the parison which will give a uniform thickness in the inflated article.

During moulding, the inflation rate and pressure must be carefully selected so that the parison does not burst. Inflation of the parison is generally fast but the overall cycle time is dictated by the cooling of the melt when it touches the mould. Various methods have been tried in order to improve the cooling rate e.g. injection of liquid carbon dioxide, cold air or high pressure moist air. These usually provide a significant reduction in cycle times but since the cooling rate affects the mechanical properties and dimensional stability of the moulding it is necessary to try to optimise the cooling in terms of production rate and quality.

Extrusion blow moulding is continually developing to be capable of producing even more complex shapes. These include unsymmetrical geometries and double wall mouldings. In recent years there have also been considerable developments in the use of in-the-mould transfers. This technology enables lables to be attached to bottles and containers as they are being moulded. Fig. 4.22 illustrates three stages in the blow moulding of a complex container.

Analysis of Blow Moulding

As mentioned previously, when the molten plastic emerges from the die it swells due to the recovery of elastic deformations in the melt. It will be shown later that the following relationship applies:

$$B_{SH} = B_{ST}^2 \text{ (from Chapter 5)}$$

where B_{SH} = swelling of the thickness $(= h_1/h_d)$

B_{ST} = swelling of the diameter $(= D_1/D_d)$

therefore
$$\frac{h_1}{h_d} = \left(\frac{D_1}{D_d}\right)^2$$

$$h_1 = h_d(B_{ST})^2 \tag{4.17}$$

Now consider the situation where the parison is inflated to fill a cylindrical die of diameter, D,n. Assuming constancy of volume and neglecting draw-down effects, then from Fig. 4.23

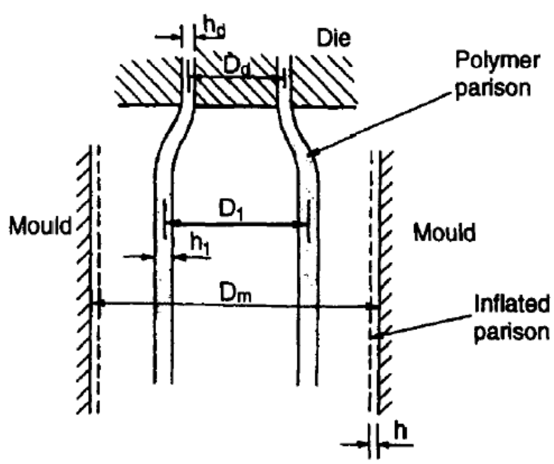


Fig. 4.23 Analysis of blow moulding

$$\pi D_1 h_1 = \pi D_m h$$

$$h = \frac{D_1}{D_m} h_1$$

$$= \frac{D_1}{D_m}(h_d \cdot B_{ST}^2)$$

$$= \frac{B_{ST} \cdot D_d}{D_m}(h_d \cdot B_{ST}^2)$$

$$h = B_{ST}^3 h_d \left(\frac{D_d}{D_m}\right)$$

This expression therefore enables the thickness of the moulded article to be calculated from a knowledge of the die dimensions, the swelling ratio and the mould diameter. The following example illustrates the use of this analysis. A further example on blow moulding may be found towards the end of Chapter 5 where there is also an example to illustrate how the amount of sagging of the parison may be estimated.

Extrusion Stretch Blow Moulding

Molecular orientation has a very large effect on the properties of a moulded article. During conventional blow moulding the inflation of the parison causes molecular orientation in the hoop direction. However, bi-axial stretching of the plastic before it starts to cool in the mould has been found to provide even more significant improvements in the quality of blow-moulded bottles. Advantages claimed include improved mechanical properties, greater clarity and superior permeation characteristics. Cost savings can also be achieved through the use of lower material grades or thinner wall sections.

Biaxial orientation may be achieved in blow moulding by

(a) stretching the extruded parison longitudinally before it is clamped by the mould and inflated. This is based on the Neck Ring process developed as early as the 1950s. In this case, molten plastic is extruded into a ring mould which forms the neck of the bottle and the parison is then stretched. After the mould closes around the parison, inflation of the bottle occurs in the normal way. The principle is illustrated in Fig. 4.24.

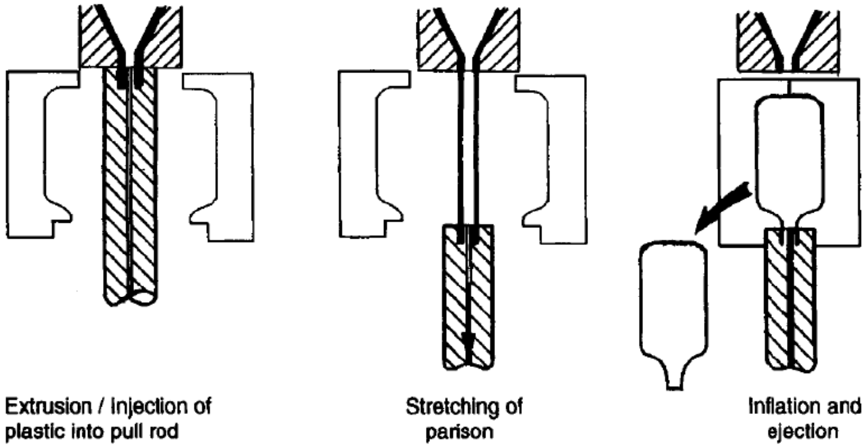


Fig. 4.24 Neck ring stretch blow moulding

(b) producing a preform 'bottle' in one mould and then stretching this longitudinally prior to inflation in the full size bottle mould. This is illustrated in Fig. 4.25.

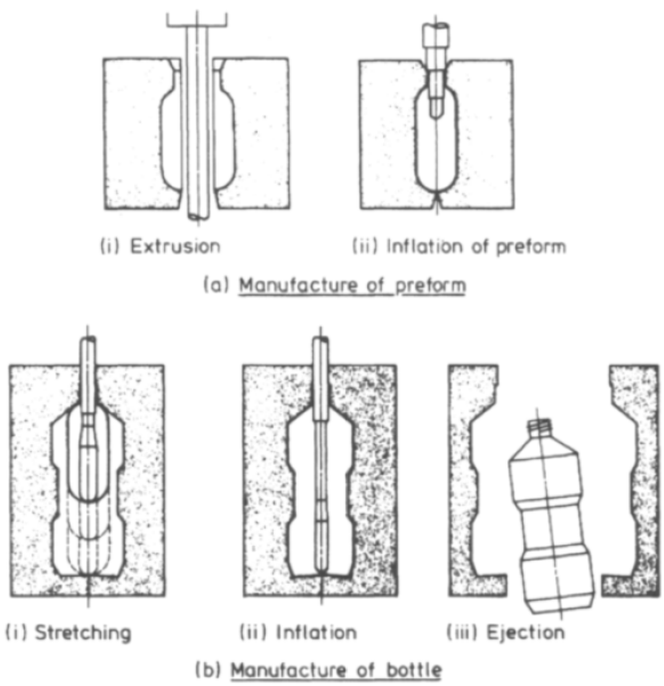


Fig. 4.25 Extrusion stretch blow moulding

Injection Blow Moulding

In Section 4.2.7 we considered the process of extrusion blow moulding which is used to produce hollow articles such as bottles. At that time it was mentioned that if molecular orientation can be introduced to the moulding then the properties are significantly improved. In recent years the process of injection blow moulding has been developed to achieve this objective. It is now very widely used for the manufacture of bottles for soft drinks.

The steps in the process are illustrated in Fig. 4.48. Initially a preform is injection moulded. This is subsequently inflated in a blow mould in order to produce the bottle shape. In most cases the second stage inflation step occurs immediately after the injection moulding step but in some cases the performs are removed from the injection moulding machine and subsequently re-heated for inflation.

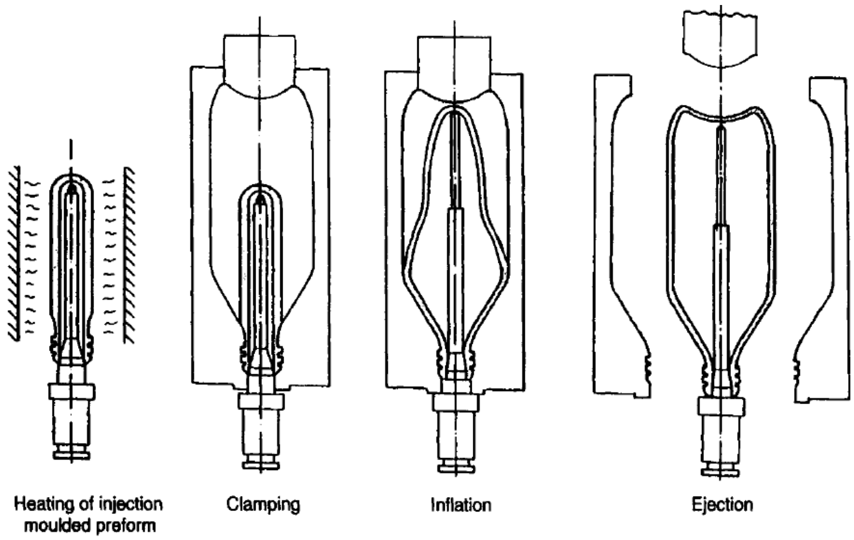


Fig. 4.48 Injection blow moulding process

The advantages of injection blow moulding are that

(i) the injection moulded parison may have a carefully controlled wall thickness profile to ensure a uniform wall thickness in the inflated bottle.

(ii) it is possible to have intricate detail in the bottle neck.

(iii) there is no trimming or flash (compare with extrusion blow moulding).

A variation of this basic concept is the *Injection Orientation Blow Moulding* technique developed in the 1960s in the USA but upgraded for commercial use in the 1980s by AOKI in Japan. The principle is very similar to that described above and is illustrated in Fig. 4.49. It may be seen that the method essentially combines injection moulding, blow moulding and thermoforming to manufacture high quality containers.

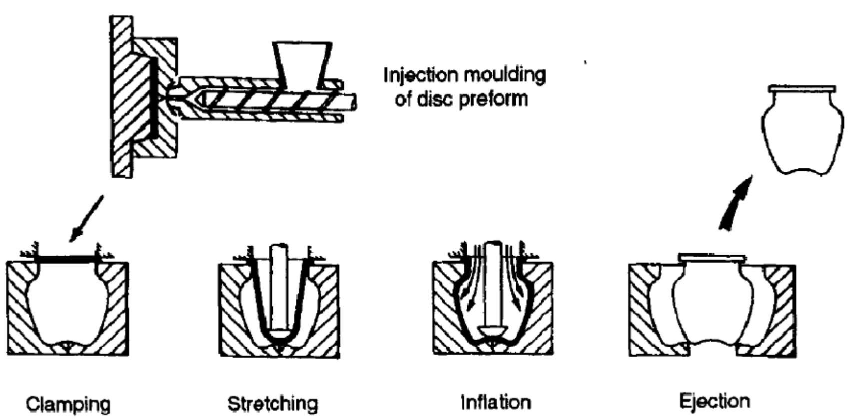


Fig. 4.49 Injection orientation strech blow moulding