Powder Metallurgy

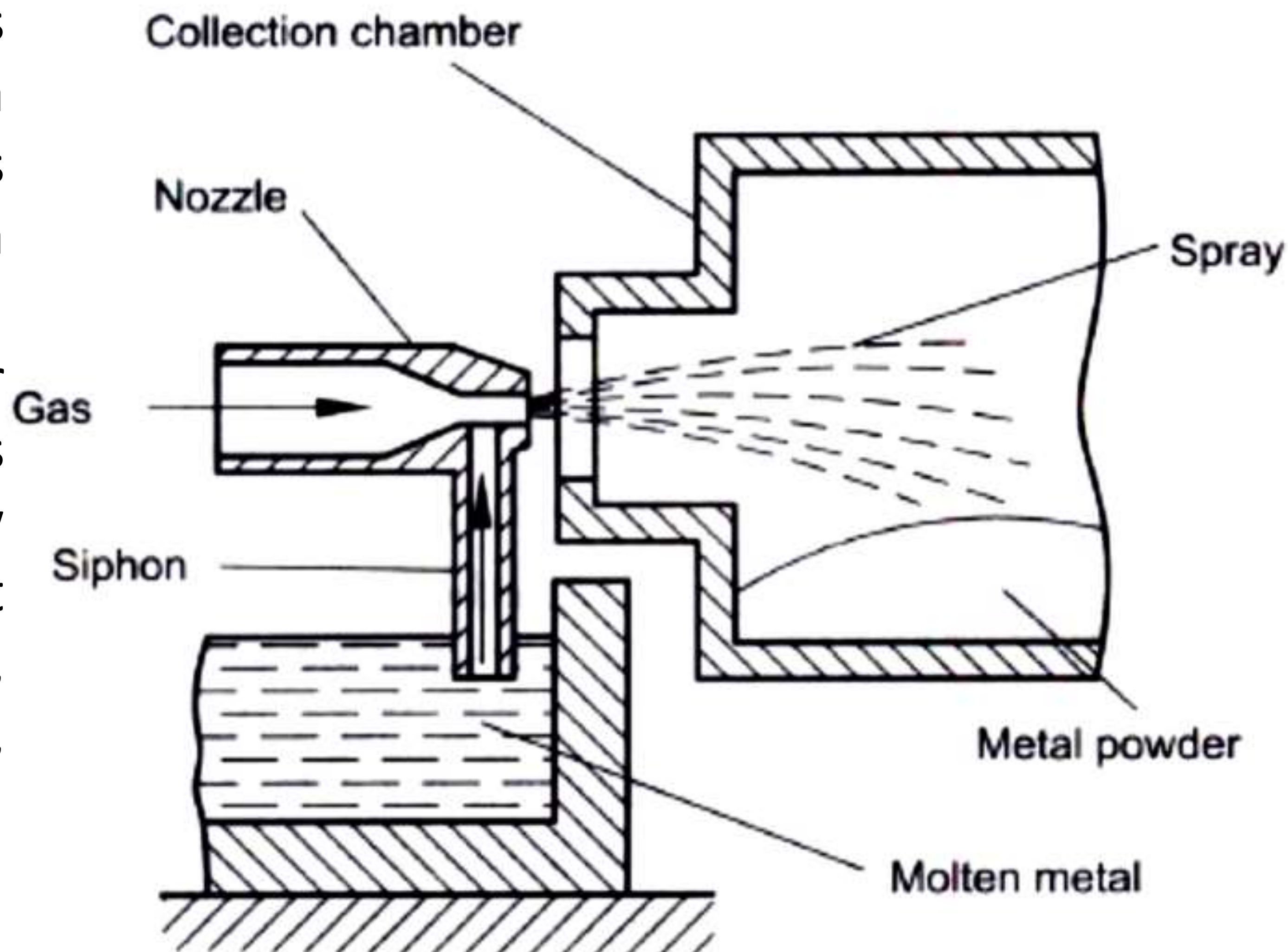
Powder Metallurgy

- Powder metallurgy is the name given to the process by which fine powdered materials are blended, pressed into a desired shape (compacted), and then heated (sintered) in a controlled atmosphere to bond the contacting surfaces of the particles and establish the desired properties.

Manufacturing of Powder

Atomization using a gas stream

Molten metal is forced through a small orifice and is disintegrated by a jet of compressed air, inert gas or water jet,. It is used for low melting point materials, brass, bronze, Zn, Tn, Al, Pb etc.



Manufacturing of Powder

Reduction

- Metal oxides are turned to pure metal powder when exposed to below melting point gases results in a product of cake of sponge metal.
- The irregular sponge-like particles are soft, readily compressible, and give compacts of good pre-sinter (“green”) strength
- Used for iron, Cu, tungsten, molybdenum, Ni and Cobalt.

Manufacturing of Powder

Electrolytic Deposition

- Used for iron, copper, silver
- Process is similar to electroplating.
- For making copper powder, copper plates are placed as anode in the tank of electrolyte, whereas the aluminium plates are placed in the electrolyte to act as cathode. When DC current is passed, the copper gets deposited on cathode. The cathode plated are taken out and powder is scrapped off. The powder is washed, dried and pulverized to the desired grain size.
- The cost of manufacturing is high.

Manufacturing of Powder

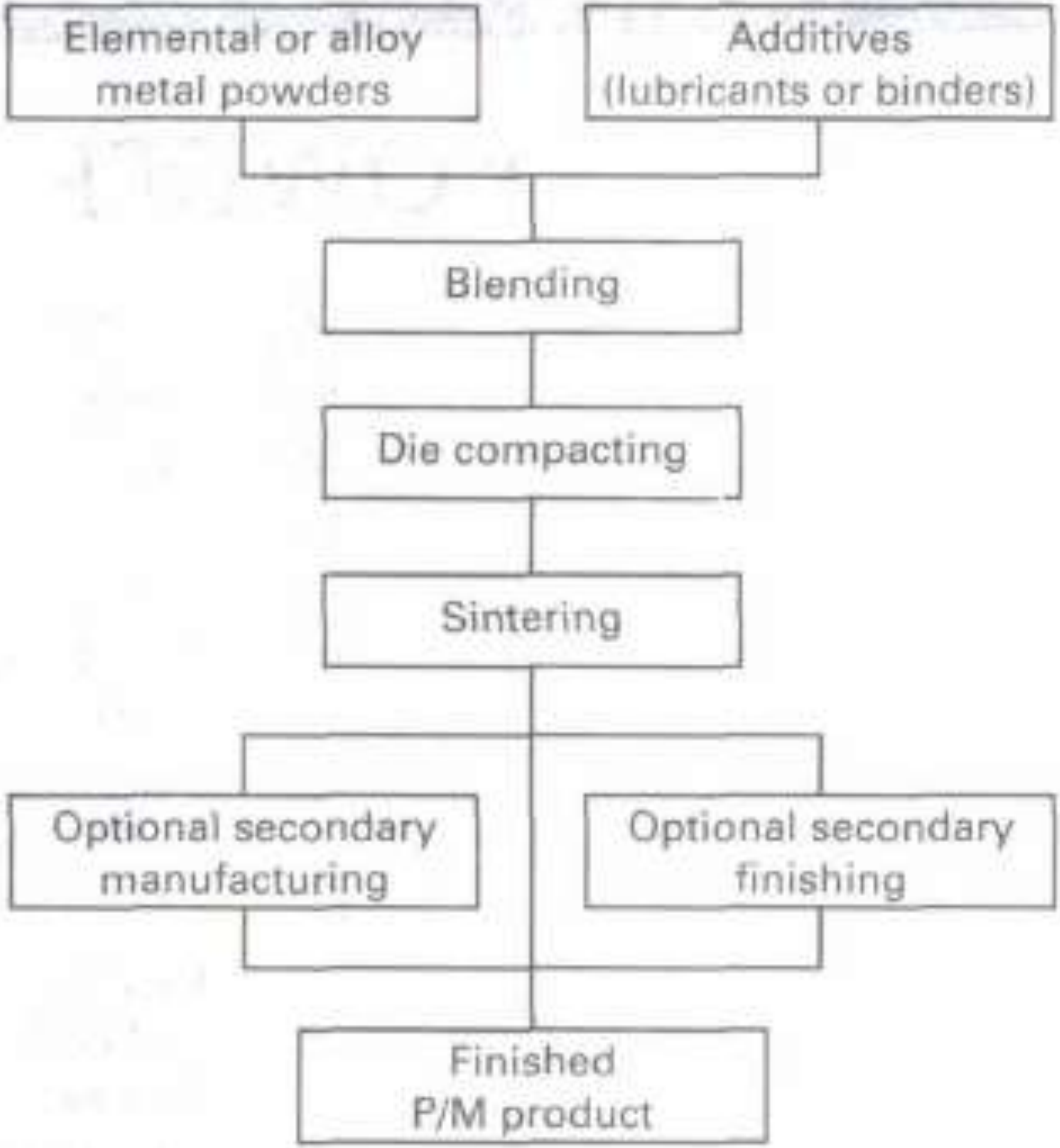
Granulations - as metals are cooled they are stirred rapidly

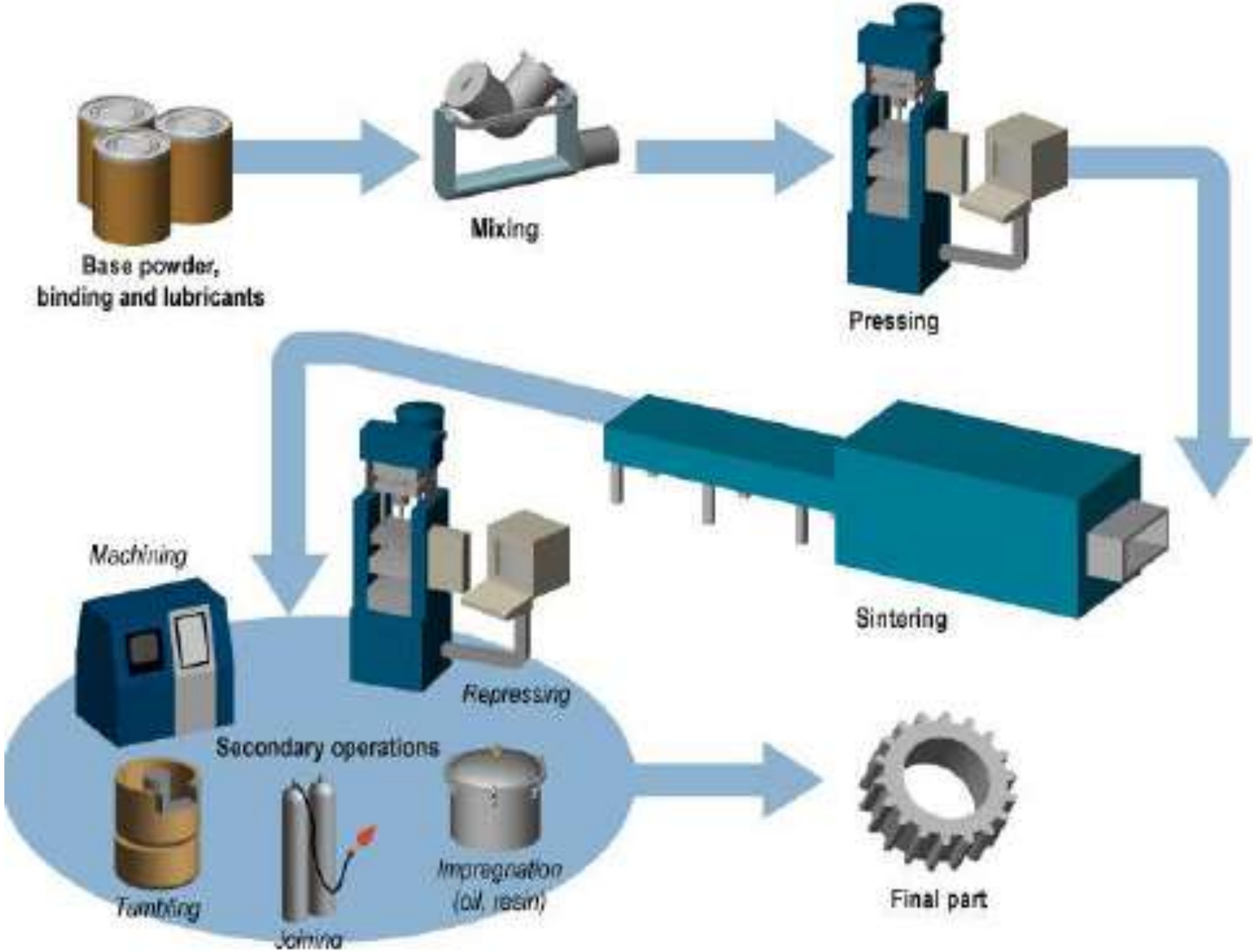
Machining - coarse powders such as magnesium

Milling - crushers and rollers to break down metals. Used for brittle materials.

Shooting - drops of molten metal are dropped in water, used for low melting point materials.

Condensation – Metals are boiled to produce metal vapours and then condensed to obtain metal powders. Used for Zn, Mg, Cd.


Elemental or alloy metal powders
Additives (lubricants or binders)
Blending
Die compacting
Sintering
Optional secondary manufacturing
Optional secondary finishing
Finished P/M product



Steps of powder metallurgy

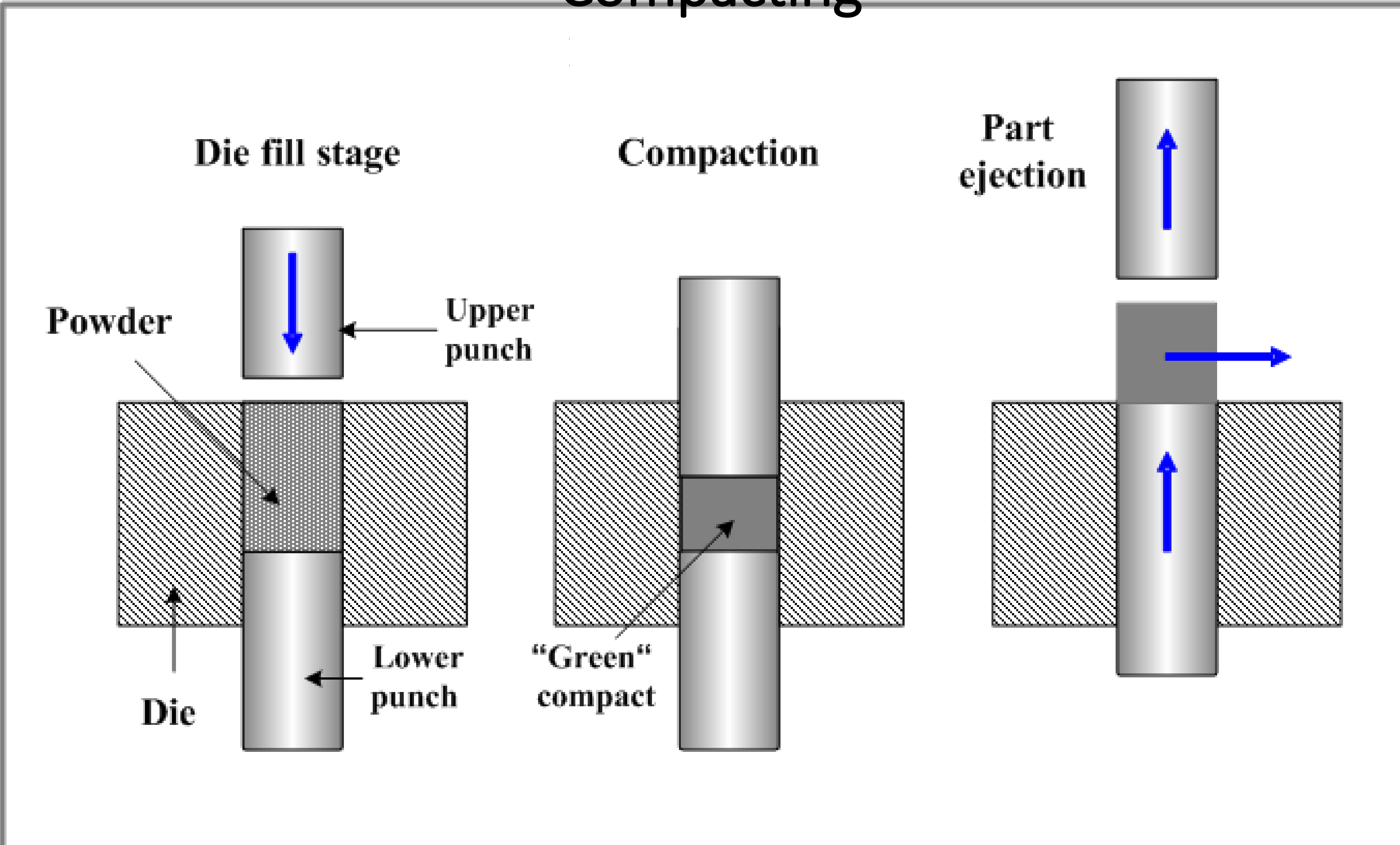
Blending

- Blending or mixing operations can be done either dry or wet.
- Lubricants such as graphite or stearic acid improve the flow characteristics and compressibility at the expense of reduced strength.
- Binders produce the reverse effect of lubricants. Thermoplastics or a water-soluble methylcellulose binder is used.
- Most lubricants or binders are not wanted in the final product and are removed (volatilized or burned off)

Compacting

- Powder is pressed into a “green compact”
- 40 to 1650 MPa pressure (Depends on materials, product complexity)
- Still very porous, ~70% density
- May be done cold or warm (higher density)

Compacting



Die fill stage
Compaction
Part ejection
Powder
Upper punch
Lower punch
Die
"Green" compact

Sintering

- Controlled atmosphere: no oxygen
- Heat to 0.75*T melt
- Particles bind together, diffusion, recrystalization and grain growth takes place.
- Part shrinks in size
- Density increases, up to 95%
- Strength increases, Brittleness reduces, Porosity decreases. Toughness increases.

Production of magnets

- 50:50 Fe-Al alloys is used for magnetic parts
- Al-Ni-Fe is used for permanent magnets
- Sintering is done in a wire coil to align the magnetic poles of the material
- H_2 is used to rapidly cool the part (to maintain magnetic alignment)
- Total shrinkage is approximately 3-7% (for accurate parts an extra sintering step may be added before magnetic alignment)
- The sintering temperature is 600°C in H_2

Advantages

- Good tolerances and surface finish
- Highly complex shapes made quickly
- Can produce porous parts and hard to manufacture materials (e.g. cemented oxides)
- Pores in the metal can be filled with other materials/metals
- Surfaces can have high wear resistance
- Porosity can be controlled
- Low waste
- Automation is easy

Advantages Contd….

- Physical properties can be controlled
- Variation from part to part is low
- Hard to machine metals can be used easily
- No molten metals
- No need for many/any finishing operations
- Permits high volume production of complex shapes
- Allows non-traditional alloy combinations
- Good control of final density

Applications

- Oil-impregnated bearings made from either iron or copper alloys for home appliance and automotive applications
- P/M filters can be made with pores of almost any size.
- Pressure or flow regulators.
- Small gears, cams etc.
- Products where the combined properties of two or more metals (or both metals and nonmetals) are desired.
- Cemented carbides are produced by the cold-compaction of tungsten carbide powder in a binder, such as cobalt (5 to 12%), followed by liquid-phase sintering.

Pre - Sintering

- If a part made by PM needs some machining, it will be rather very difficult if the material is very hard and strong. These machining operations are made easier by the pre-sintering operation which is done before sintering operation.

Repressing

- Repressing is performed to increase the density and improve the mechanical properties.
- Further improvement is achieved by re-sintering.

Infiltration

- Component is dipped into a low melting-temperature alloy liquid
- The liquid would flow into the voids simply by capillary action, thereby decreasing the porosity and improving the strength of the component.
- The process is used quite extensively with ferrous parts using copper as an infiltrate but to avoid erosion, an alloy of copper containing iron and manganese is often used.

Impregnation

- Impregnation is similar to infiltration
- PM component is kept in an oil bath. The oil penetrates into the voids by capillary forces and remains there.
- The oil is used for lubrication of the component when necessary. During the actual service conditions, the oil is released slowly to provide the necessary lubrication.
- The components can absorb between 12% and 30% oil by volume.
- It is being used on P/M **self-lubricating bearing** components since the late 1920's.

Oil-impregnated Porous Bronze Bearings

Plastics

Plastics or polymer

- **Definition:** A group of engineered materials characterized by large molecules that are built up by the joining of smaller molecules.
- They are natural or synthetics resins.

Properties of plastics

- Light weight
- Good resistance to corrosion
- Easy of fabrication into complex shapes
- Low electrical and thermal conductivity
- Good surface finish
- Good optical properties
- Good resistance to shock and vibration.

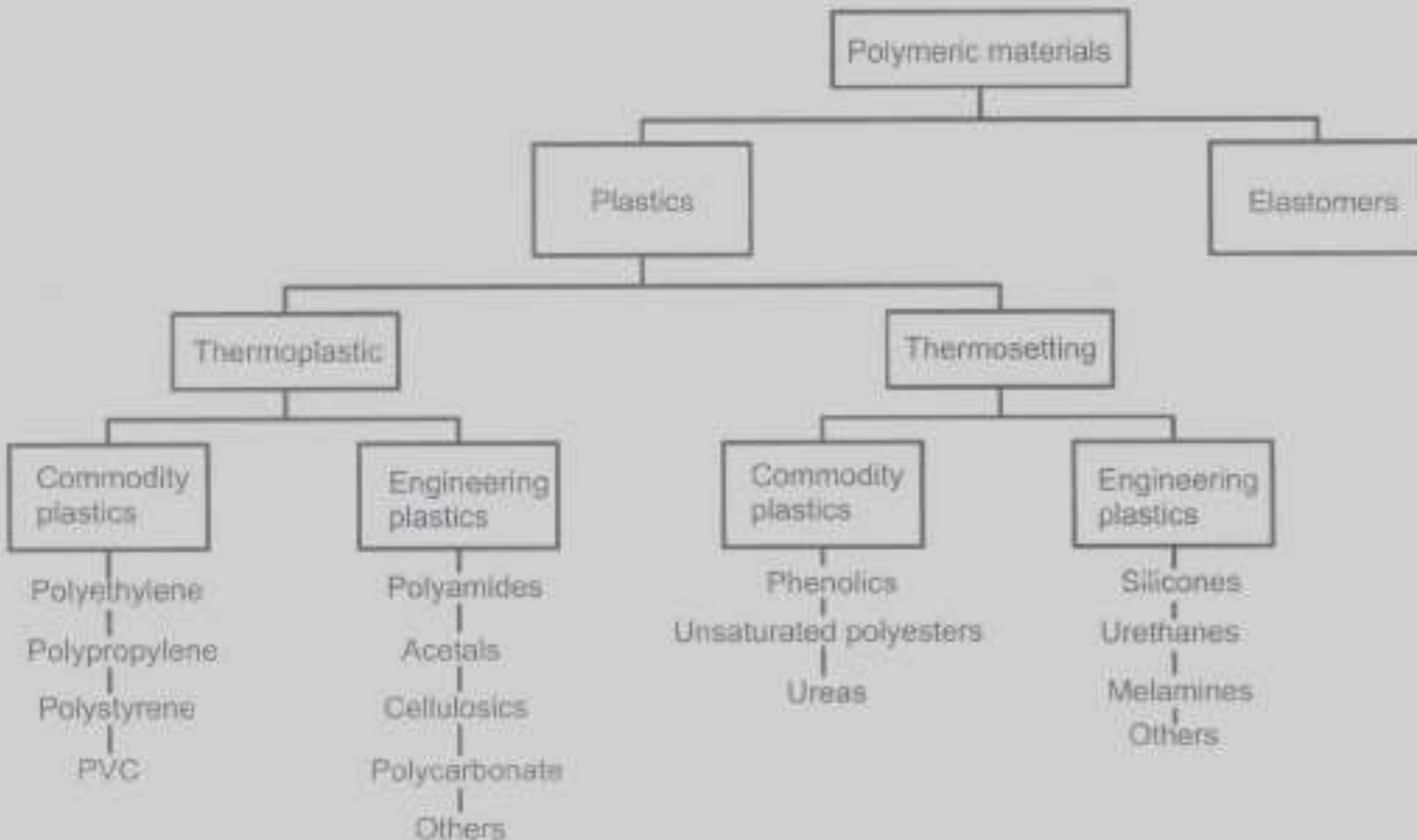


Fig. 12.1 *Classification of the different polymeric materials*

Classification – Polymers

- Classification based on their industrial usage:
  (a) plastics and
  (b) elastomers.
- Classification based on their temperature dependence:
  (a) thermoplasts and
  (b) thermosets

Thermoplasts

- Plastics which softens up on heating and hardens up on cooling where the softening and hardening are totally reversible processes.
- Hence thermoplasts can be recycled.
- They consist of linear molecular chains bonded together by weak secondary bonds or by inter-winding.
- Cross-linking between molecular chains is absent in theromplasts.
- E.g.: Acrylics, PVC, Nylons, Perspex glass, etc.

Thermoplastics

- **Acrylonitrile-butadiene-styrene (ABS):**

  Characteristics: Outstanding strength and toughness, resistance to heat distortion; good electrical properties; flammable and soluble in some organic solvents.

  Application: Refrigerator lining, lawn and garden equipment, toys, highway safety devices.

- **Acrylics (poly-methyl-methacrylate) PMMA**

  Characteristics: Outstanding light transmission and resistance to weathering; only fair mechanical properties.

  Application: Lenses, transparent aircraft enclosures, drafting equipment, outdoor signs.

Contd…

- **Fluorocarbons (PTFE or TFE,Teflon)**

  Characteristics: Chemically inert in almost all environments, excellent electrical properties; low coefficient of friction; may be used to 260o^{o}C; relatively weak and poor cold-flow properties.

  Application: Anticorrosive seals, chemical pipes and valves, bearings, anti adhesive coatings, high temperature electronic parts.

- **Polyamides (nylons)**

  Characteristics: Good mechanical strength, abrasion resistance, and toughness; low coefficient of friction; absorbs water and some other liquids.

  Application: Bearings, gears, cams, bushings, handles, and jacketing for wires and cables.

Contd…

- **Polycarbonates**

  Characteristics: Dimensionally stable: low water absorption; transparent; very good impact resistance and ductility.

  Application: Safety helmets, lenses light globes, base for photographic film

- **Polyethylene**

  Characteristics: Chemically resistant and electrically insulating; tough and relatively low coefficient of friction; low strength and poor resistance to weathering.

  Application: Flexible bottles, toys, tumblers, battery parts, ice trays, film wrapping materials.

Contd…

- **Polypropylene**

  Characteristics: Resistant to heat distortion; excellent electrical properties and fatigue strength; chemically inert; relatively inexpensive; poor resistance to UV light.

  Application: Sterilizable bottles, packaging film, TV cabinets, luggage

- **Polystyrene**

  Characteristics: Excellent electrical properties and optical clarity; good thermal and dimensional stability; relatively inexpensive

  Application: Wall tile, battery cases, toys, indoor lighting panels, appliance housings.

Contd…

Thermosets

- Plastics which are ‘set’ under the application of heat and/or pressure.
- This process is not reversible, hence thermosets can not be recycled.
- They consist of 3-D network structures based on strong covalent bonds to form rigid solids. linear molecular chains bonded together by weak secondary bonds or by interwinding.
- Characterized by high modulus / rigidity /dimensional stability when compared with thermoplasts.
- E.g.: Epoxies, Amino resins, some polyester resins, etc.

Contd…

- Thermosets are strengthened by reinforcements .
- Different reinforcements are in use according to the necessity. Glass fibers are most commonly used to form structural and molding plastic compounds.
- Two most important types of glass fibers are E (electrical)- and S (high strength)- glasses.
- E-glass (lime-aluminium-borosilicate glass with zero or low sodium and potassium levels) is often used for continuous fibers.
- S-glass (65%SiO2, 25%Al2O3 and 10% MgO) has higher strength-to-weight ratio and is more expansive thus primary applications include military and aerospace applications.
- Carbon fiber reinforced plastics are also often used in aerospace applications. However they are very expansive.

Contd…

- The other classes of reinforcements include **aramid** (aromatic polyamide) fibers.
- They are popularly known as **Kevlar.**

Examples – Thermo setting polymers

- **Epoxies**

  Characteristics: Excellent combination of mechanical properties and corrosion resistance; dimensionally stable; good adhesion; relatively inexpensive; good electrical properties.

  Application: Electrical moldings, sinks, adhesives, protective coatings, used with fiberglass laminates.

- **Phenolics**

  Characteristics: Excellent thermal stability to over 150o C; may be compounded with a large number of resins, fillers, etc.; inexpensive.

  Application: Motor housing, telephones, auto distributors, electrical fixtures.

Contd…

- **Polyester (PET or PETE)**

  Characteristics: One of the toughest of plastic films; excellent fatigue and tear strength, and resistance to humidity acids, greases, oils and solvents

  Application: Magnetic recording tapes, clothing, automotive tire cords, beverage containers.

Elastomers

- These polymers are known for their high elongations, which are reversible upon release of applied loads.
- They consist of coil-like molecular chains, which straightens up on application of load.
- Characterized by low modulus / rigidity / strength, but high toughness.
- E.g.: natural and synthetic rubber.

Plastic Process

- The common forms of raw materials for processing plastics into products are :- pellets, granules, powders, sheet, plate, rod and tubing.
- Liquid plastics are used especially in the fabrication of reinforced - plastic parts.
- Thermoplastics can be processed to their final shape by moulding and extrusion processes.
- However, extruding is often used as an intermediate process to be followed by other processes, for example, vacuum forming or machining.

Injection Moulding

- The polymer is melted and than forced into a mould.
- Thermoplastic pellets melted and melt injected under high pressure (70 MPa) into a mold. Molten plastic takes the shape of the mold, cools, solidifies, shrinks and is ejected.
- Molds usually made in two parts (internal and external part).
- Use of injection molding machine mainly used for thermoplastics (gears, cams, pistons, rollers, valves, fan blades, rotors, washing machine agitators, knobs, handles, camera cases, battery cases, sports helmets etc…)

Contd…

– thermoplastic & some thermosets

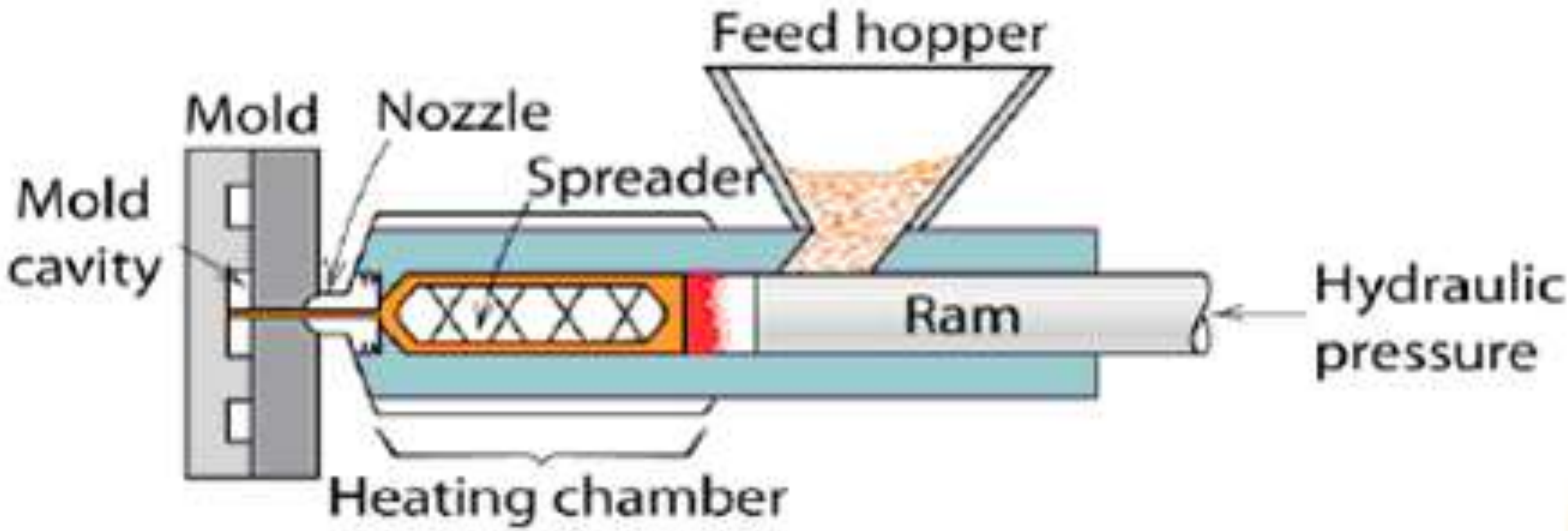


Fig. Injection moulding

Extrusion

- Long plastic products with uniform cross sections are readily produced by the extrusion process.
- Thermoplastic pellets & powders are fed through a hopper into the barrel chamber of a screw extruder. A rotating screw propels the material through a preheating section, where it is heated, homogenized, and compressed, and then forces it through a heated die and onto a conveyor belt.
- As the plastic passes onto the belt, it is cooled by jets of air or sprays of water which harden it sufficiently to preserve its newly imparted shape.
- It continues to cool as it passes along the belt and is then either cut into lengths or coiled.

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- The process is continuous and provides a cheap and rapid method of moulding.
- Common production shapes include a wide variety of solid forms, as well as tubes, pipes, and even coated wires and cables.

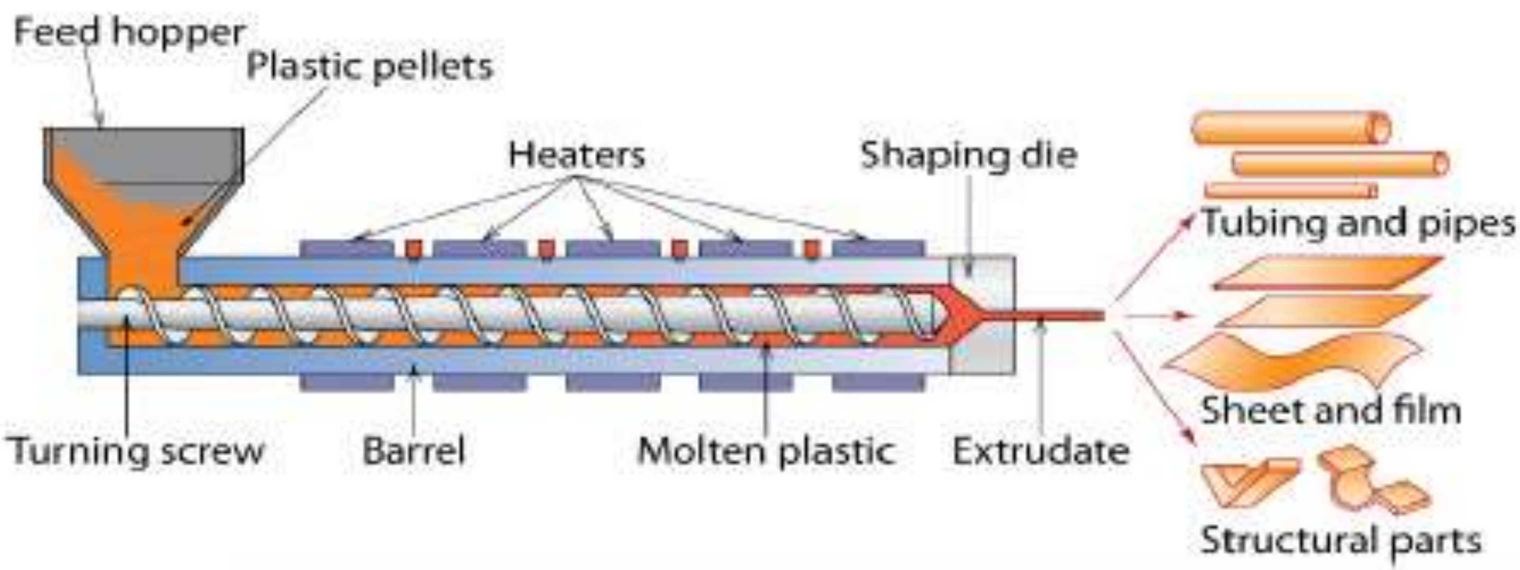

Fig. Extrusion

Compression moulding

- A compression mould is made of two halves with one each being connected to the platens of the press.
- The mould is electrically heated to maintain the required temperature.
- Material is placed in the mould, and it is closed with a hydraulic cylinder, or toggle clamp.
- The pressure maintained on the material is of the order of 14 to 40 MPa of moulding area.
- As the material comes in contact with the heated mould surface, it softens and fills the entire cavity and at the same time initiates the chemical reaction which cures the part.

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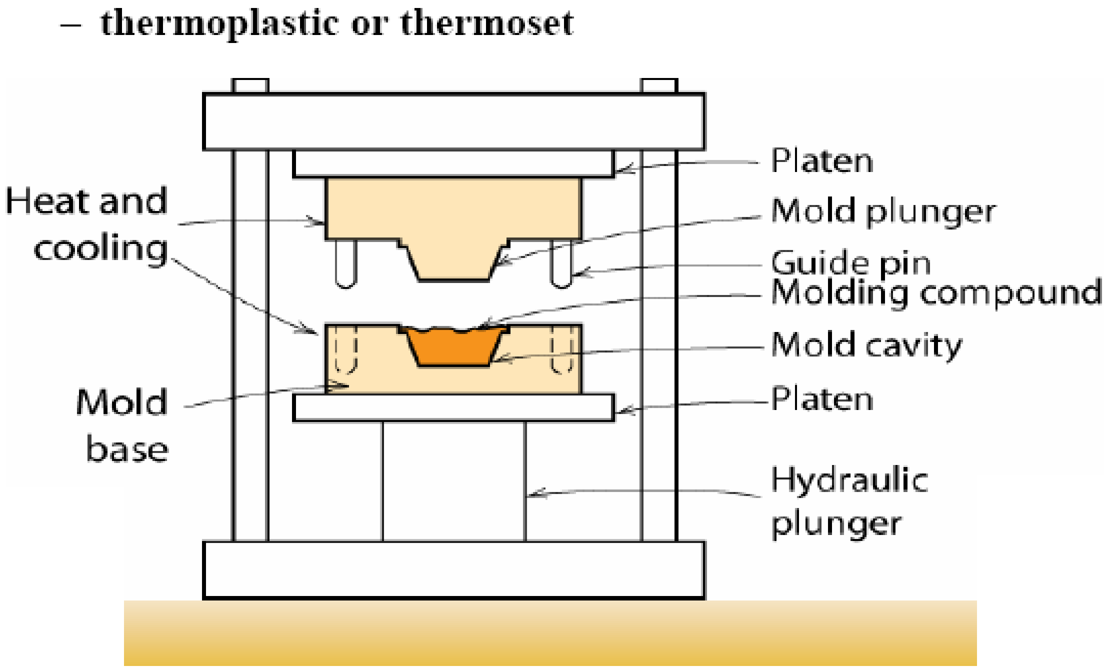
- Cure time is determined by the thickest cross section, mould temperature, material type and grade.
- After curing, the mould opens and the part is ejected.
- The most widely used plastic is phenol- formaldehyde, commonly known as 'Bakelite'.



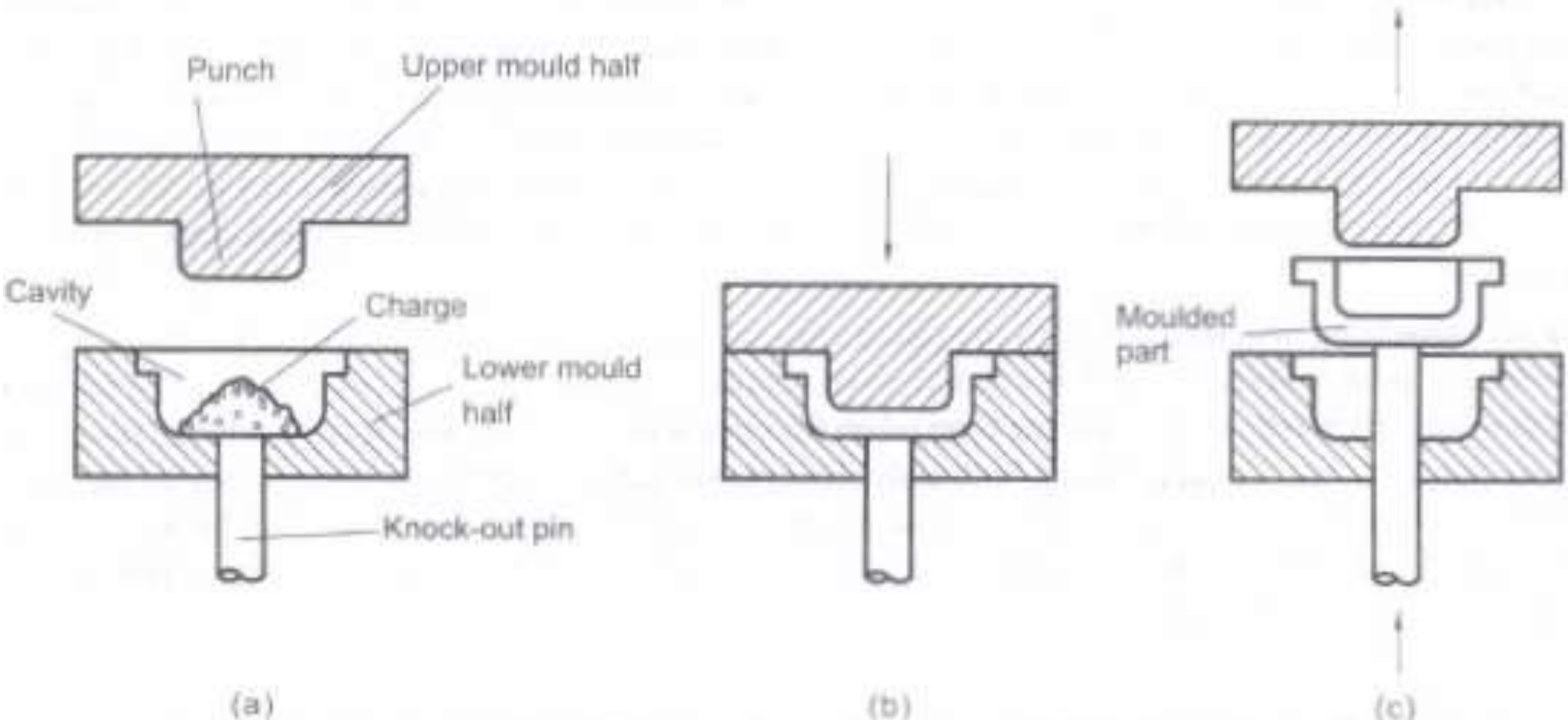


Fig. 12.20 *Steps in compression moulding for thermosetting materials*

Transfer Moulding

- Transfer moulding is very similar to compression moulding and is developed to avoid the disadvantages found in that process.
- In this method, thermosetting charge is heated and compressed in a separate chamber and then injected into the closed mould where it is allowed to cool and solidify.
- Transfer moulding is capable of moulding part shapes that are more intricate than compression moulding but not as intricate as injection moulding.

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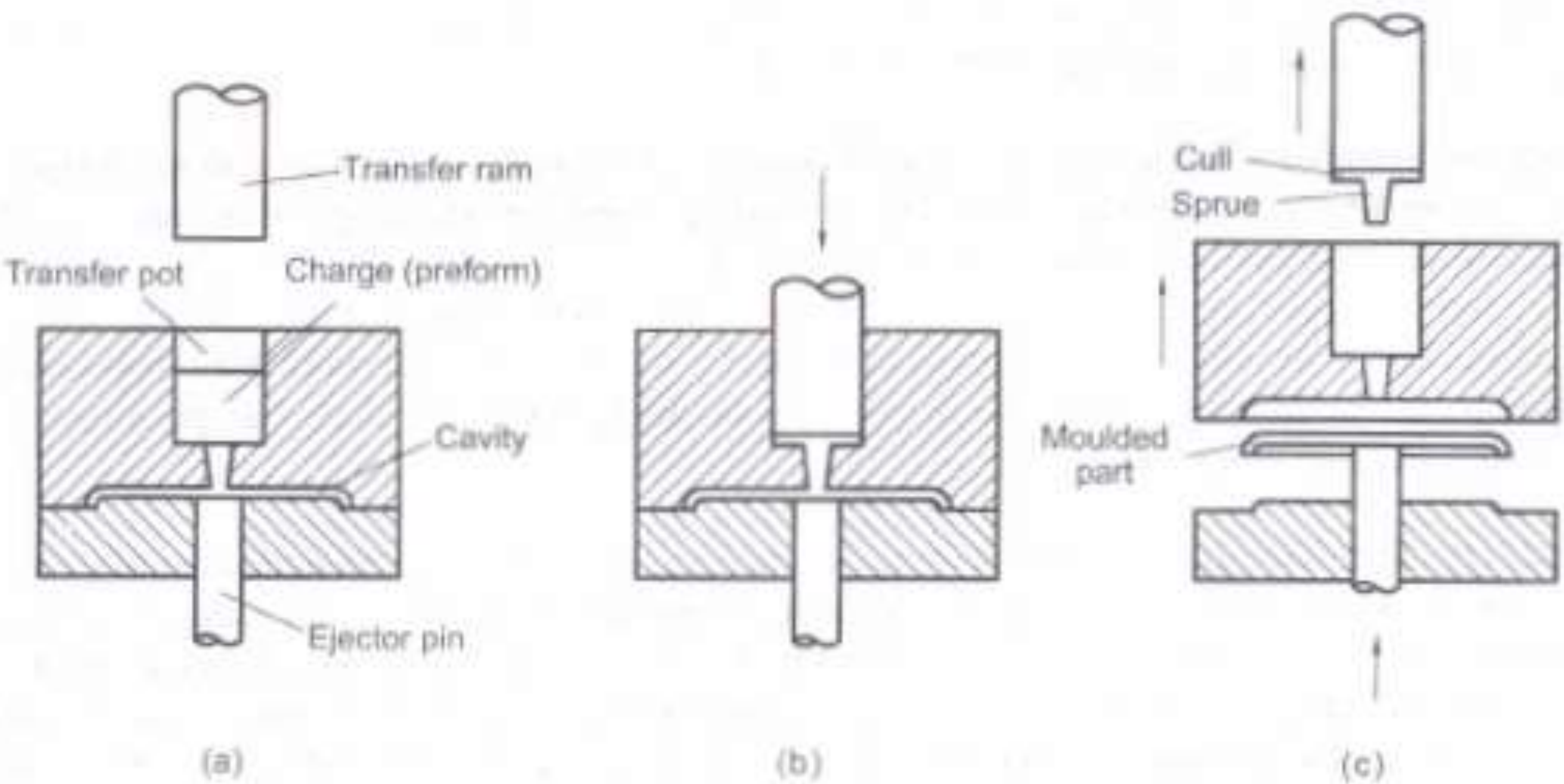

Fig. 12.21 *Steps in transfer moulding for thermosetting materials*

Blow moulding

- Blow moulding is the process of inflating a hot, hollow, thermoplastic preform or parison inside a closed mould so that its shape conforms to that of the mould cavity.
- Typical parts made are bottles, toys, air ducts of automobiles, chemical and gasoline tanks, and a number of housholds goods.

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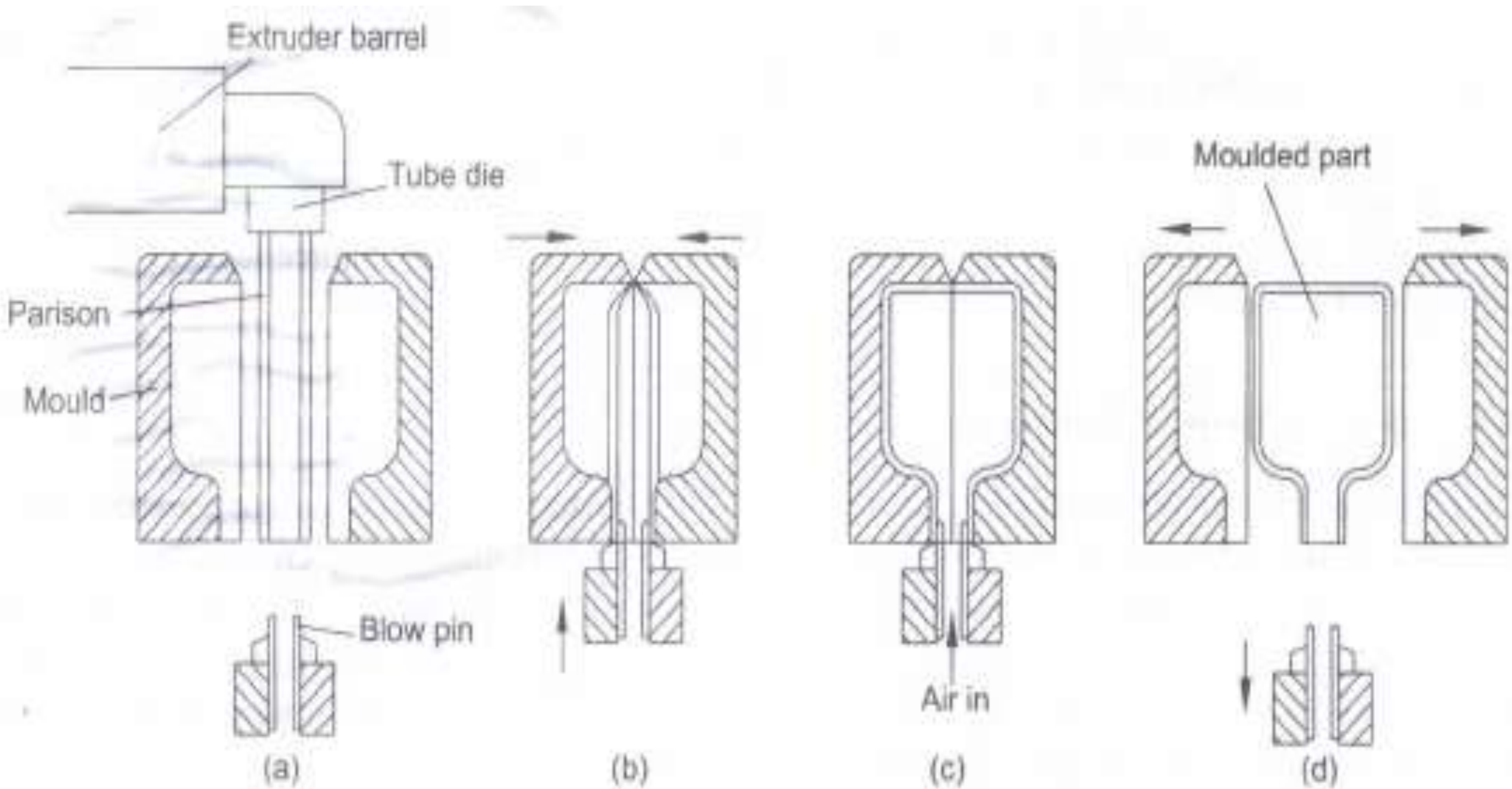
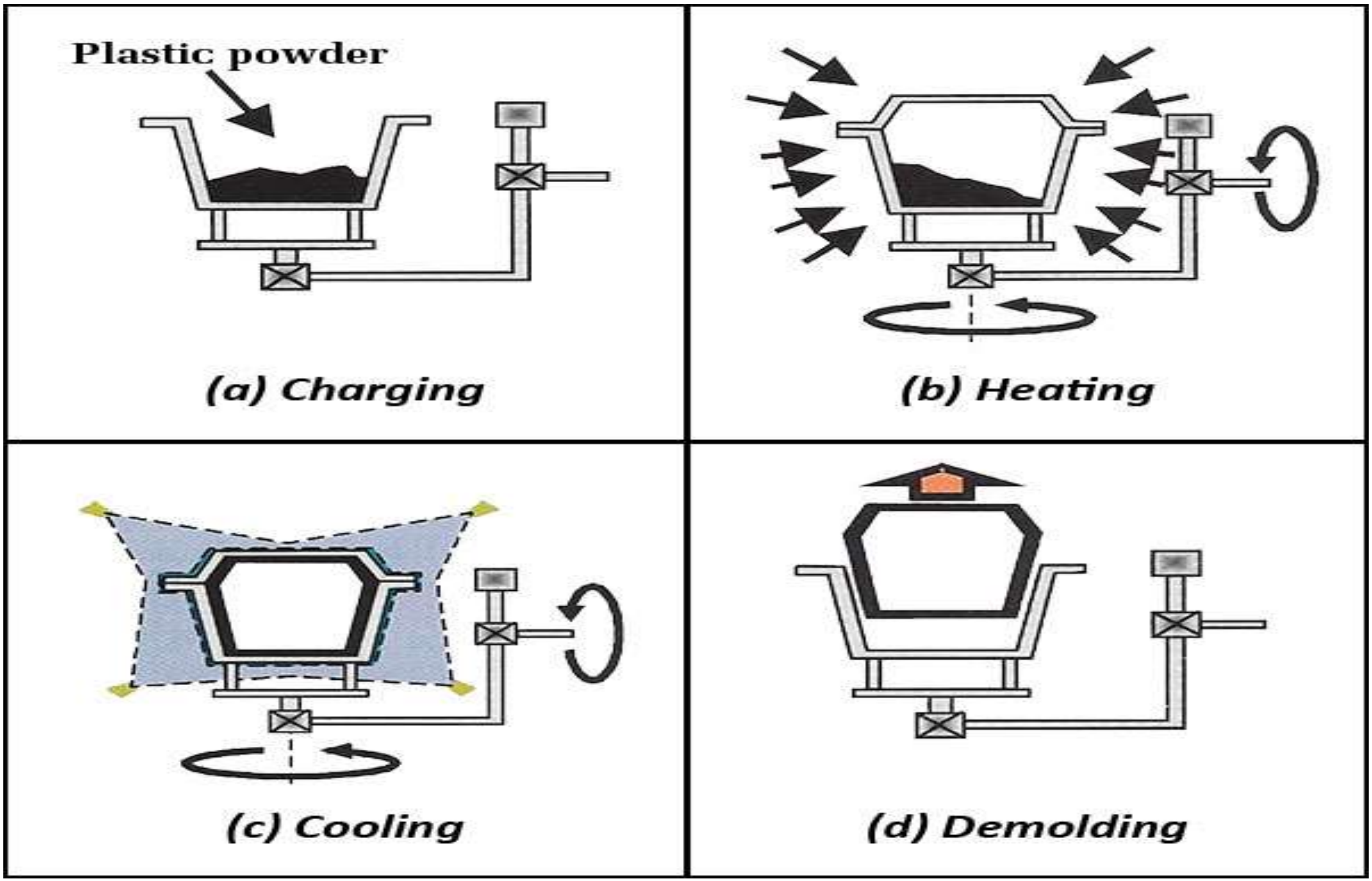


Fig. 12.13 *Operating steps in a blow-moulding operation: (a) Hollow parison is formed with the extruder (b) Mould closes around the parison and blow pin inserted (c) Air is blown into the parison thus expanding it to confirm to the contours of the mould (d) Mould opens and the finished part is removed*

Rotation Moulding



Thermoforming

- In this process, a thermoplastic sheet can be formed into a three- dimensional shape by the application of heat and differential pressures.
- First, the plastic sheet is clamped to a frame and uniformly heated to make it soft and flowable.
- Then a differential pressure (either vacuum or pressure or both) is applied to make the sheet conform to the shape of a mould or die positioned below the frame.
- It is possible to use most of the thermoplastic materials. The starting material is a plastic sheet of uniform thickness.
- It is a relatively simple process and is used for making such parts as covers, displays, blister packaging, trays, drinking cups and food packaging.

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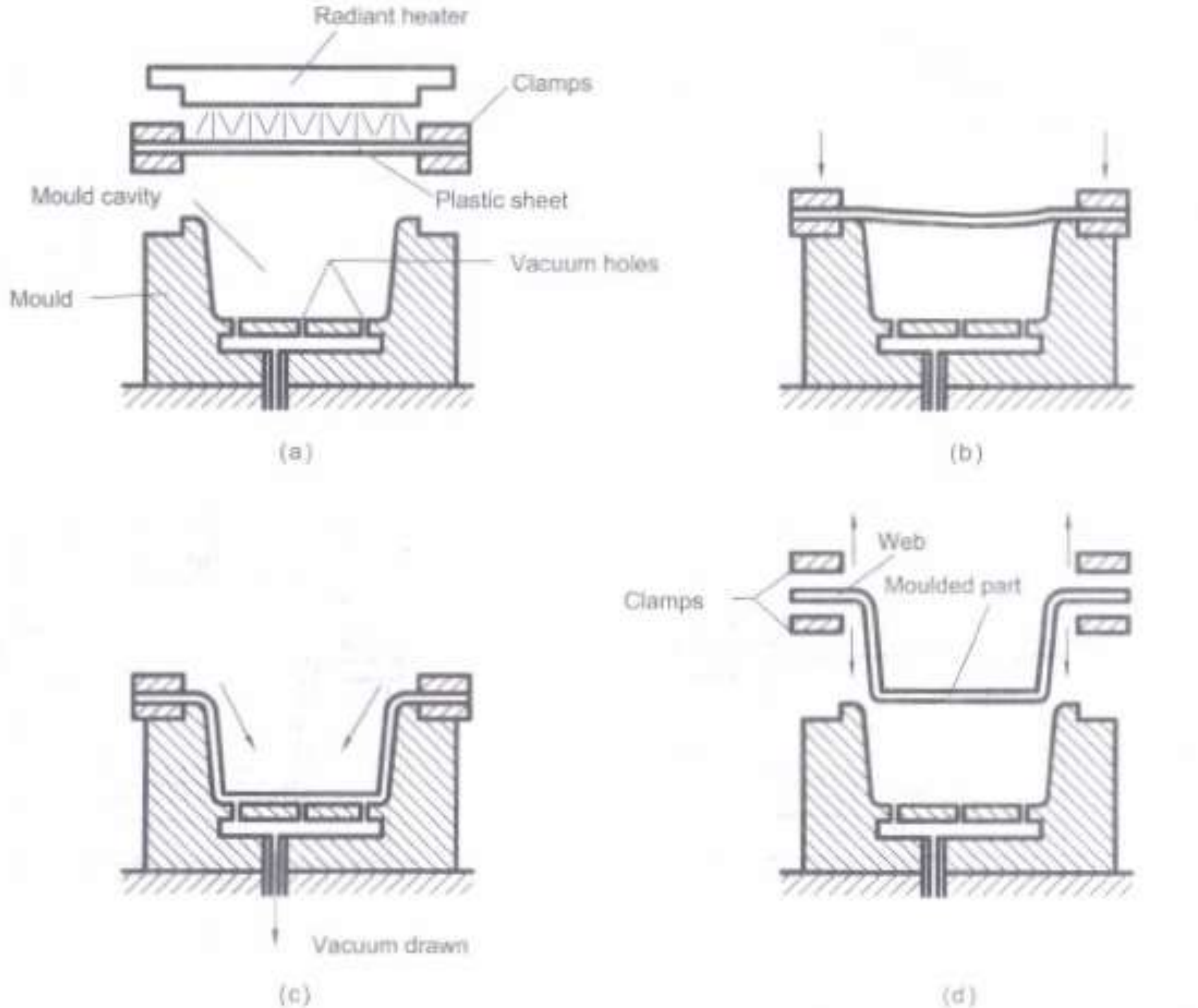

Fig. 12.16 *Steps in vacuum-thermoforming process: (a) Plastic sheet is clamped in a frame and heated. (b) Heated plastic sheet is attached to the mould. (c) Vacuum is applied drawing the plastic sheet to follow the contours of the mould. (d) The moulded part is released*

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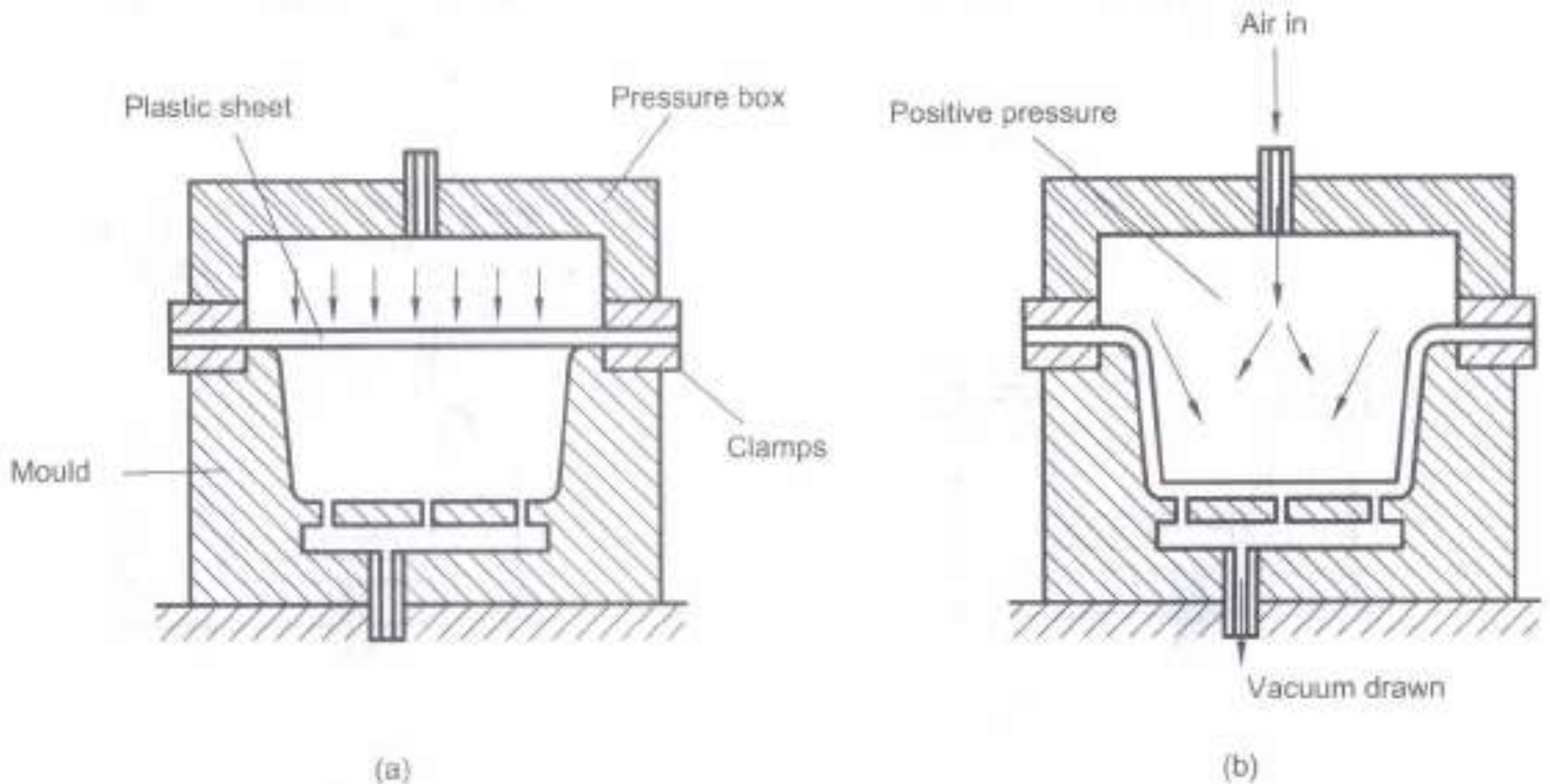
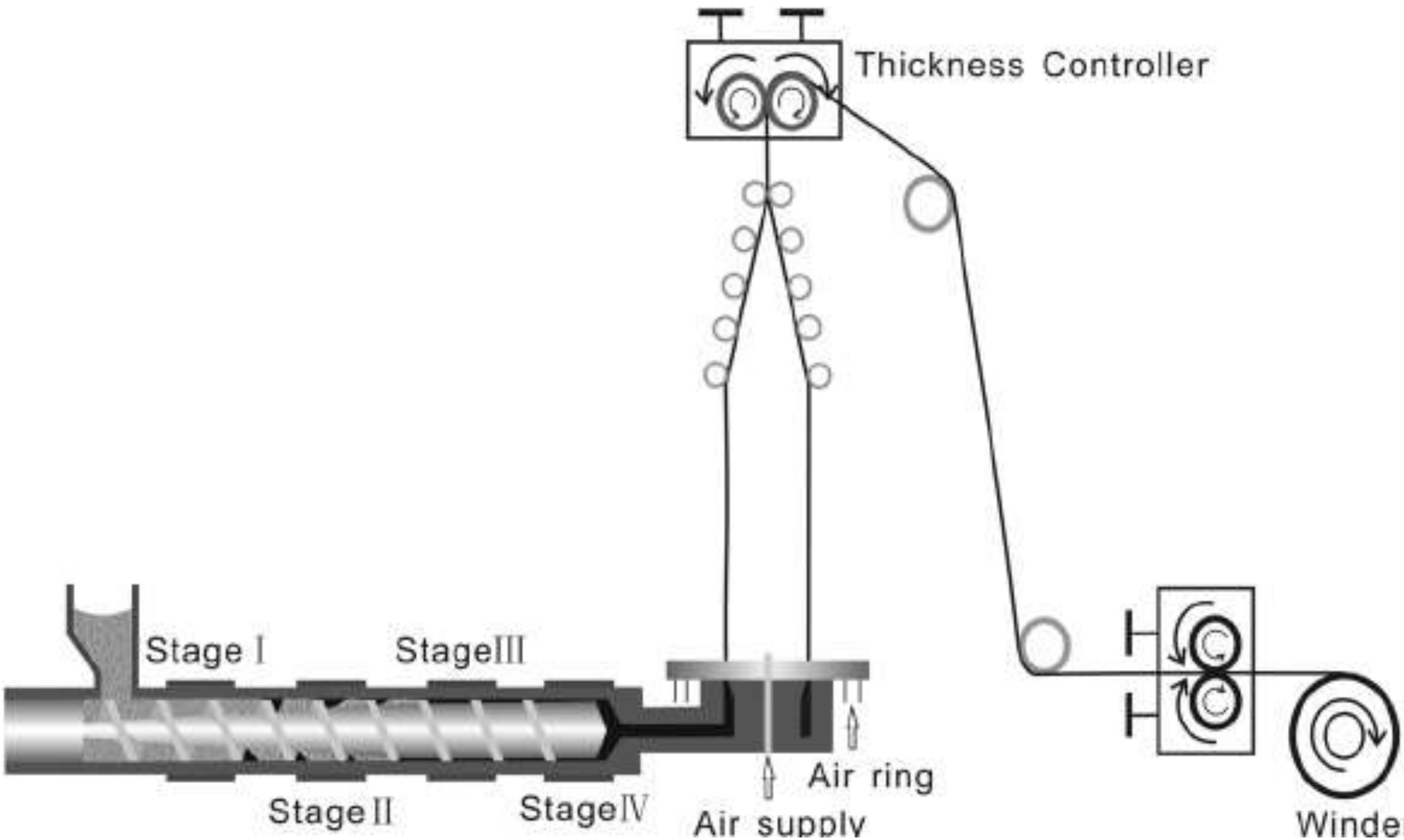


Fig. 12.17 *Steps in pressure thermoforming process: (a) Plastic sheet is clamped in a frame, attached to the mould and heated. (b) Pressure applied on the top forces the plate to follow the contour of the mould. Vacuum is applied from the bottom to assist the forming process.*

Film blowing



The End