
Chapter Extra 1-2

Polymer Processing

Shear and elongational viscosity

Normal stress difference

Rheometry

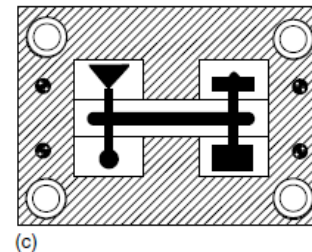
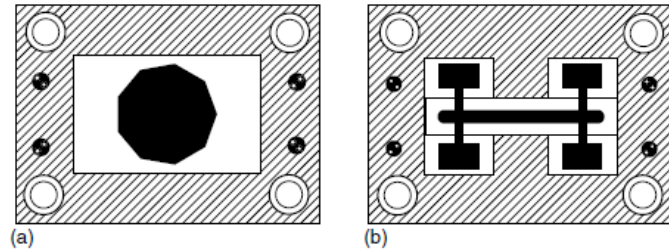
Materials and tooling

□ materials

- thermoplastics ~ chips
 - extrusion grade [壓出用] ~ higher MW
 - injection grade [射出用] ~ lower MW
- thermosets ~ molding compound
 - prepolymer + hardener (+ fillers)
 - less economical

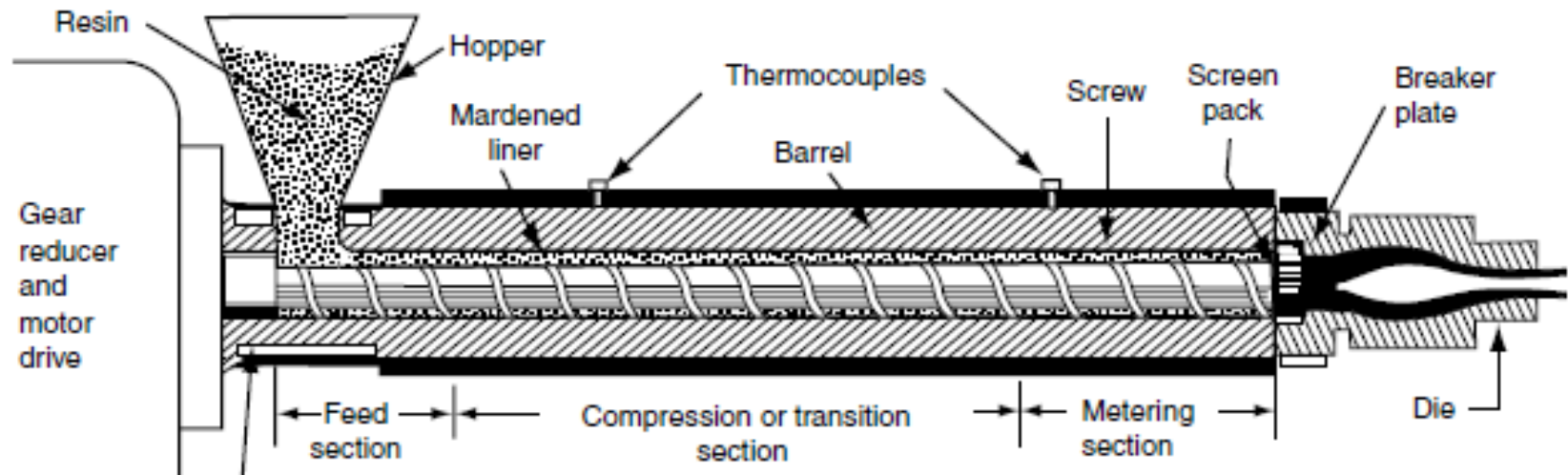
□ tooling

- die
 - extrusion, pultrusion
- mold
 - single- or multi-cavity
 - compression, injection, blow



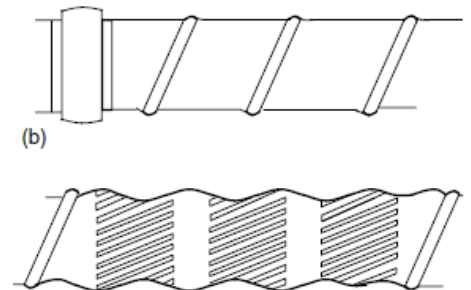
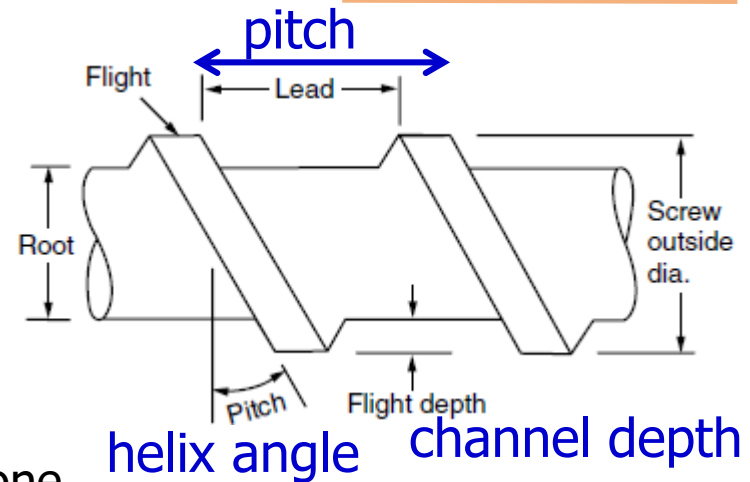
Extrusion

- 4 zones of extruder
 - feed zone ~ preheating and conveying
 - compression or transition zone ~ pressurizing
 - metering zone ~ homogenizing
 - die zone ~ providing back-pressure and profiling



- design and operating
 - extruder spec
 - barrel diameter and L/D
 - screw and die design
 - special designs ~ mixing zone, venting zone
 - temperature and rpm

- twin-screw extruder
 - better mixing
 - for compounding additives, blends



Extrusion-based processing

□ profile extrusion

□ film, sheet ($t > .01''$)

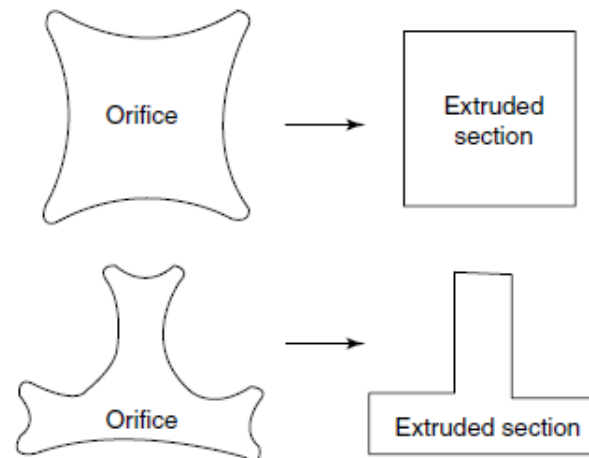
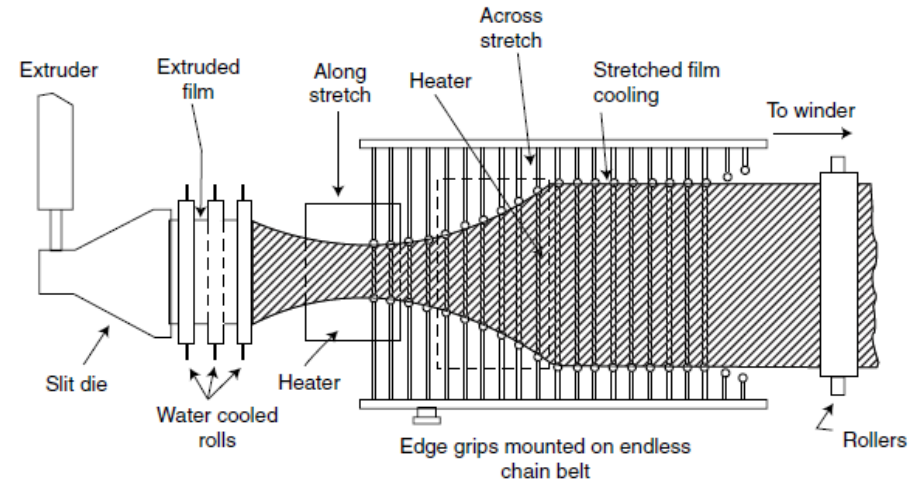
■ orientation

■ biaxial stretching

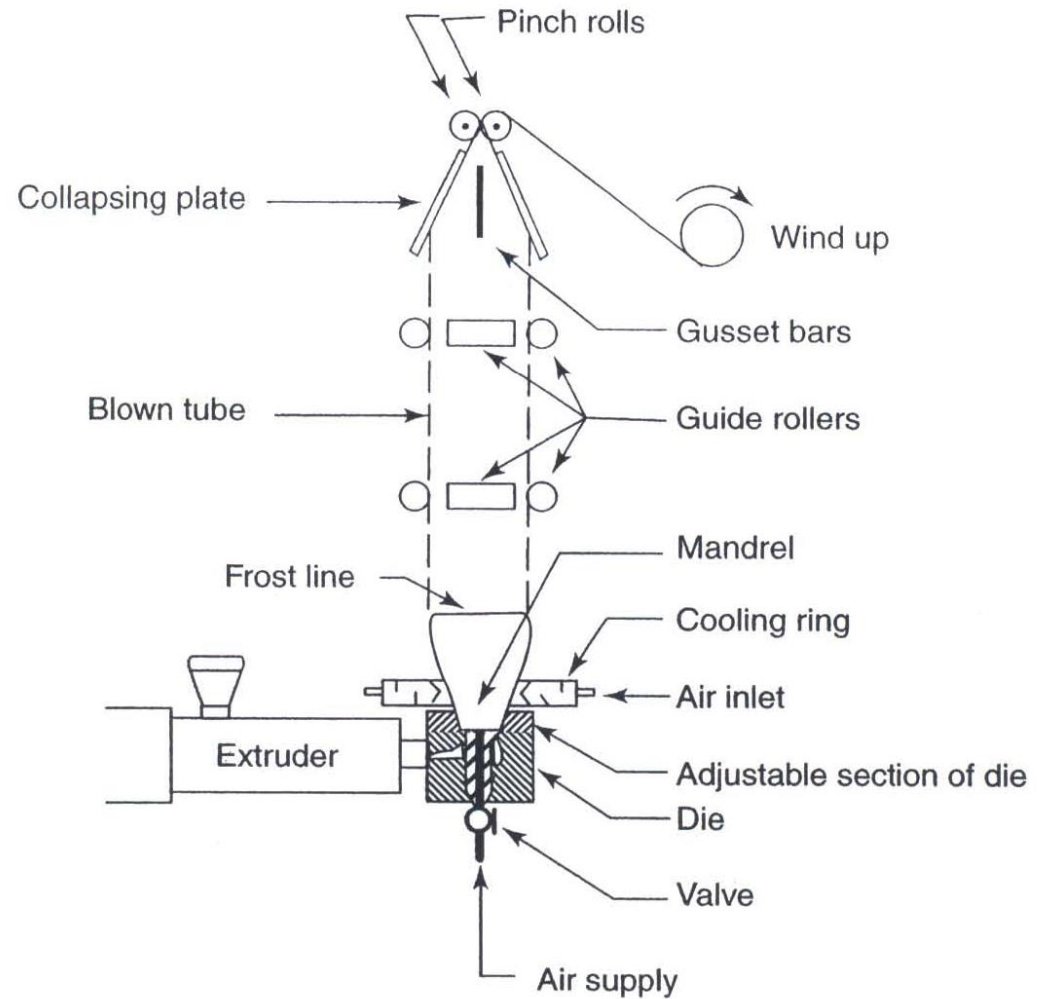
□ pipe (id), tube (od/wt)

□ complex

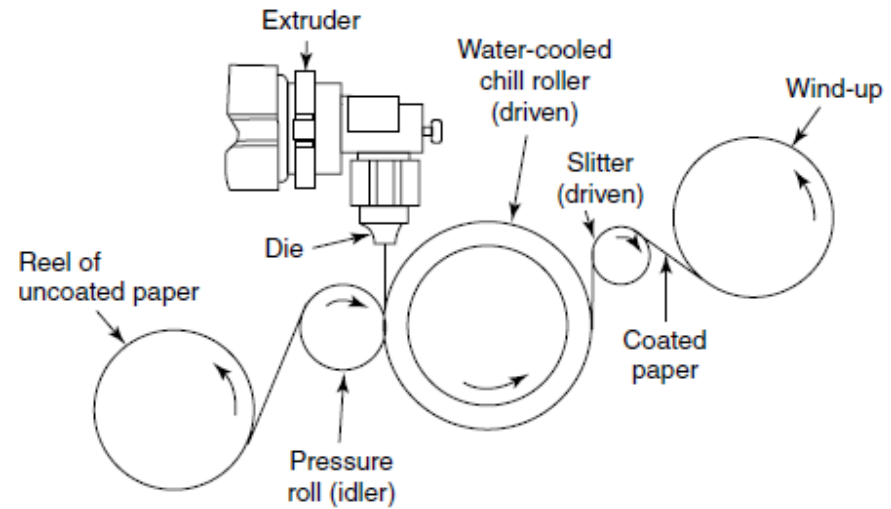
■ die-swell



- film-blowing
 - extensional viscosity critical

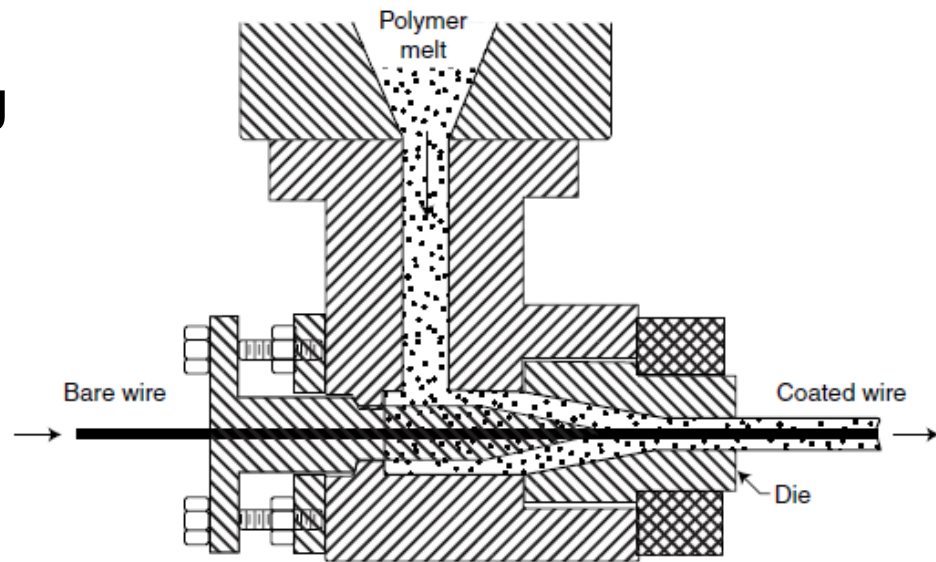


□ extrusion coating



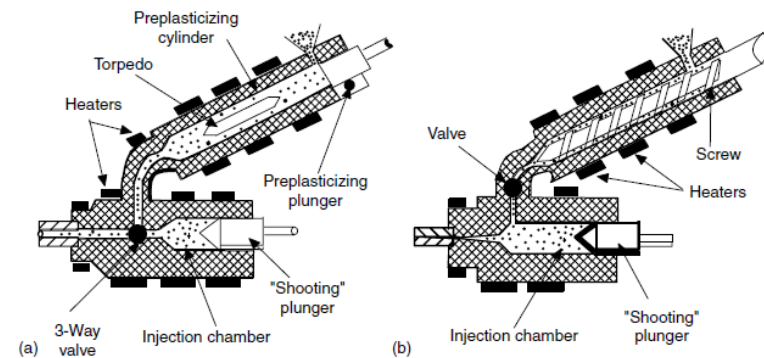
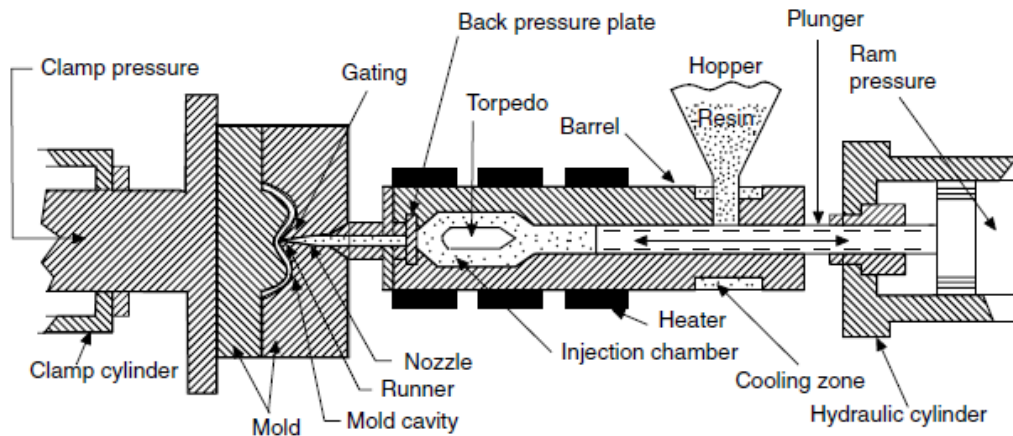
□ crosshead extrusion

□ wire and cable covering



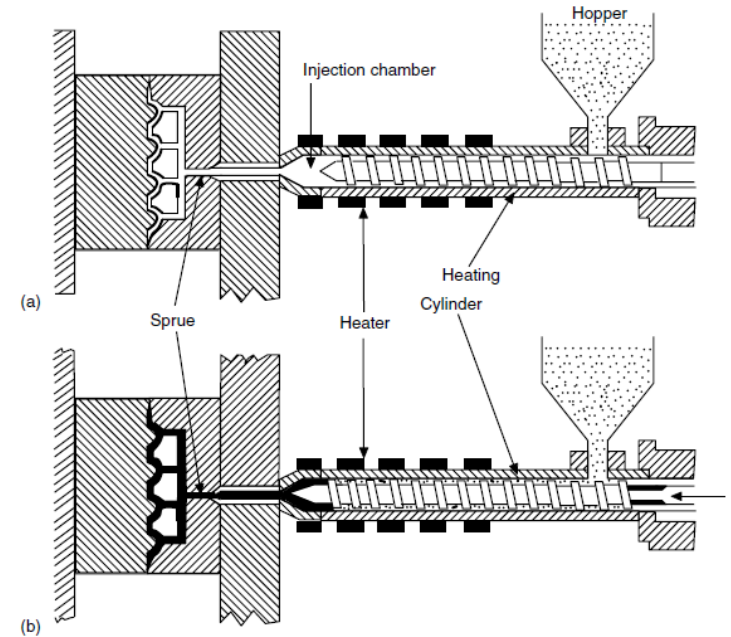
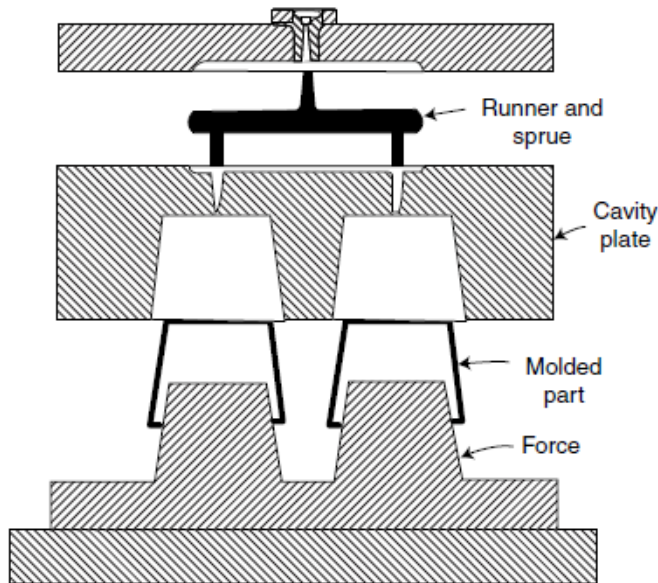
Injection molding

- one of the two most important processes for thermoplastics
 - The other is extrusion. ~ for continuous 2-D
- injection unit
 - plunger-type ~ w or w/o preplasticizer ~ less popular
 - reciprocating screw-type ~ popular
 - rotating – accumulating – injecting – hold – ejecting



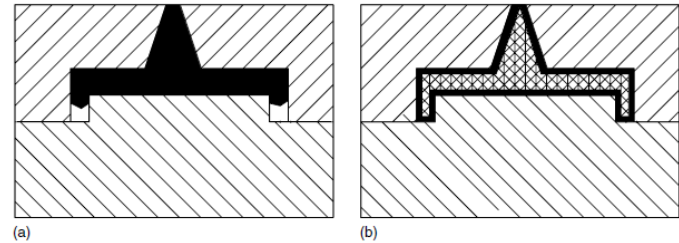
Injection molding

- clamping unit
 - press ~ ton
- mold ~ gram
 - sprue – runner – gate – cavity

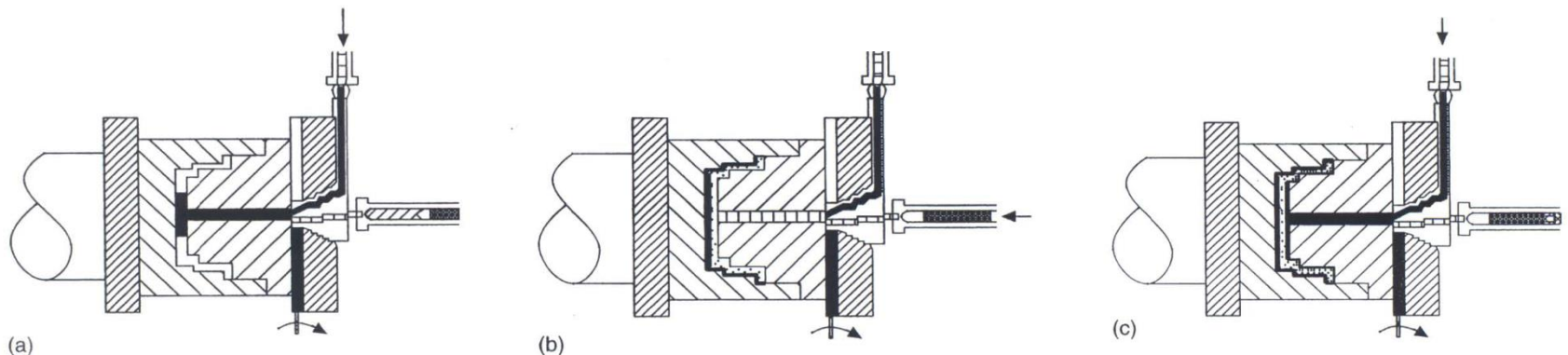


Variations of injection molding

- structural foam (injection) molding
 - short shot of (melt + gas or foaming agent)
 - resin skin + foam core

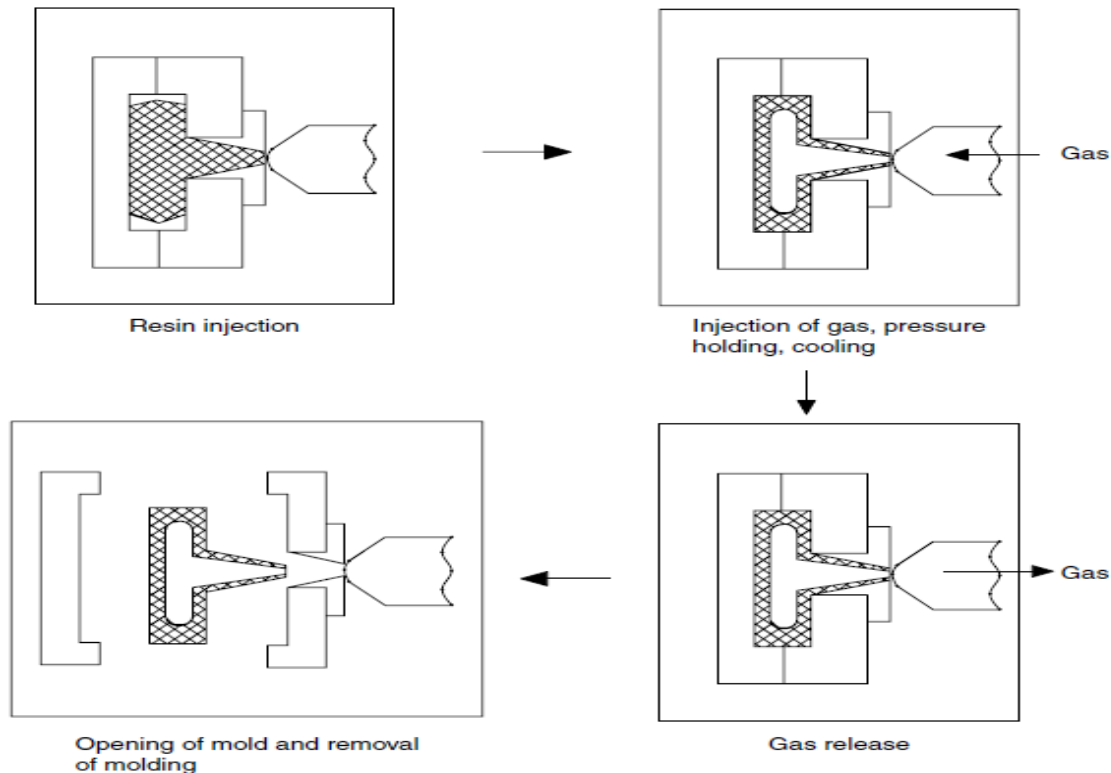


- sandwich molding [co-injection]
 - skin polymer – core polymer – skin polymer
 - for performance or cost

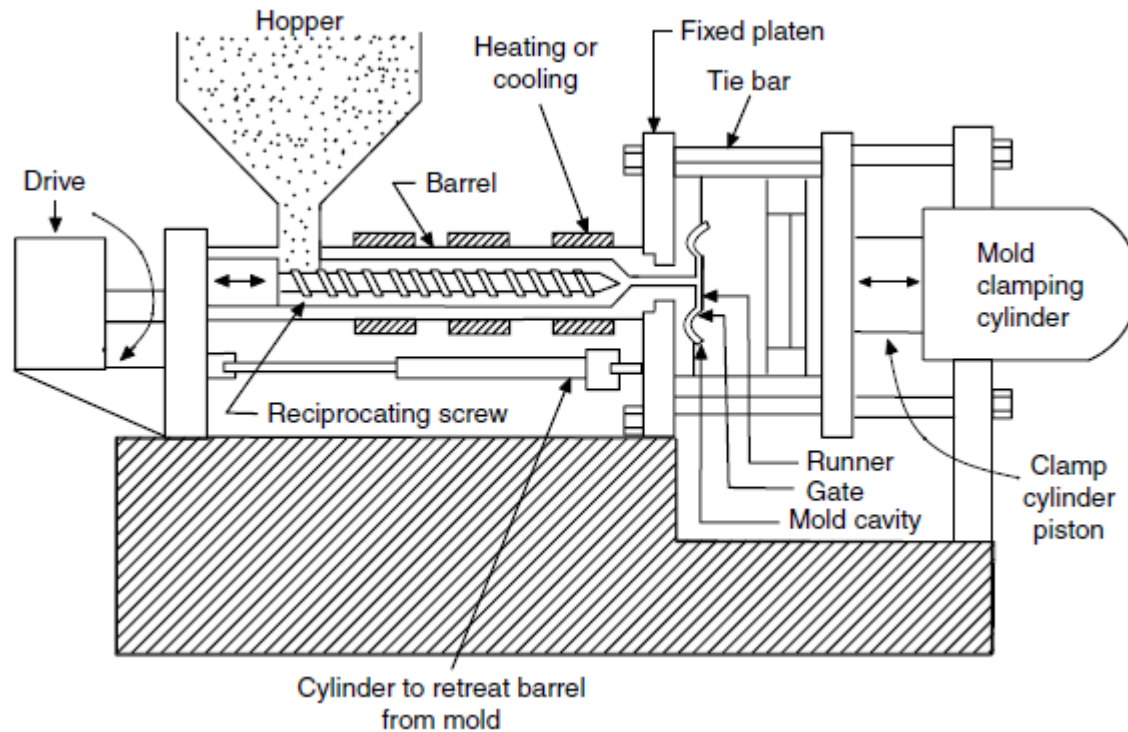


Variations of injection molding

- gas(-assisted) injection molding
 - resin injection – gas injection
 - for hollow parts
 - 'cinpres' [controlled injection pressure]



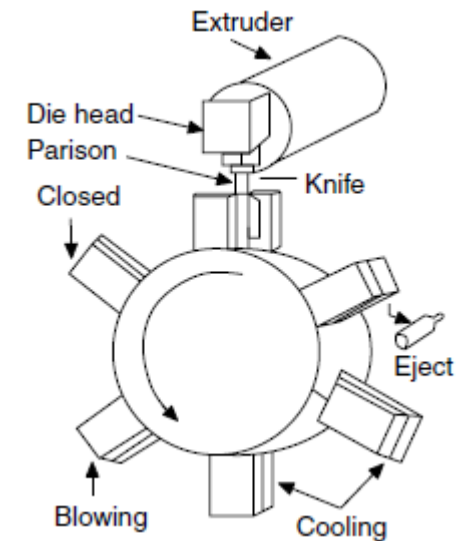
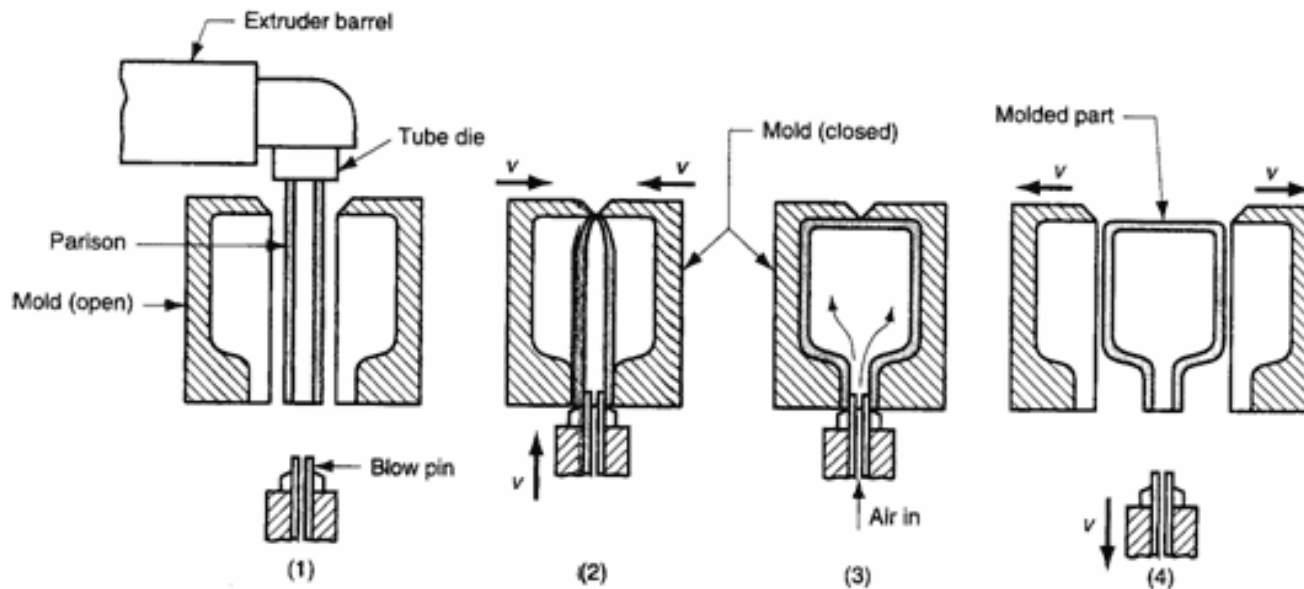
- injection molding for thermosets
 - screw transfer molding
 - warm barrel + hot mold
 - for thermosets and reinforced thermosets



Blow molding

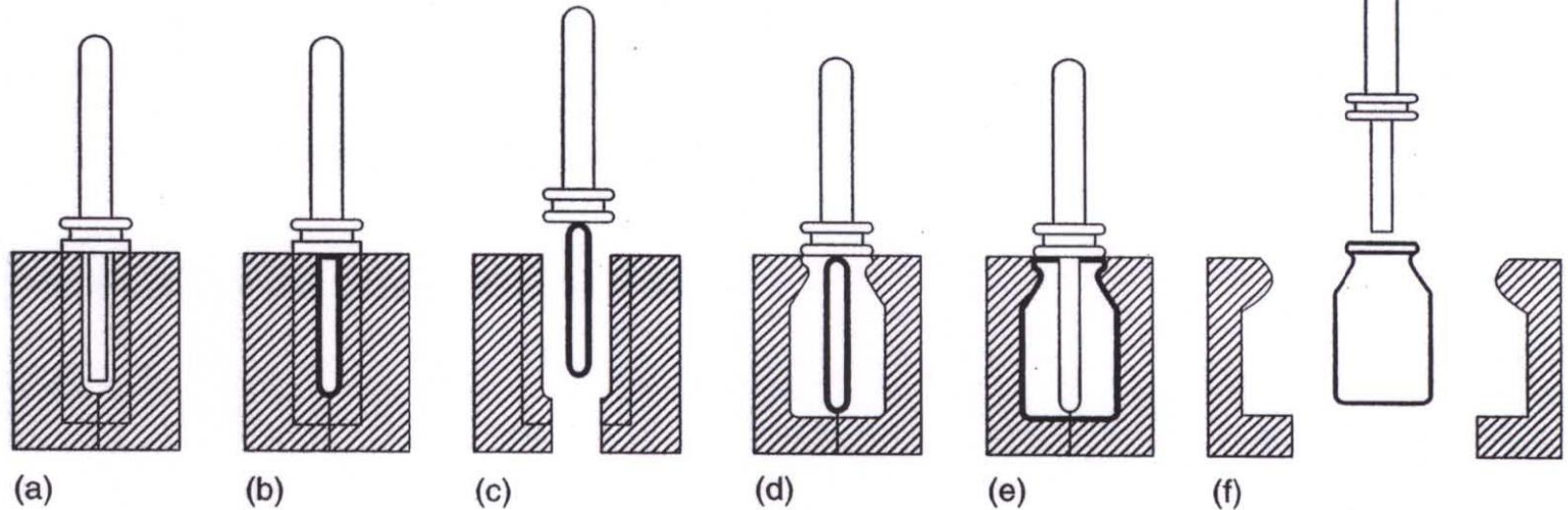
extrusion BM

- extrude 'parison' – close mold – blow – cool
- 1 mold
- for PE bottles



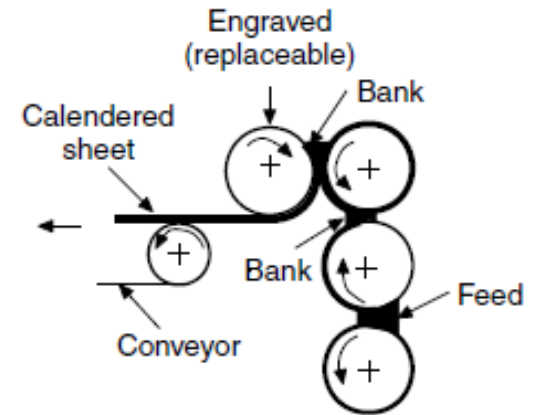
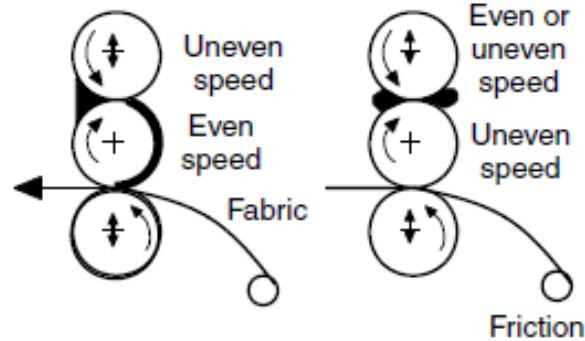
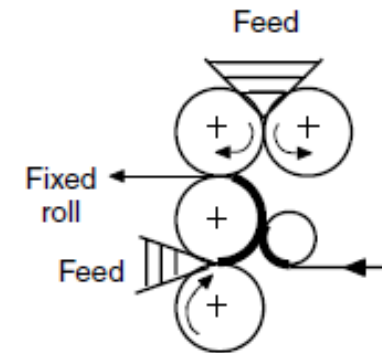
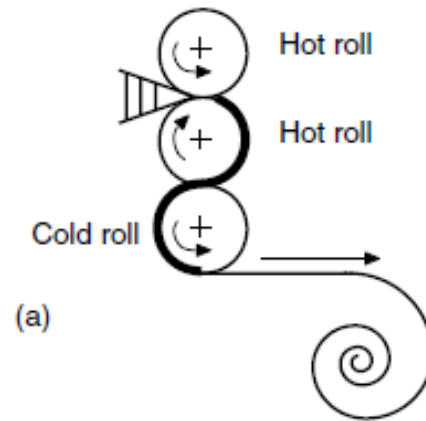
□ injection BM

- injection-mold 'preform' (onto metal core) – transfer to 2nd mold – blow
- for PET bottles
 - quench in 1st mold – reheat – blow in 2nd mold
 - 'stretch blow molding'



Calendering

- for films, sheets, coatings of
 - plasticized PVC
 - rubbers

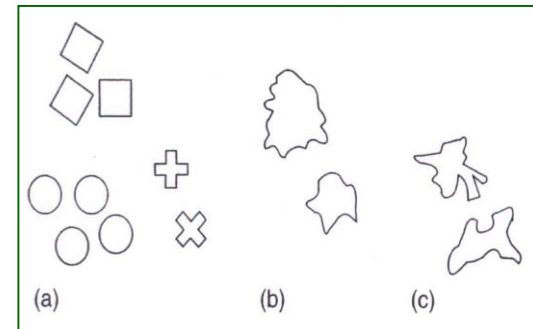
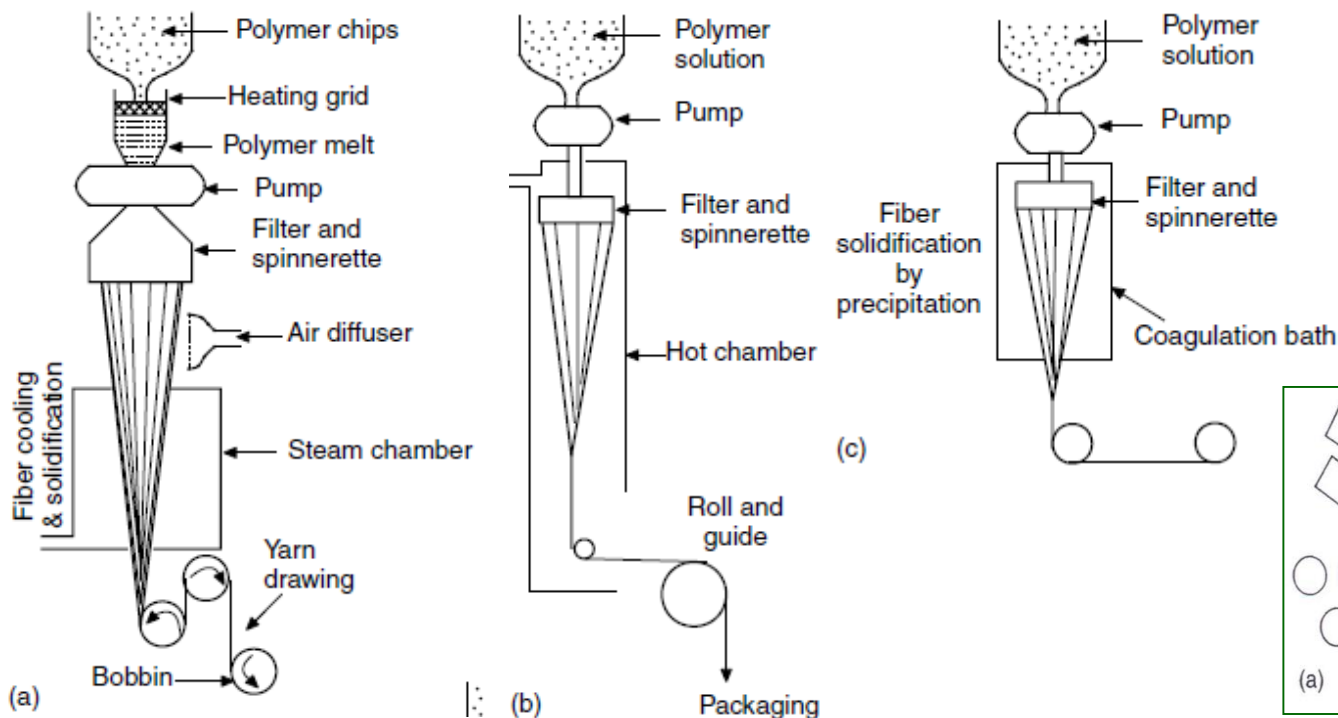


(c)

(d)

Fiber spinning

- for fibers
 - spinning through spinneret, then cold-drawing
- 3 types
 - melt ~ melt – cooled
 - dry ~ solution – solvent removed by heated gas
 - wet ~ solution – polymer ppt by nonsolvent



Thermoforming

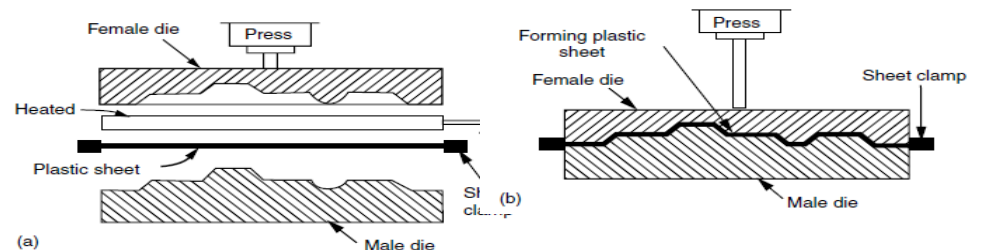
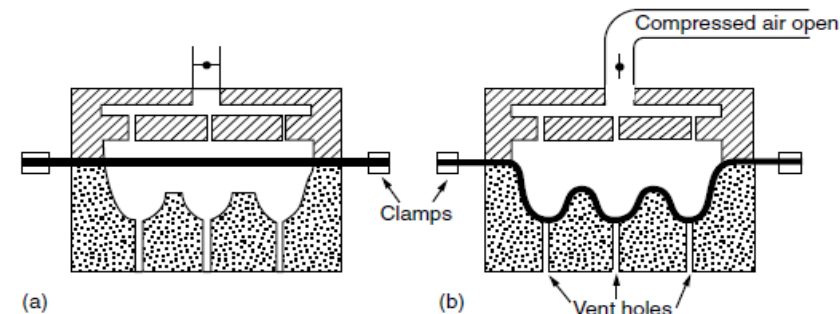
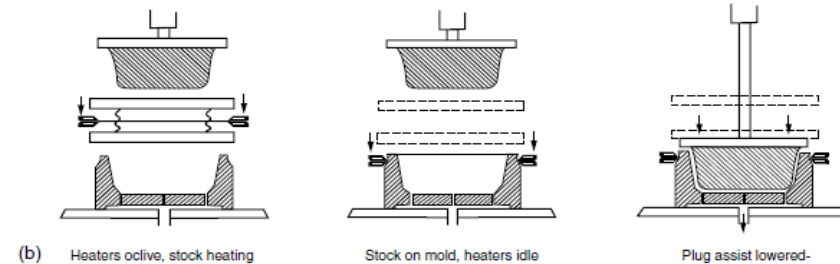
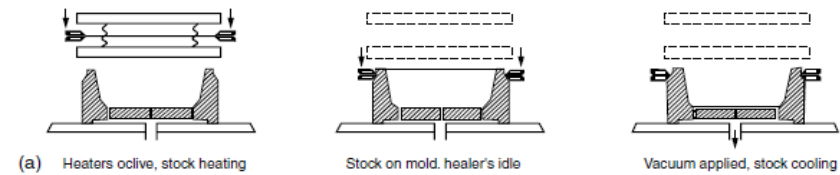
thermoplastics sheet heated and formed

types

- vacuum forming
- plug-assisted vac forming
- pressure forming
- mechanical forming

for simple shapes

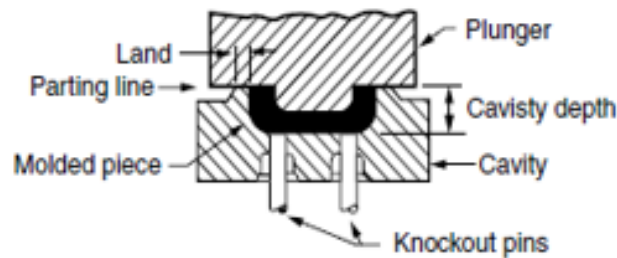
- cups
- bathtubs
- packaging



Compression and transfer molding Ch 21+e1 sl 34

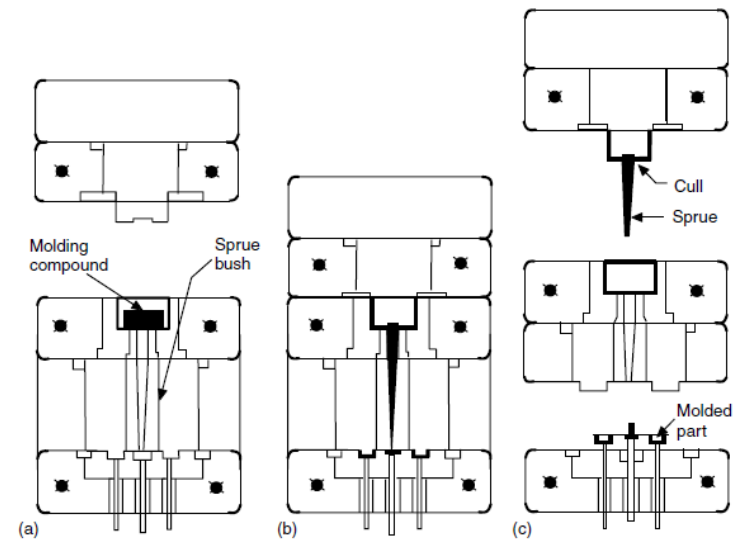
compression molding

- for thermosets
- weigh – preheat – load – compress – hold – open – remove
- holding for curing ~ cooling is not necessary



transfer molding

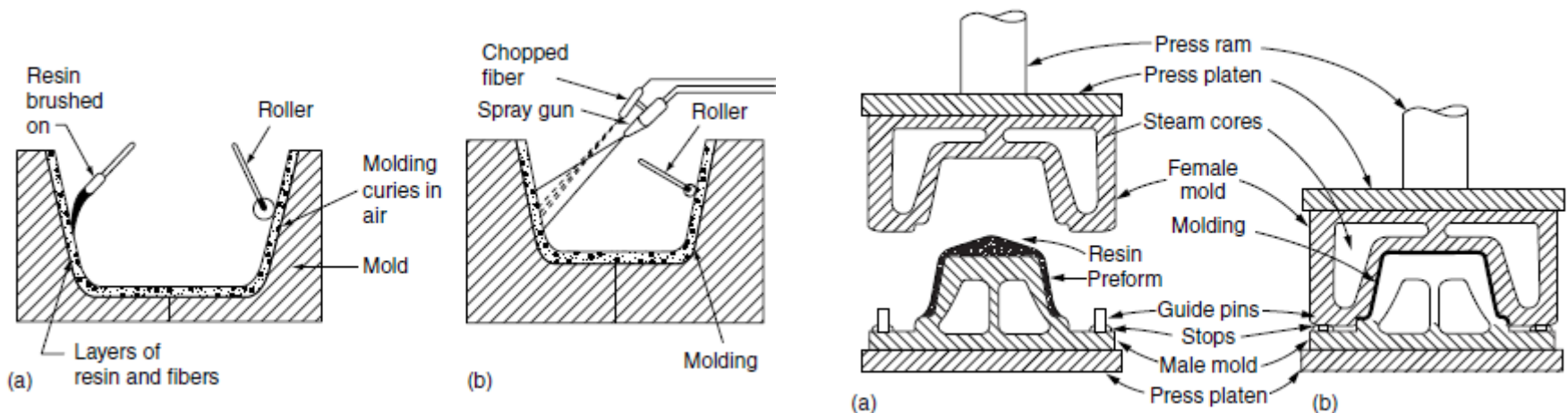
- for thermosets
- for smaller objects ~ multi-cavity
- injection + compression



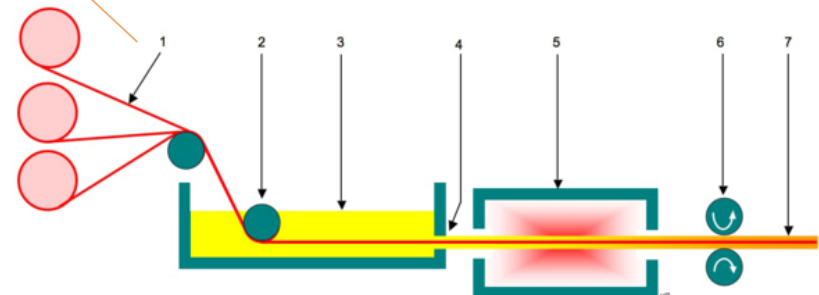
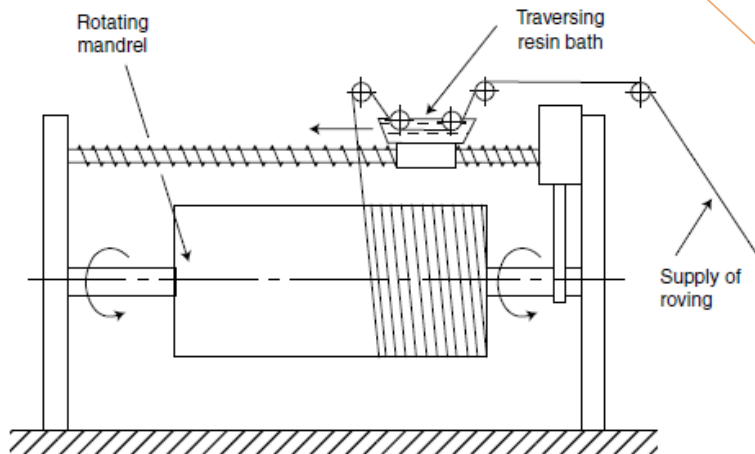
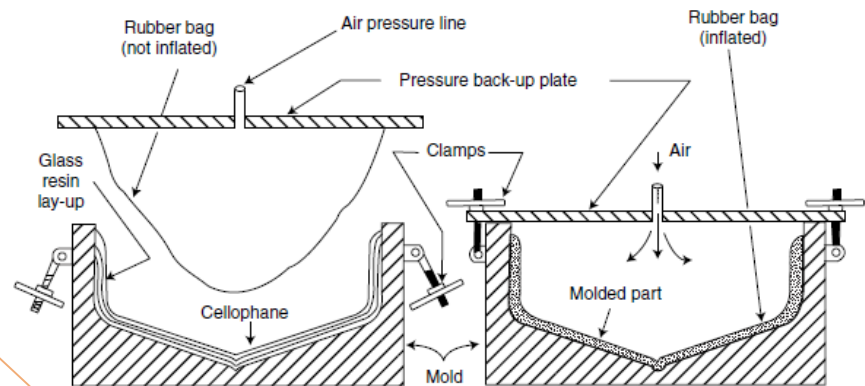
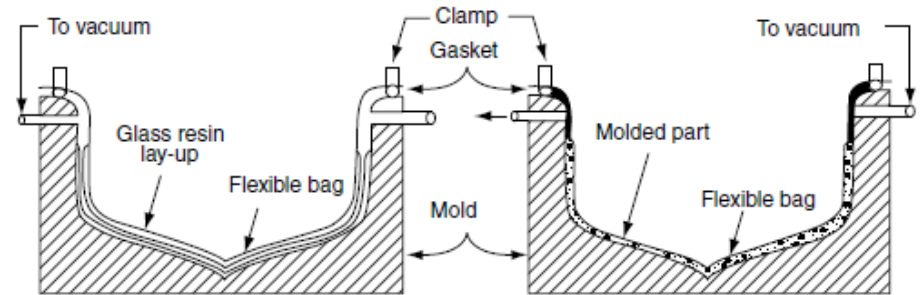
Processing of reinforced plastics

Ch 21+e1 sl 35

- hand lay-up
 - releasing agent – gelcoat – resin/reinforcement – resin
- spray-up
 - for chopped fiber
- preform molding
 - preform to general shape – transfer – press



- ❑ vacuum-bag molding
- ❑ pressure-bag molding
- ❑ pultrusion
 - ❑ unidirectional
- ❑ filament winding
 - ❑ hoop strength



Reaction injection molding [RIM]

Ch 21+e1 sl 37

- polymerization/curing in the mold
 - PU, nylon,---
 - nylon ~ prepolymer + C/L
 - linear or crosslinked
 - bumper, fender
- structural RIM
 - to mat, preform
- reinforced RIM
 - fiber mixed in feed
- resin transfer molding (RTM)
 - resin injection to mold with preform

