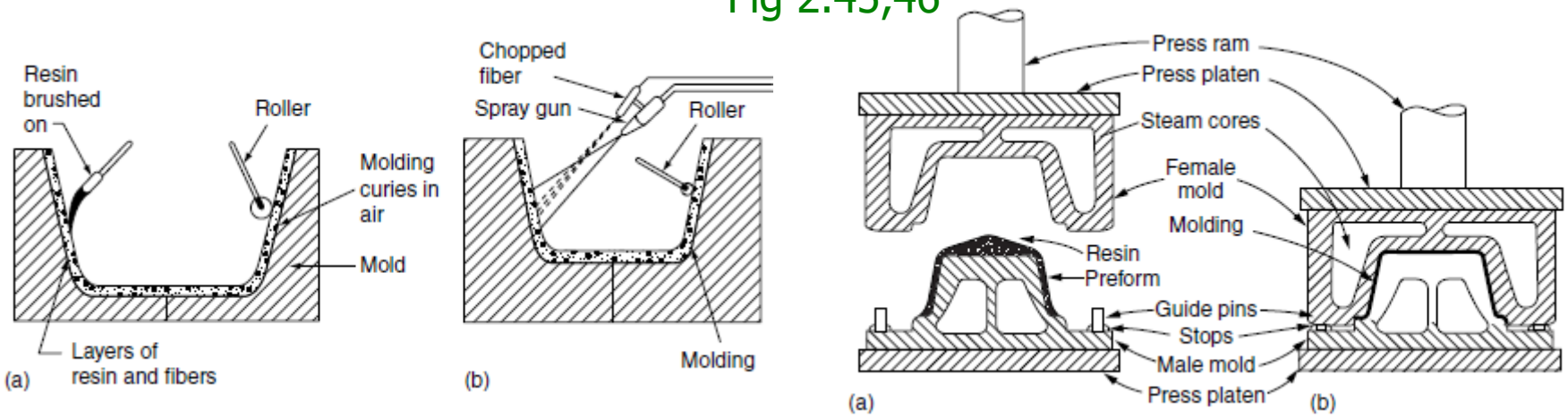
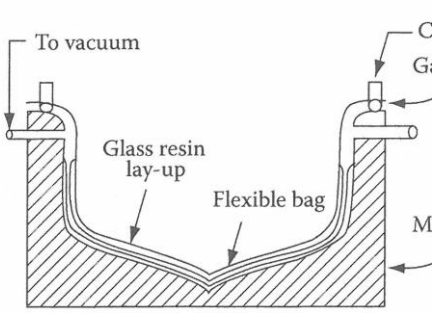
Processing of reinforced plastics

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

Fig 2.45,46



- vacuum-bag molding
- pressure-bag molding
- pultrusion
  - unidiectional
- filament winding
  - hoop strength



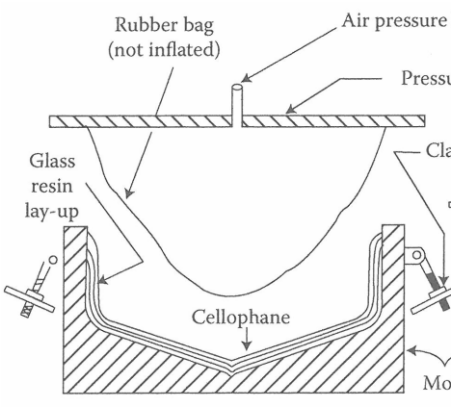


Fig 2.47,48

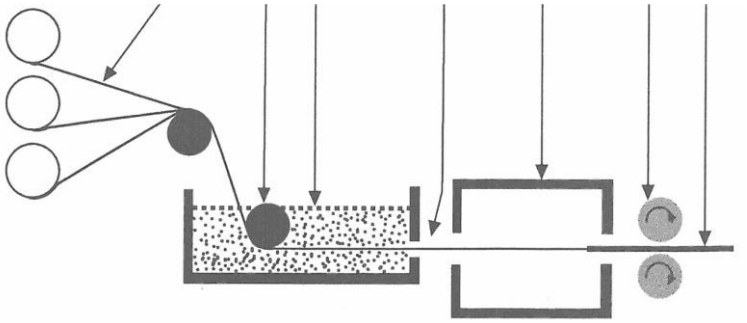
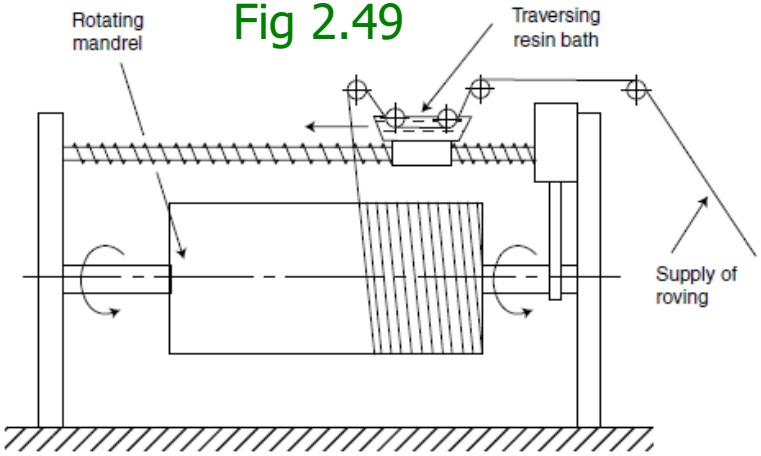


Fig 2.49



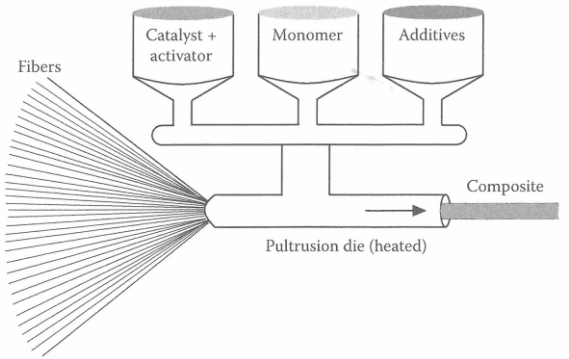
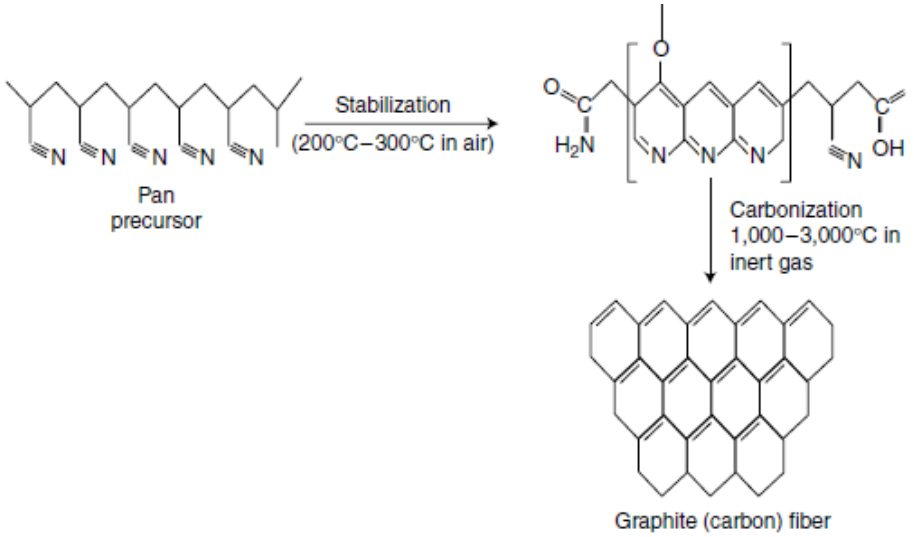


Fig 2.50 TS
Fig 2.51 TP

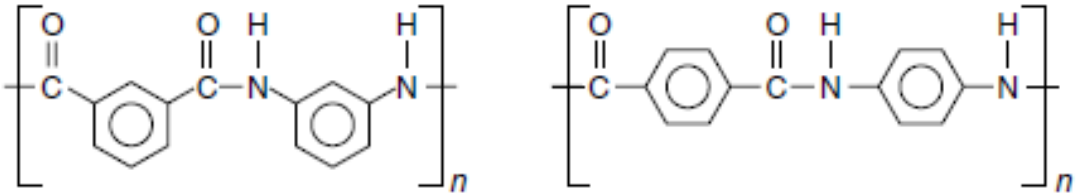
- compression molding
  - dough [bulk] molding compound (DMC [BMC])
    - short-fiber
  - sheet molding compound (SMC)
    - 2-D random fiber
  - thick molding compound (TMC)
    - 3-D random fiber
  - prepreg
    - 2-D unidirectional fibers
    - high-performance composite (multi-ply)

Fibers for FRP

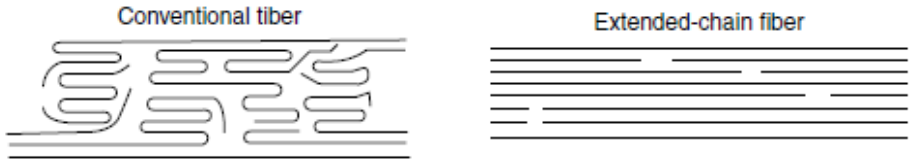
- glass fibers [GF]
  - A- (high alkali), E- (low alkali), S-, C-glass
- carbon (or graphite) fibers [CF]



- Aramid fibers
  - Nomex, Kevlar



- Spectra
  - UHMWPE extended-chain



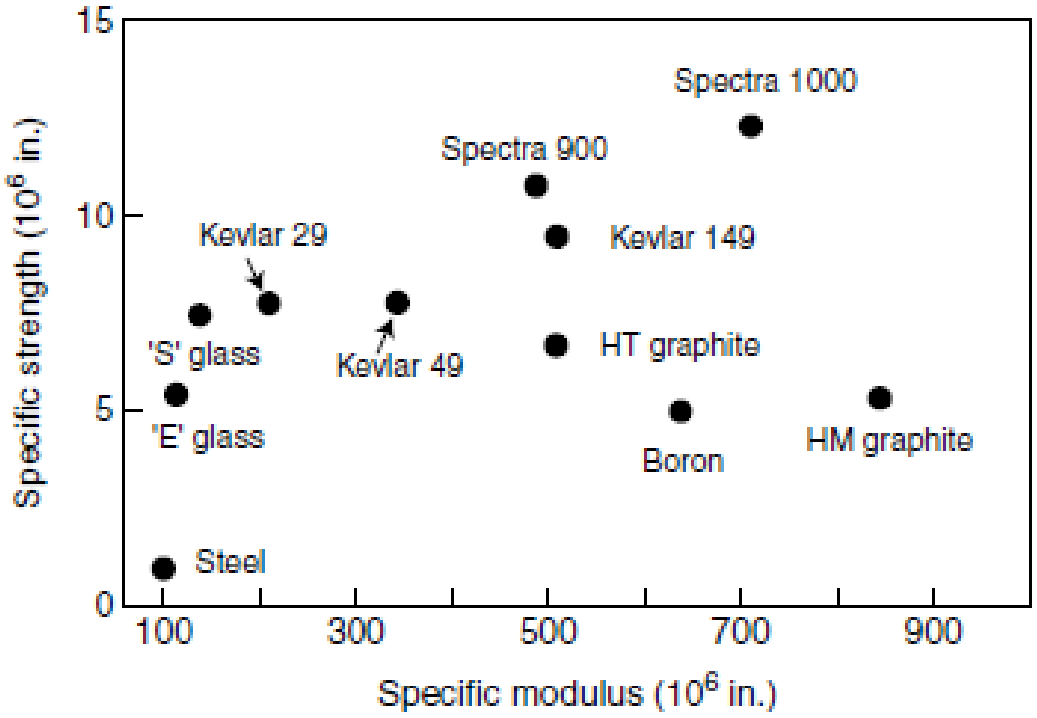


Fig 2.60

Reaction injection molding [RIM]

- polymerization/curing in the mold
  - PU ~ DI + polyol
  - 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

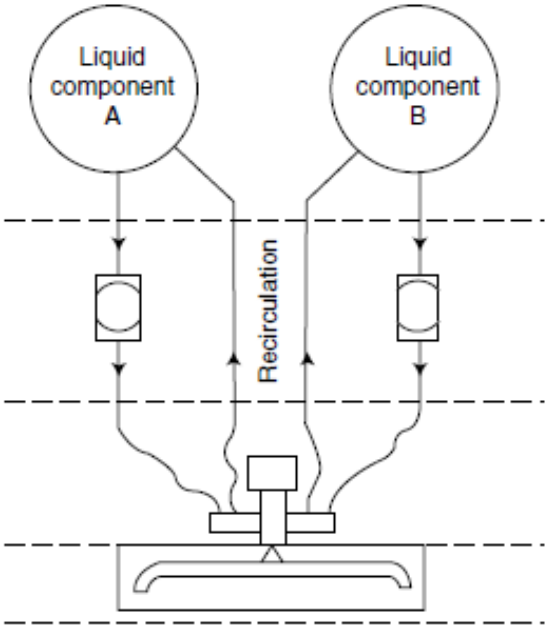


Fig 2.61

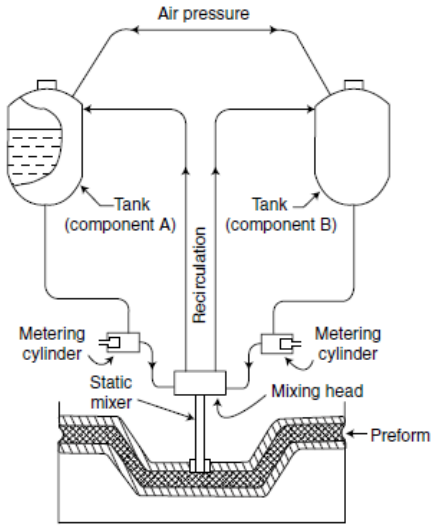


Fig 2.62

Foamed plastics

- foamed, cellular, or expanded plastics
- properties and applications
  - low density ~ cheap
  - low (heat) conductivity of air ~ (heat) insulator
  - high load-bearing/wt ~ load-bearing core
  - energy-dissipating ~ packaging, cushion

- types
  - by structure
    - open-cell ~ processed w/o pressure, better for cushioning
    - closed-cell ~ w/ pressure, better for insulating
  - by matrix (T_g, X_c, M_c) ~ flexible, semirigid, or rigid
  - by density ~ low, medium (.05-.35), high
  - special ~ structural, reinforced, syntactic

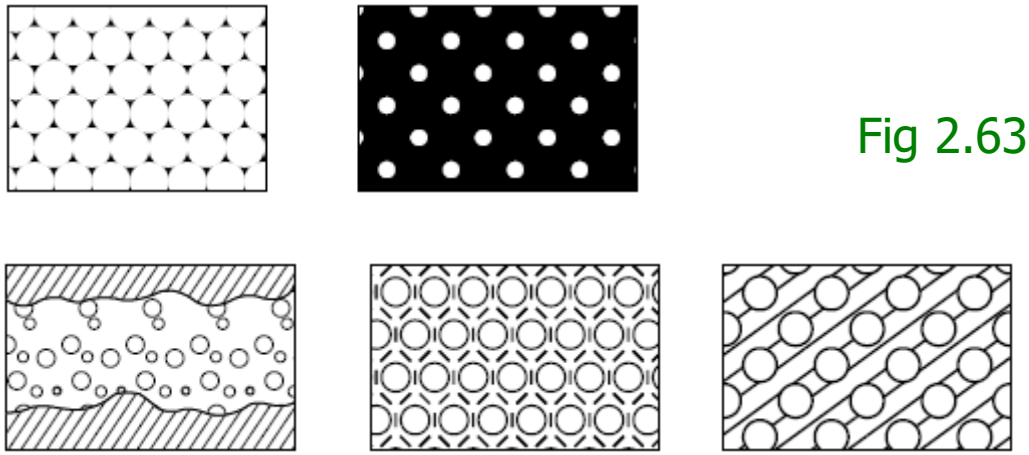


Fig 2.63

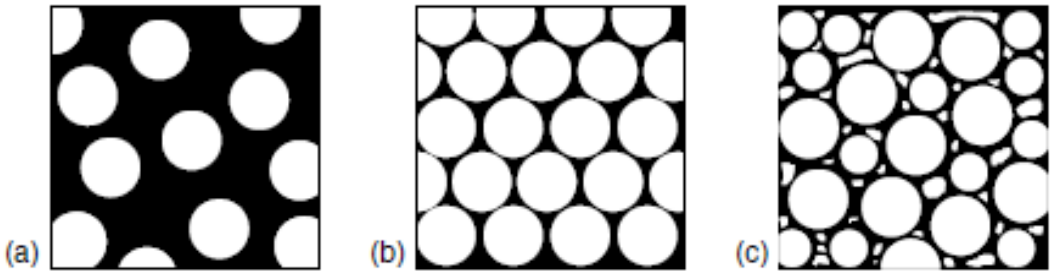
Foaming processes

- foaming
  - air ~ whipped into dispersion or solution ~ hardened
  - low bp liquid ~ volatilization
  - CO_2 ~ formed by reaction
  - gas (N_2) dissolved w/ pressure ~ expand
  - gas (N_2) ~ formed by decomposition of blowing [foaming] agent (Table 2.4)
  - hollow beads (syntactic)
  - CFC → HCFC, HC, CO_2
- stabilization
  - thermoplastics ~ physical ~ cooling
  - thermosets ~ chemical ~ Xlinking

Foamed plastics

- made of most polymers and to various forms
  - PS ~ EPS [XPS] ~ rigid, closed-cell
    - expanded, expandable, or structural foam
  - PO ~ flexible to rigid, linear or Xlinked
  - PU
    - flexible ~ high M_c, 'sponge'
      - one-shot (Table 2.2) or prepolymer (xs DI) process
    - semirigid to rigid ~ low M_c, better than most foams
      - many applications and processes
  - rubber ~ Table 2.3
  - epoxy, UF, PF, silicone, PVC (Fig 2.69), ---

- special foams
  - structural foams
    - one polymer or two polymers
  - syntactic foams [spheroplastics]
    - hollow microspheres embedded in polymer
    - multifoam ~ syntactic foam + foaming polymer
    - high resistance to compressive stress
  - reinforced foams
    - very high mechanical strength



3D printing

= additive manufacturing [AM]

- read CAD and add material(s) by layers
- methods
  - material extrusion (of thermoplastics filament)
  - material jetting (and curing of thermosets drops)
  - binding, sintering, melting (of various materials)
- applications
  - design mock-up, fast prototyping
  - flexible manufacturing
    - shape, size, time, place
    - resolution? ~ 100 μm

Rubber technology

- formulation
  - S
  - accelerator ~ reduce S, lower temp, prevent scorching [premature Xlinking] Table 2.5
  - activator ~ disperse accelerator
    - metal oxide/fatty acid (ZnO/stearic acid ~ universal)
  - processing aid ~ facilitate mixing
    - peptizer ~ chain-breaking
    - oils ~ softens
  - filler ~ reinforcing or cost-saving
    - carbon black
  - antioxidants, pigments, ---

- general process
  - premix with filler
  - mix with S, etc
  - preform ~ extrusion, calendering
  - cure and shape
- mixing
  - w/ or w/o mastication [chain-scission]
    - mastication necessary for NR
  - two-roll mill
  - internal mixer
- special types
  - reclaimed rubber
  - cellular rubber

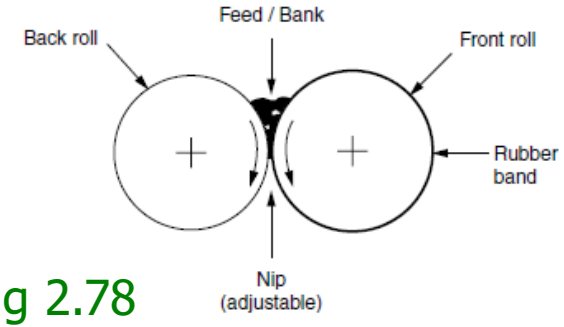
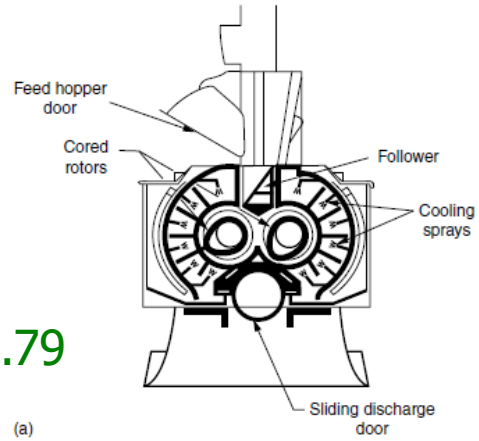
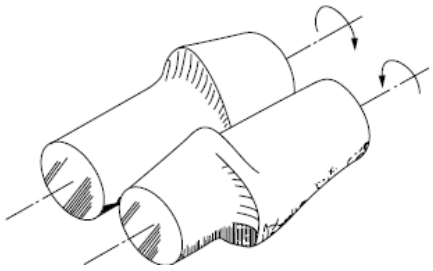


Fig 2.78



'Banbury' mixer Fig 2.79

'Haake' mixer

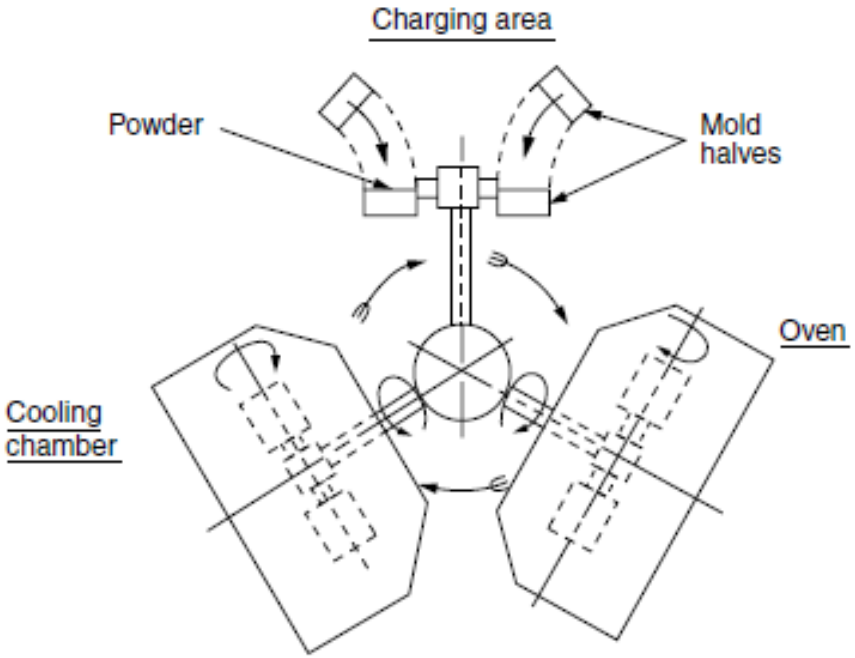


Coating

- materials
  - lacquer ~ polymer solution
  - latex [emulsion] paint ~ resin + additives in water
- process
  - extrusion coating
  - calendering
  - dip coating ~ plastisol casting, powder fluidized-bed
  - spray coating ~ powder heated or electrostatic
  - knife
  - brush

Powder molding

- for low T_m [T_g] polymer like PE
  - similar to casting of PVC plastisol
- static (sinter) molding
  - for open-end container
  - sintering ~ melting of surface only
  - the same to slush casting
- rotational molding
  - for large hollow
- centrifugal casting
  - for large tubes

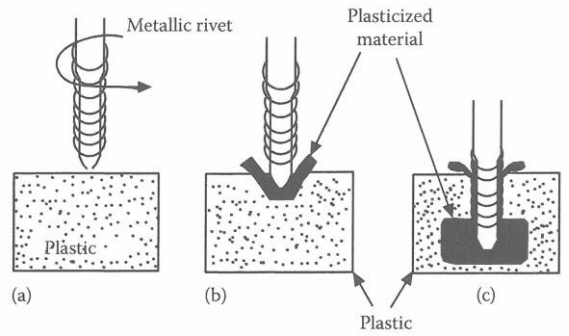


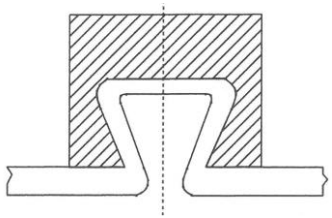
Bonding

- solvent cementing
  - use solvent or dope [= solvent + resin]
  - for thermoplastics
  - w/ or w/o pretreat
  - Table 2.12
- adhesive bonding
  - for thermoplastics and thermosets
  - use (polymeric or polymerizable) cements [adhesives]
  - doped or undoped
  - Table 2.13

Welding

- solvent welding = solvent cementing
- heat welding (of plastics)
  - hot gas
  - fusion (with hot tool)
  - friction or spin
  - dielectric (for high loss polymers)
  - ultrasonic
- joining polymer-metal hybrids
  - with or without adhesives
  - friction-riveting
  - over-molding, clinch-lock





Decoration of plastics

- coloring ~ pigments
- surface decoration
  - may need pretreatment
    - esp for PO, acetal, fluoropolymers
    - chemical, flame, corona discharge, plasma
  - painting
    - with or without primer
  - printing
    - gravure, flexography, (silk) screen, pad

- hot-stamping ~ transfer coated foil
- in-mold decorating
  - during injection or compression molding
- embossing ~ texture
  - roller or press
- electroplating
  - pretreated plastic as the cathode
- vacuum metallizing ~ vacuum deposition
  - very thin and delicate