Manufacturing Process

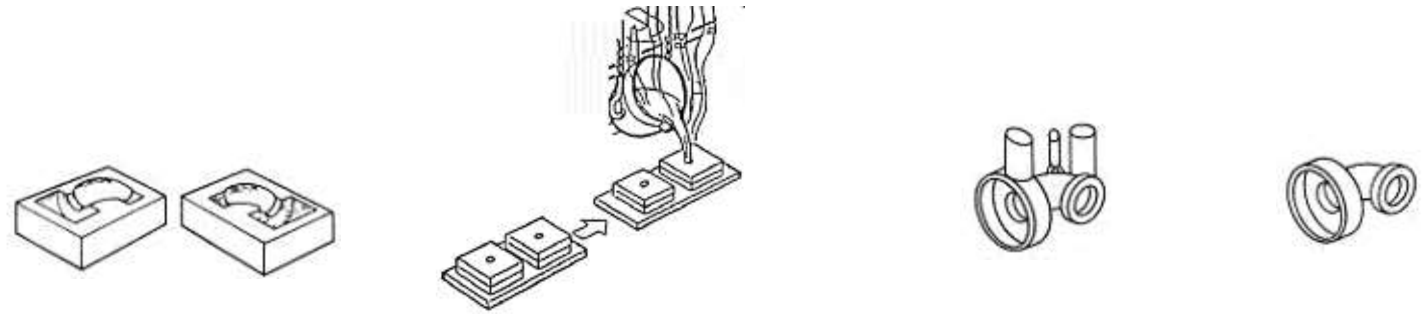
Sub Code :17AT104
Program Code : 3UABVOC(AT)
Trade : Automobile

M.Vinoth M.E.,
Guest Faculty
DDU Kaushal Kendra

Traditional Manufacturing Processes

- Casting
- Forming
- Sheet metal processing
- Powder- and Ceramics Processing
- Plastics processing
- Cutting
- Joining
- Surface treatment

Casting



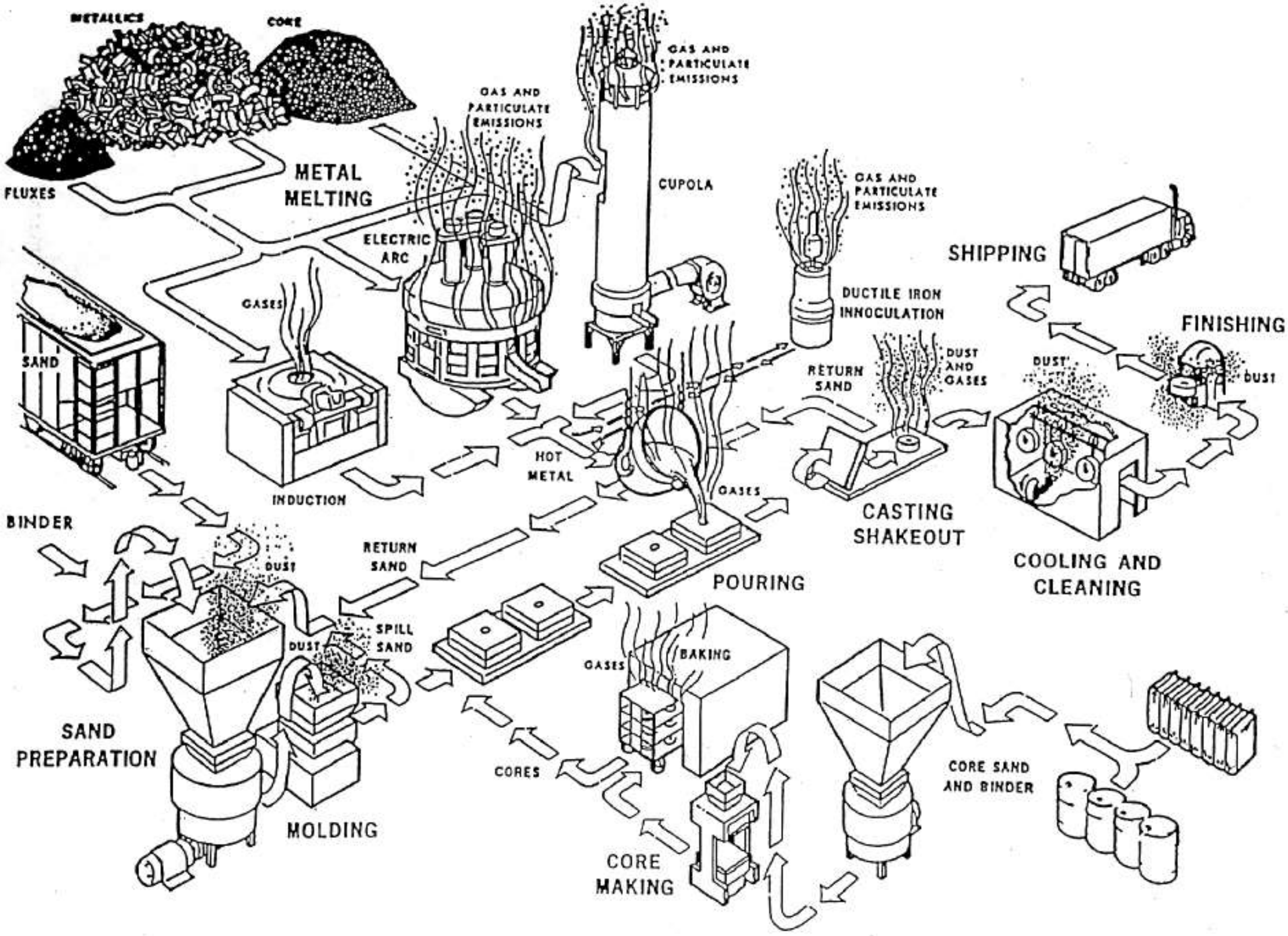
Refractory mold → pour liquid metal → solidify, remove → finish

- VERSATILE: complex geometry, internal cavities, hollow sections
- VERSATILE: small (~10 grams) → very large parts (~1000 Kg)
- ECONOMICAL: little wastage (extra metal is re-used)
- ISOTROPIC: cast parts have same properties along all directions

Different Casting Processes

Process	Advantages	Disadvantages	Examples
Sand	many metals, sizes, shapes, cheap	poor finish & tolerance	engine blocks, cylinder heads
Shell mold	better accuracy, finish, higher production rate	limited part size	connecting rods, gear housings
Expendable pattern	Wide range of metals, sizes, shapes	patterns have low strength	cylinder heads, brake components
Plaster mold	complex shapes, good surface finish	non-ferrous metals, low production rate	prototypes of mechanical parts
Ceramic mold	complex shapes, high accuracy, good finish	small sizes	impellers, injection mold tooling
Investment	complex shapes, excellent finish	small parts, expensive	jewellery
Permanent mold	good finish, low porosity, high production rate	Costly mold, simpler shapes only	gears, gear housings
Die	Excellent dimensional accuracy, high production rate	costly dies, small parts, non-ferrous metals	gears, camera bodies, car wheels
Centrifugal	Large cylindrical parts, good quality	Expensive, few shapes	pipes, boilers, flywheels

Sand Casting



Sand Casting

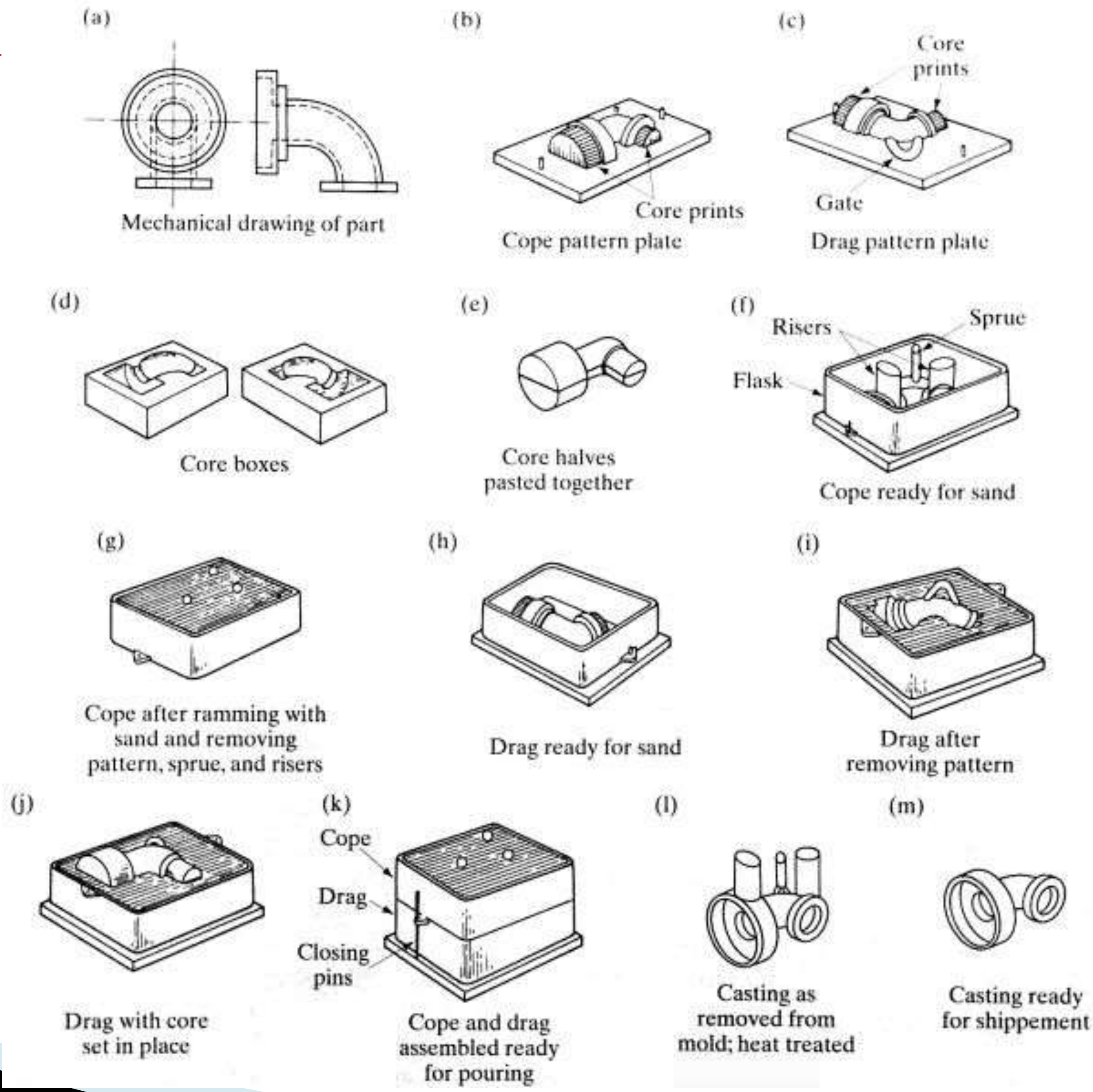
cope: top half

drag: bottom half

core: for internal cavities

pattern: positive

funnel → **sprue** →
→ **runners** → **gate** →
→ **cavity** →
→ {**risers, vents**}



Sand Casting Considerations

(a) How do we make the **pattern**?

[cut, carve, machine]

(b) Why is the pattern not exactly identical to the part shape?

- pattern → outer surfaces; (inner surfaces: core)
- shrinkage, post-processing

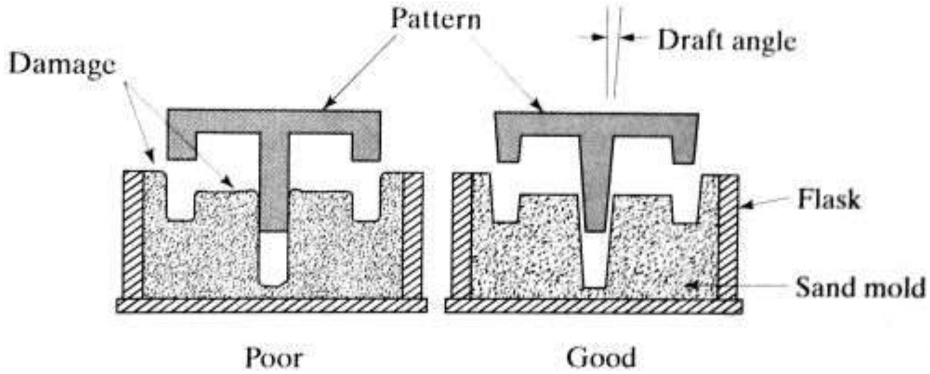
(c) **parting line**

- how to determine?

Sand Casting Considerations..

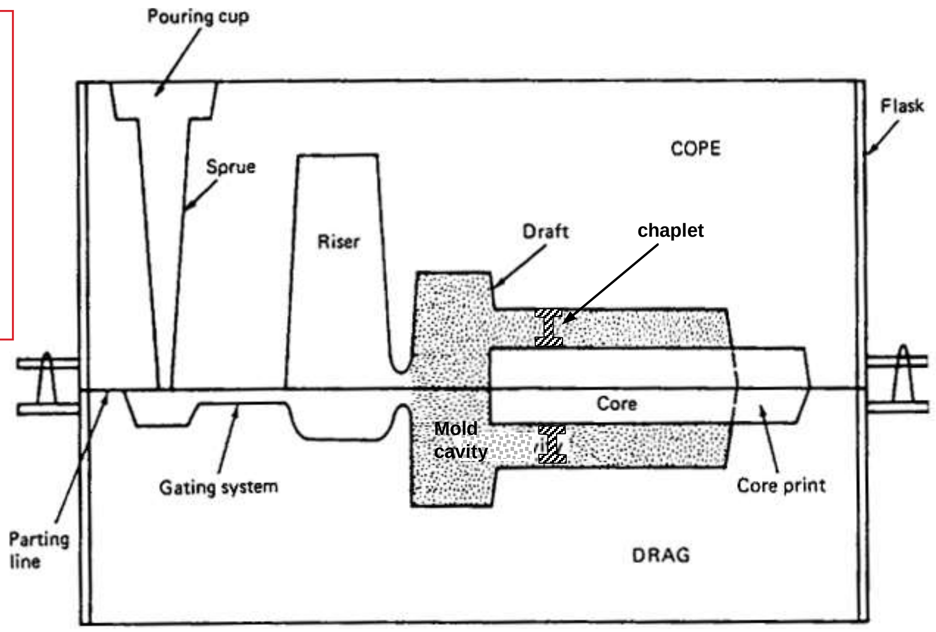
(d) **taper**

- do we need it ?



(e) **core prints, chaplets**

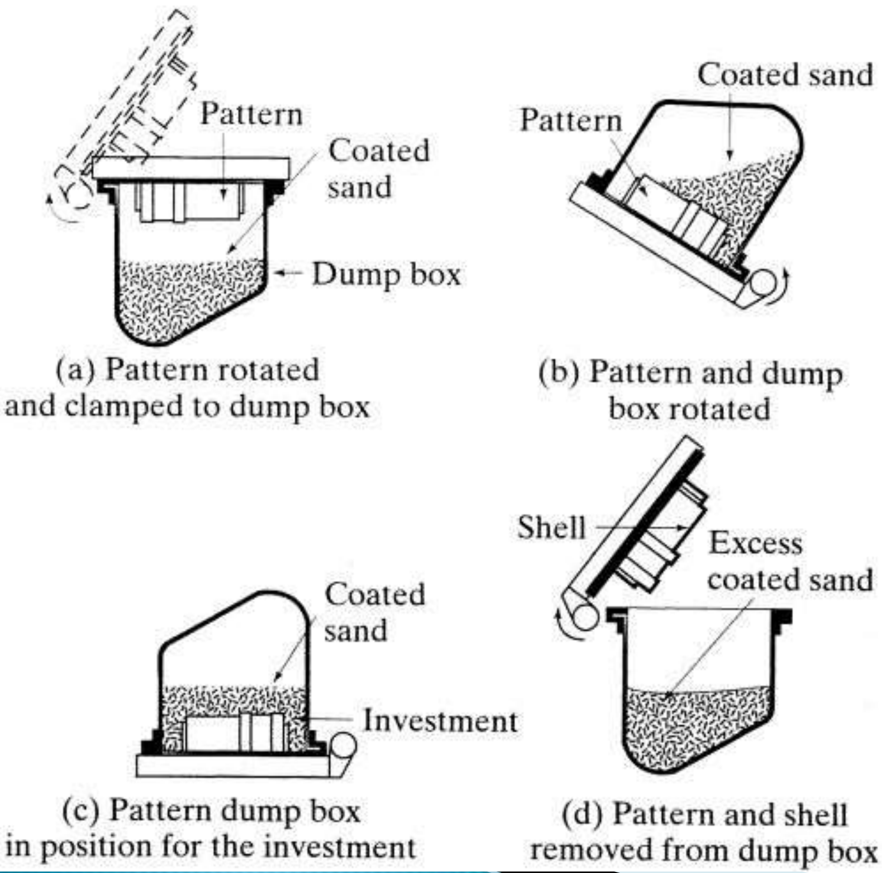
- hold the core in position
- chaplet is metal (why?)

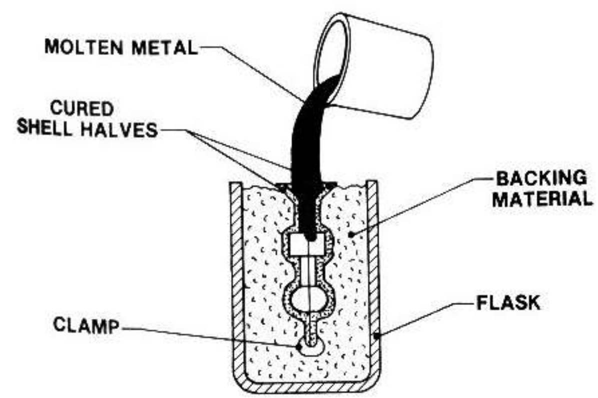


(f) **cut-off, finishing**

Shell mold casting

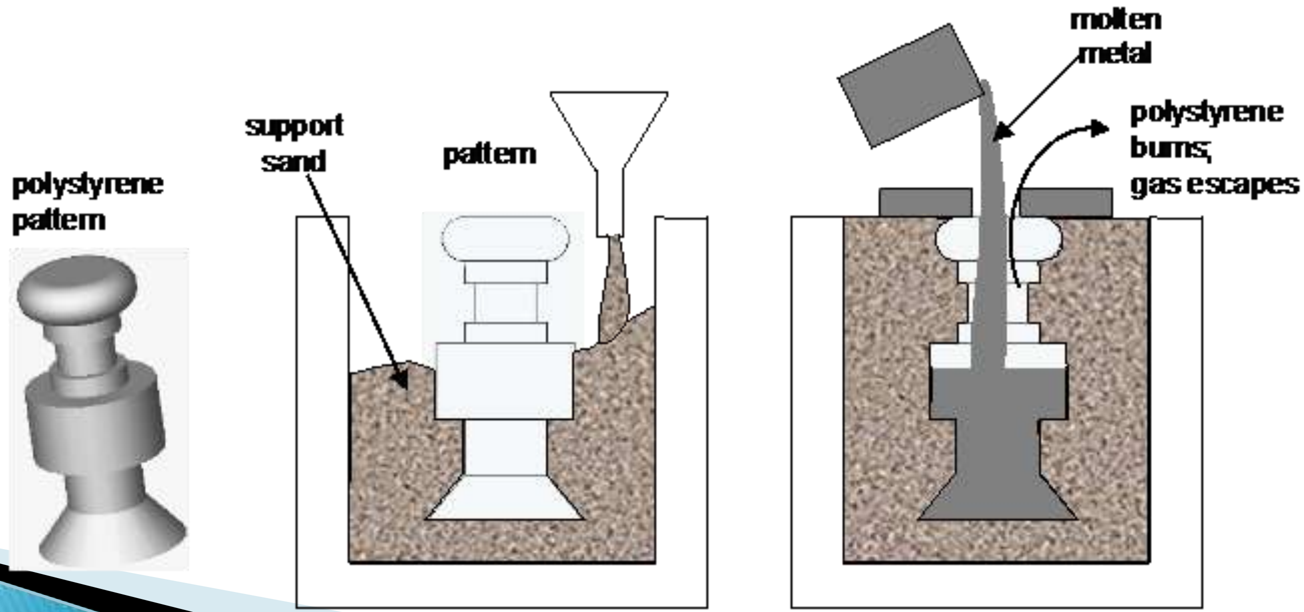
- metal, 2-piece *pattern*, 175°C-370°C
- coated with a lubricant (silicone)
- mixture of sand, thermoset resin/epoxy
- cure (baking)
- remove patterns, join half-shells → mold
- pour metal
- solidify (cooling)
- break shell → part





Expendable Mold Casting

- Styrofoam pattern
- dipped in refractory slurry → dried
- sand (support)
- pour liquid metal
- foam evaporates, metal fills the shell
- cool, solidify
- break shell → part



Plaster-mold, Ceramic-mold casting

Plaster-mold slurry: *plaster of paris* ($CaSO_4$), talc, silica flour

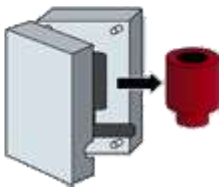
Ceramic-mold slurry: silica, powdered Zircon ($ZrSiO_4$)

- The slurry forms a shell over the pattern
- Dried in a low temperature oven
- Remove pattern
- Backed by clay (strength), baked (burn-off volatiles)
- cast the metal
- break mold → part

Plaster-mold: *good finish (Why ?)*
plaster: low conductivity => low warpage, residual stress
low mp metal (Zn, Al, Cu, Mg)

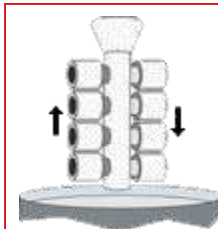
Ceramic-mold: good finish
high mp metals (steel, …) => impeller blades, turbines, …

Investment casting (lost wax casting)



(a) Wax pattern
(injection molding)

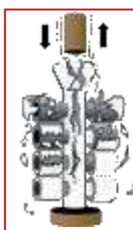
(b) Multiple patterns
assembled to wax sprue



(c) Shell built →
immerse into ceramic slurry
→ immerse into fine sand
(few layers)

(d) dry ceramic
melt out the wax
fire ceramic (burn wax)

(e) Pour molten metal (gravity)
→ cool, solidify
[Hollow casting:
pouring excess metal before solidification

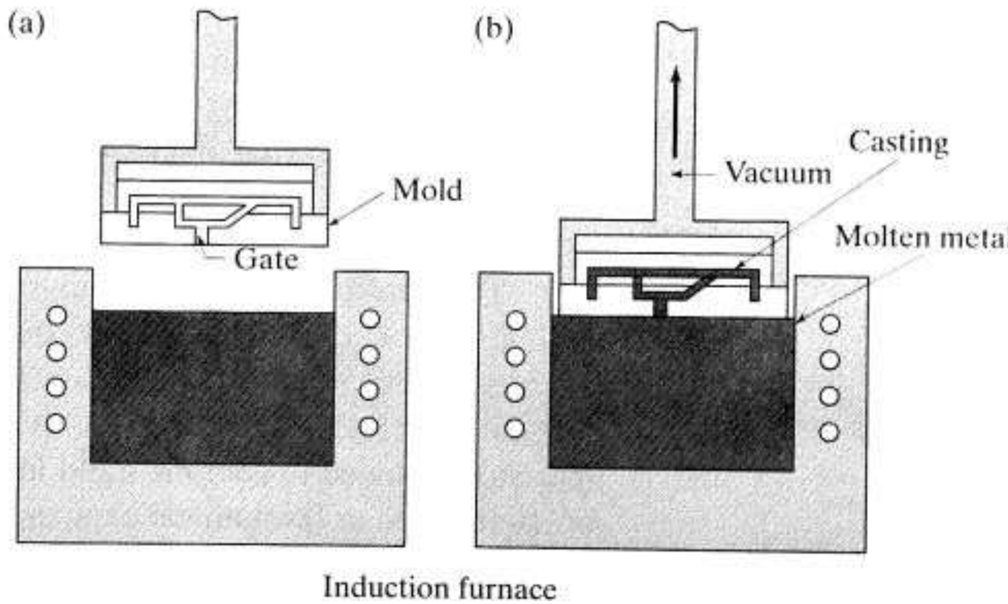


(f) Break ceramic shell
(vibration or water blasting)

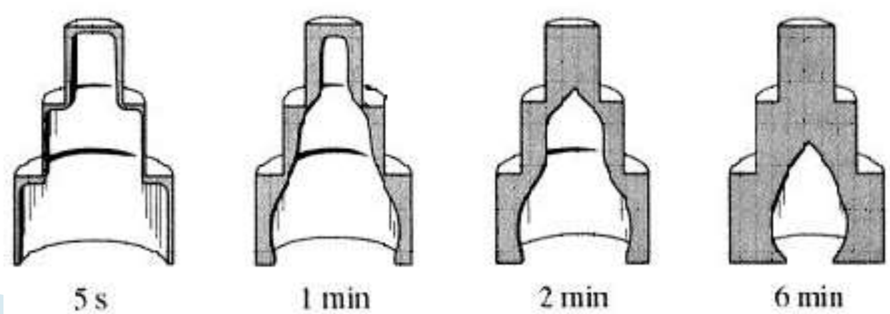
(g) Cut off parts
(high-speed friction saw)
→ finishing (polish)

Vacuum casting

Similar to investment casting, except: fill mold by reverse gravity



Easier to make hollow casting: early pour out



Permanent mold casting

MOLD: made of metal (cast iron, steel, refractory alloys)

CORE: (hollow parts)
- metal: core can be extracted from the part
- sand-bonded: core must be destroyed to remove

Mold-surface: coated with refractory material

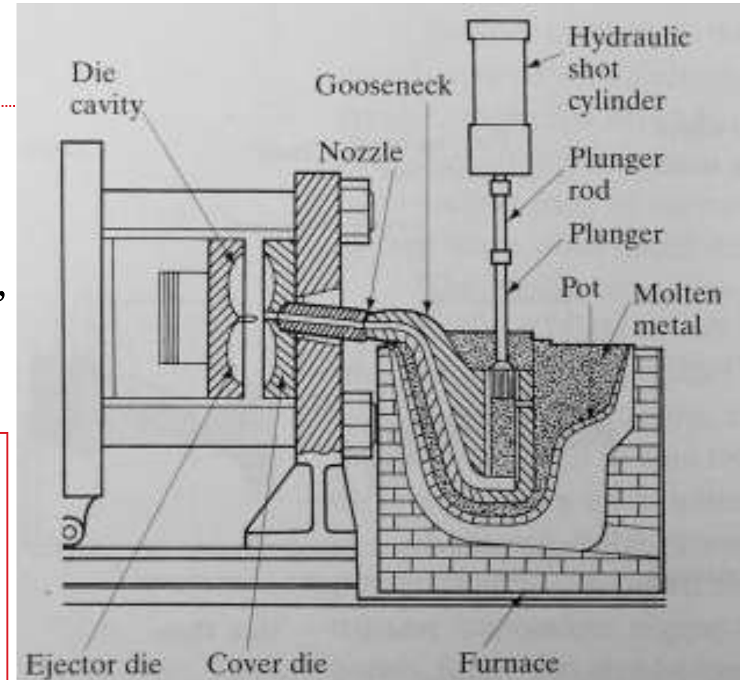
- Spray with lubricant (graphite, silica)
  - improve flow, increase life

- good tolerance, good surface finish

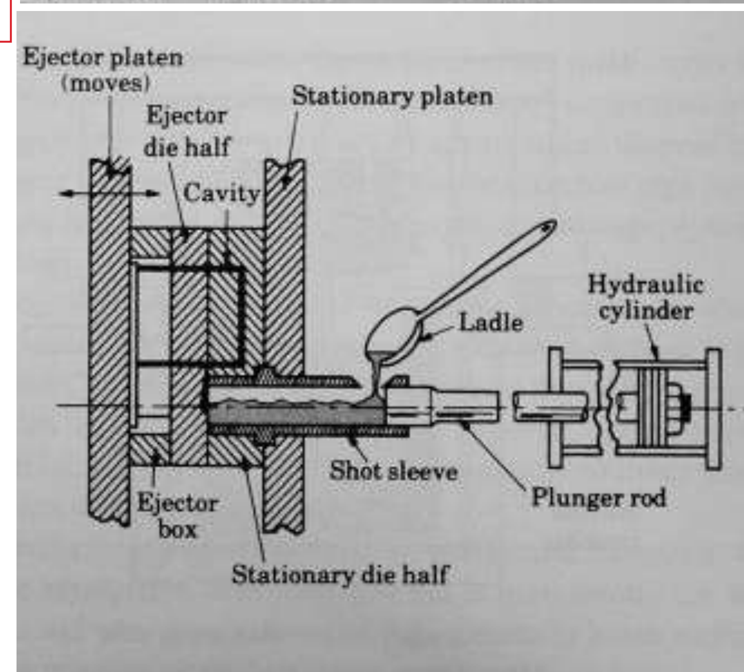
- low mp metals (Cu, Bronze, Al, Mg)

Die casting

- a type of permanent mold casting
- common uses: components for
  rice cookers, stoves, fans, washing-, drying machines, fridges, motors, toys, hand-tools, car wheels, …



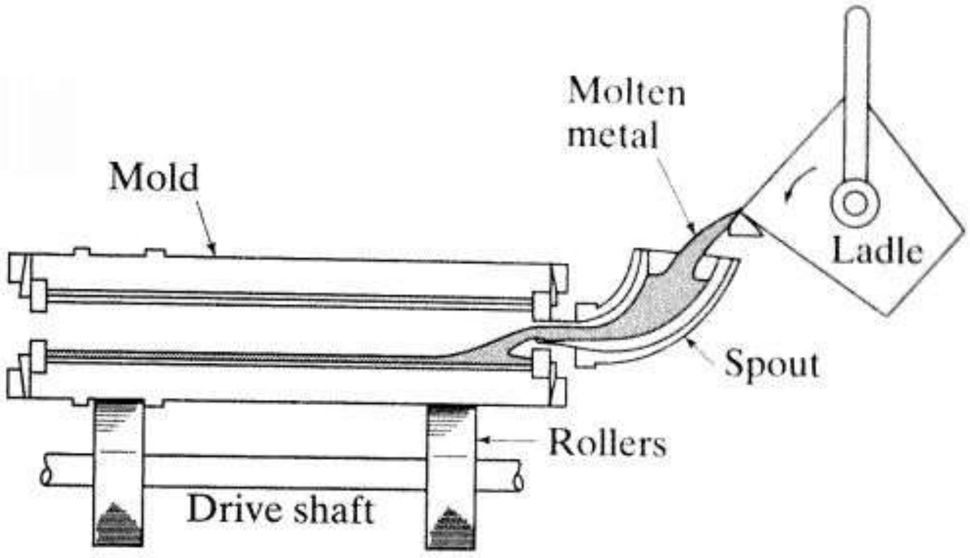
HOT CHAMBER: (low mp e.g. Zn, Pb; non-alloying)
(i) die is closed, gooseneck cylinder is filled with molten metal
(ii) plunger pushes molten metal through gooseneck into cavity
(iii) metal is held under pressure until it solidifies
(iv) die opens, cores retracted; plunger returns
(v) ejector pins push casting out of ejector die



COLD CHAMBER: (high mp e.g. Cu, Al)
(i) die closed, molten metal is ladled into cylinder
(ii) plunger pushes molten metal into die cavity
(iii) metal is held under high pressure until it solidifies
(iv) die opens, plunger pushes solidified slug from the cylinder
(v) cores retracted
(iv) ejector pins push casting off ejector die

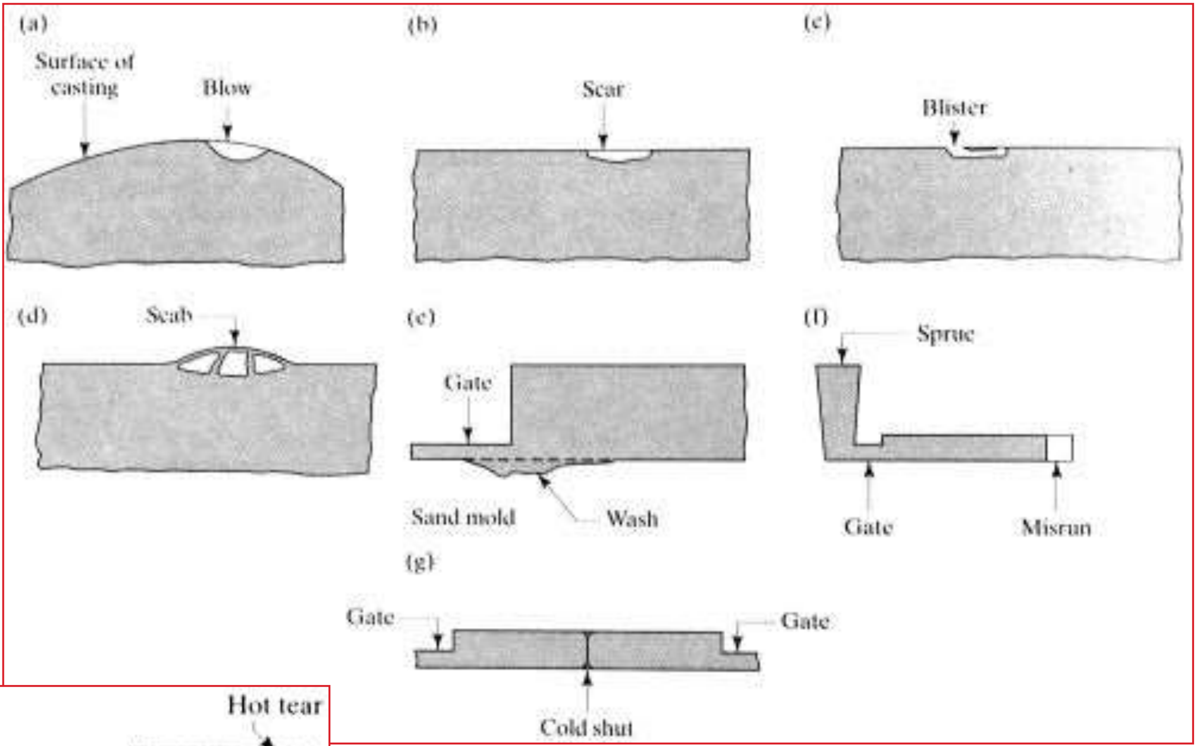
Centrifugal casting

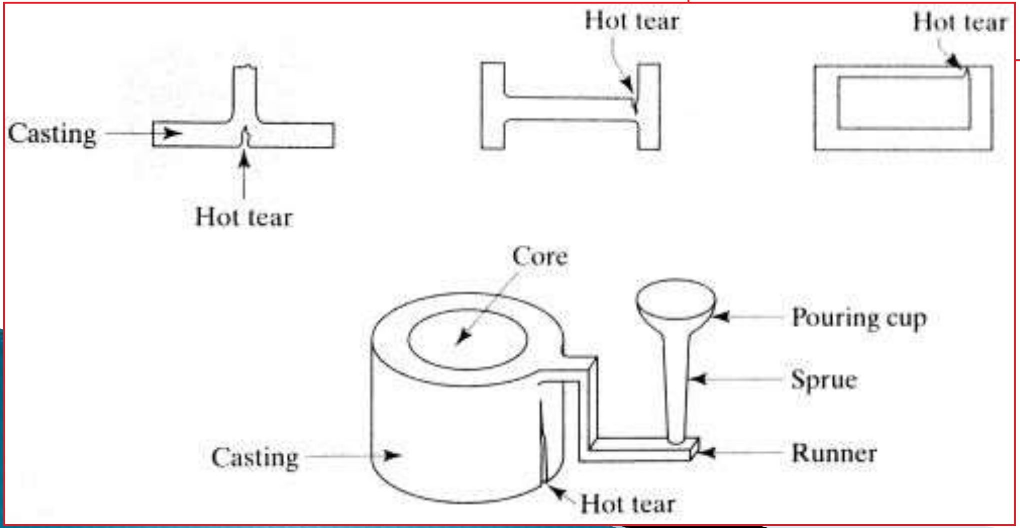
- permanent mold
- rotated about its axis at 300 ~ 3000 rpm
- molten metal is poured



- Surface finish: better along outer diameter than inner,
- Impurities, inclusions, closer to the inner diameter (why ?)

Casting Design: Typical casting defects

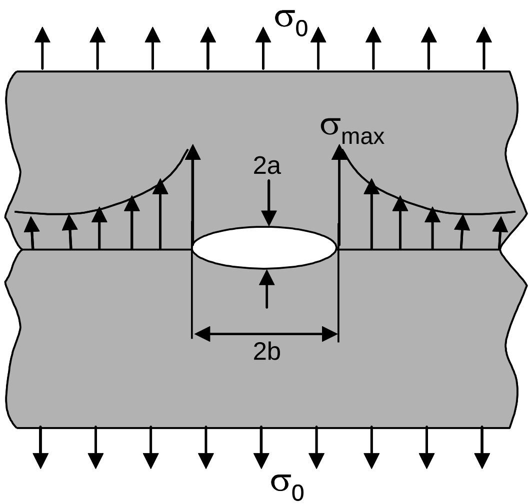




Casting Design: Defects and Associated Problems

- Surface defects: finish, stress concentration

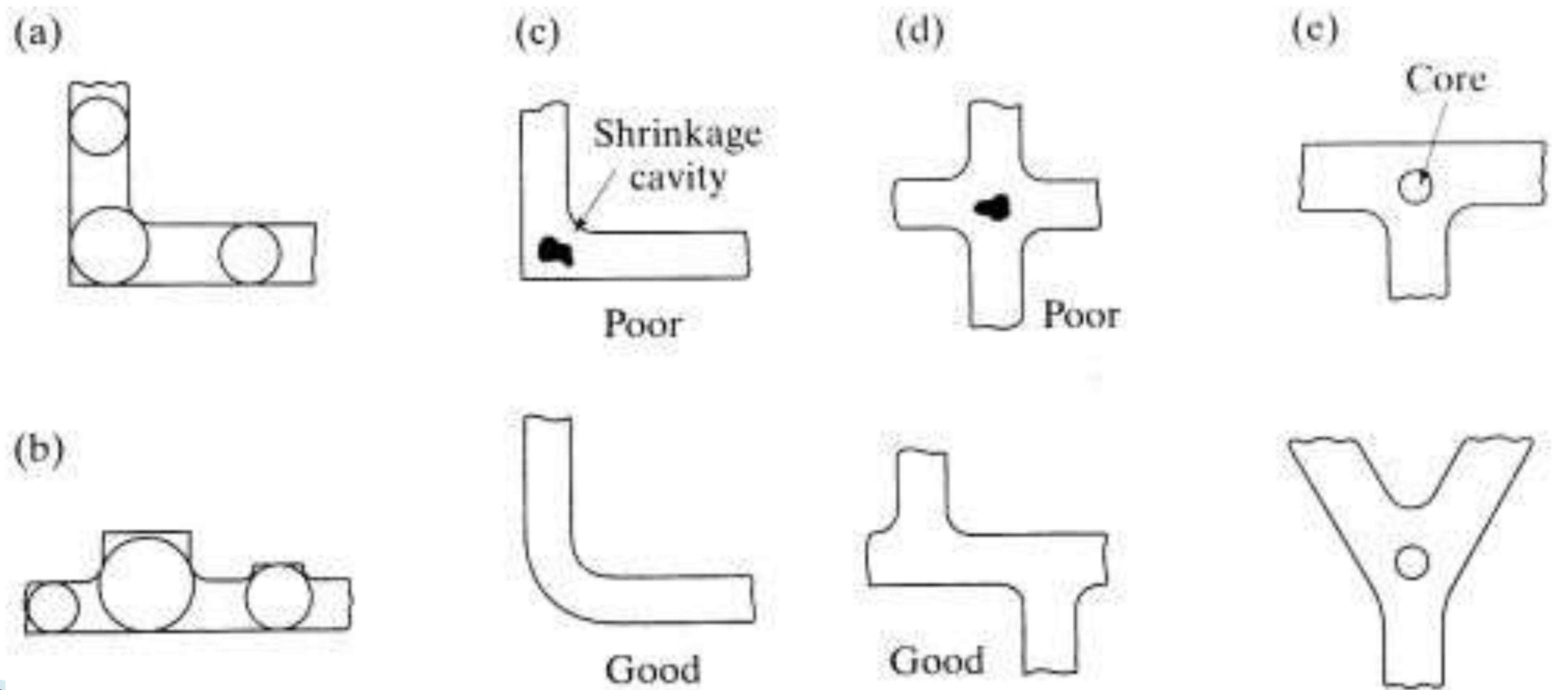
- Interior holes, inclusions: stress concentrations



$\sigma_{max} = \sigma_0(1 + 2b/a)$

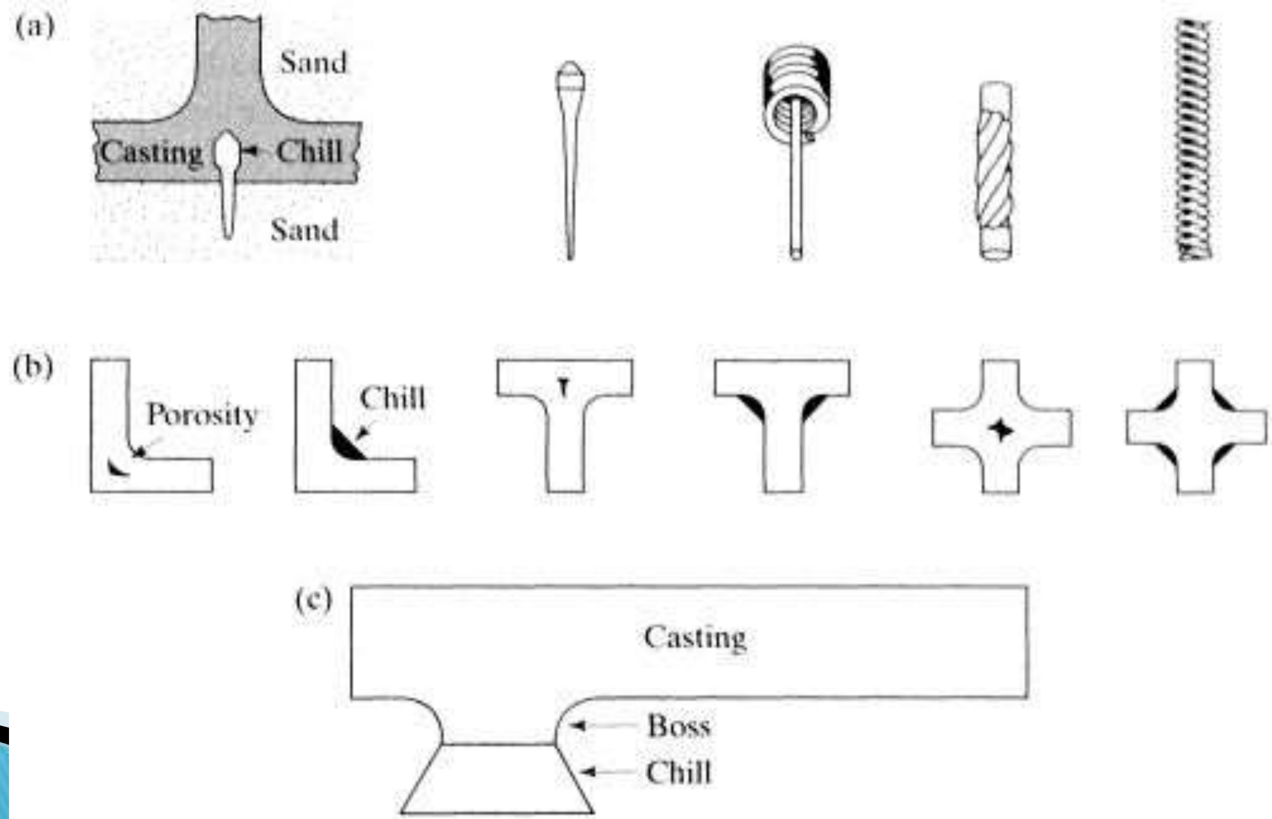
Casting Design: guidelines

(a) avoid sharp corners
(b) use fillets to blend section changes smoothly
(c1) avoid rapid changes in cross-section areas



Casting Design: guidelines

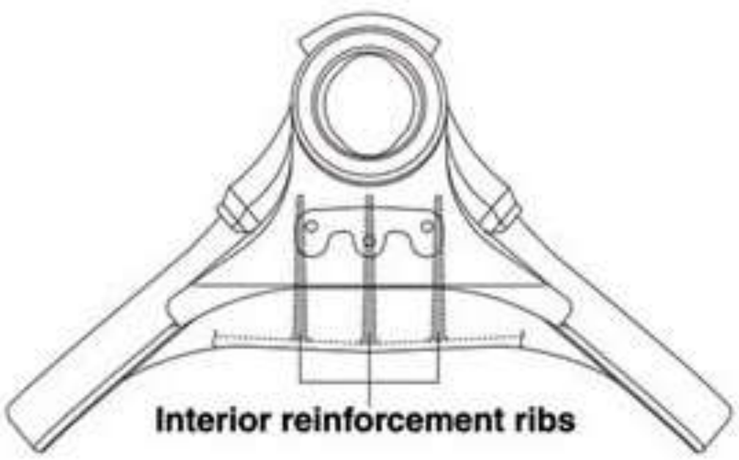
(c1) avoid rapid changes in cross-section areas
(c2) if unavoidable, design mold to ensure
- easy metal flow
- uniform, rapid cooling (use chills, fluid-cooled tubes)

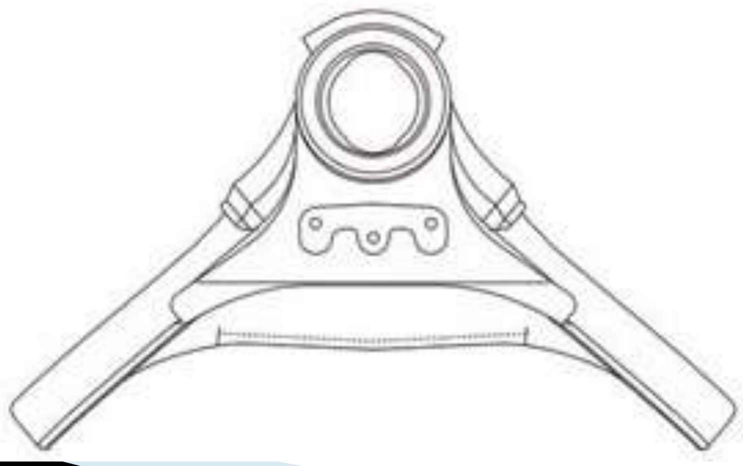


Casting Design: guidelines

(d) avoid large, flat areas

- warpage due to residual stresses (why?)

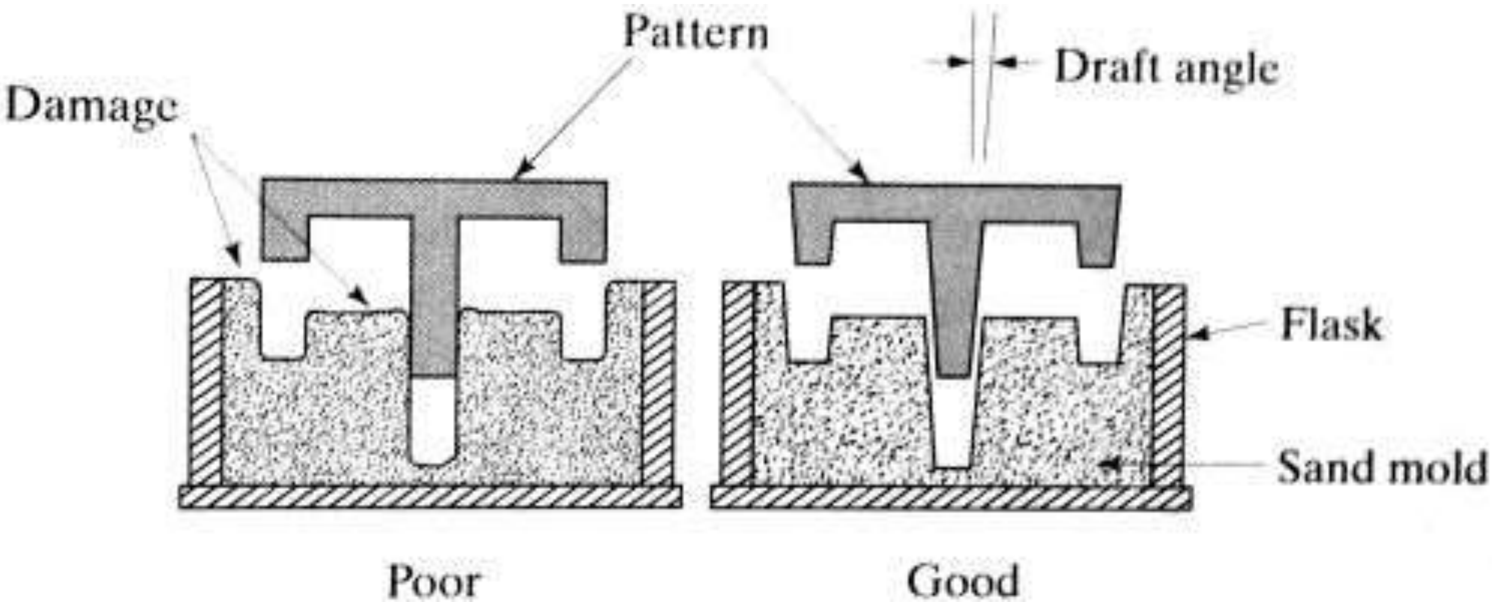




Casting Design: guidelines

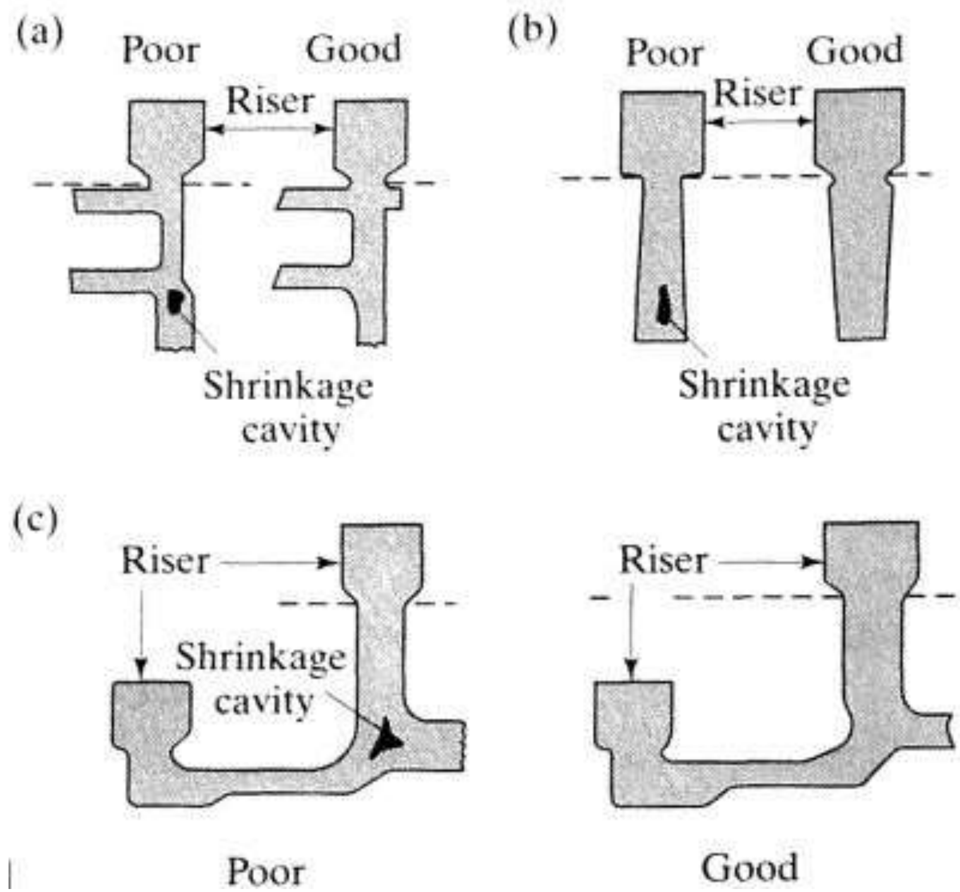
(e) provide drafts and tapers

- easy removal, avoid damage
- along what direction should we taper ?



Casting Design: guidelines

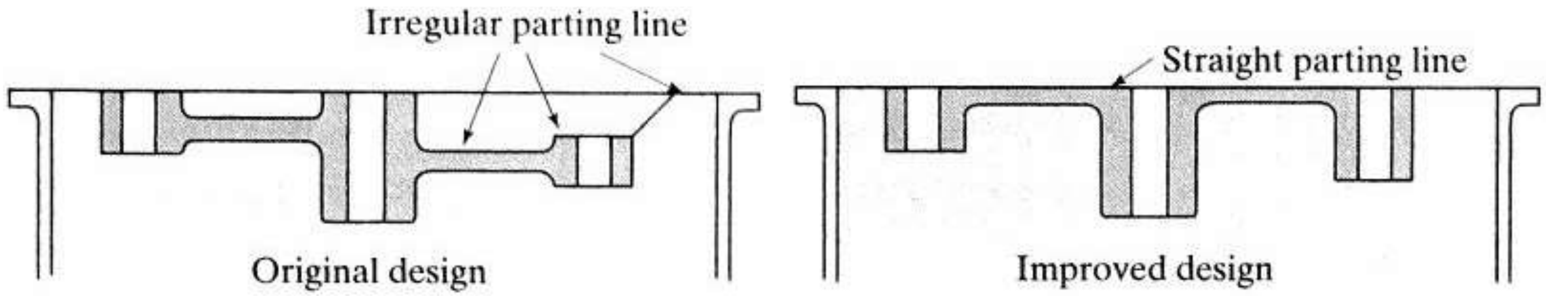
(f) account for shrinkage
- geometry
- shrinkage cavities



Casting Design: guidelines

(g) proper design of parting line

- “flattest” parting line is best



Traditional Manufacturing Processes

- Casting
- Forming
- Sheet metal processing
- Powder- and Ceramics Processing
- Plastics processing
- Cutting
- Joining
- Surface treatment

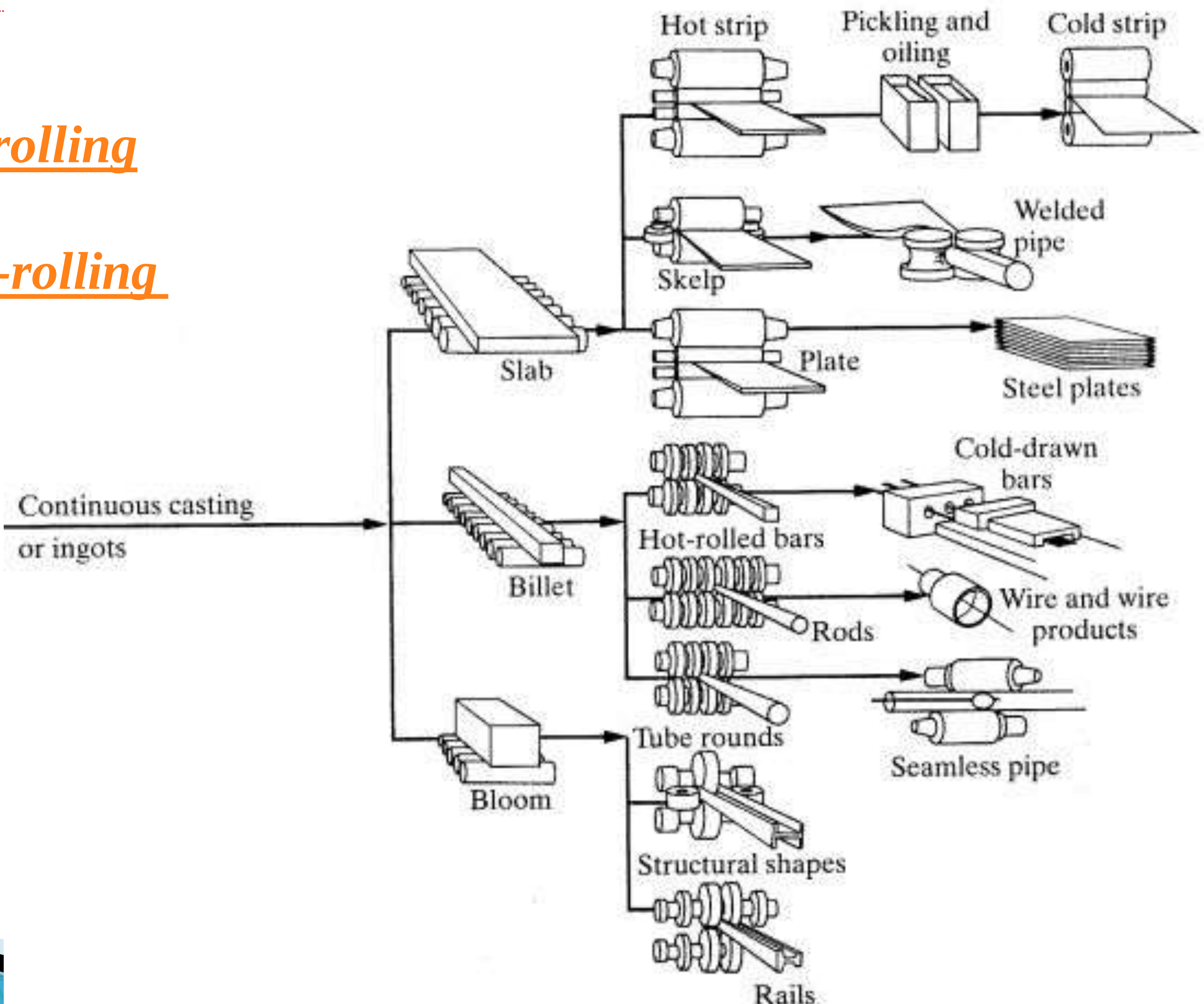
Forming

Any process that changes the shape of a raw stock without changing its phase

Example products:
Al/Steel frame of doors and windows, coins, springs,
Elevator doors, cables and wires, sheet-metal, sheet-metal parts…

Rolling

- **[Hot-rolling]**
- **[Cold-rolling]**



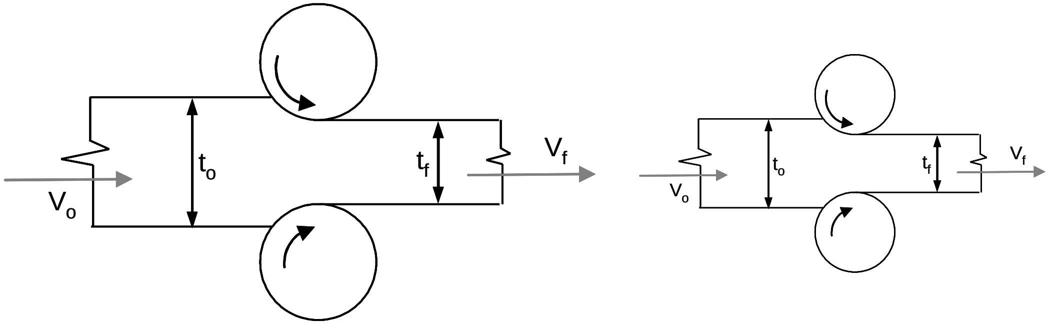
Rolling

Important Applications:

Steel Plants,
Raw stock production (sheets, tubes, Rods, etc.)
Screw manufacture

Rolling Basics

Sheets are rolled in multiple stages (why ?)

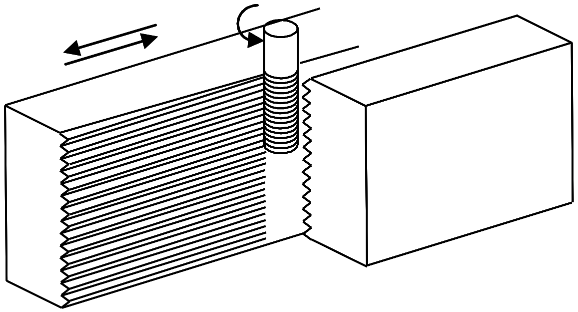


Screw manufacture:

stationary die

rolling die

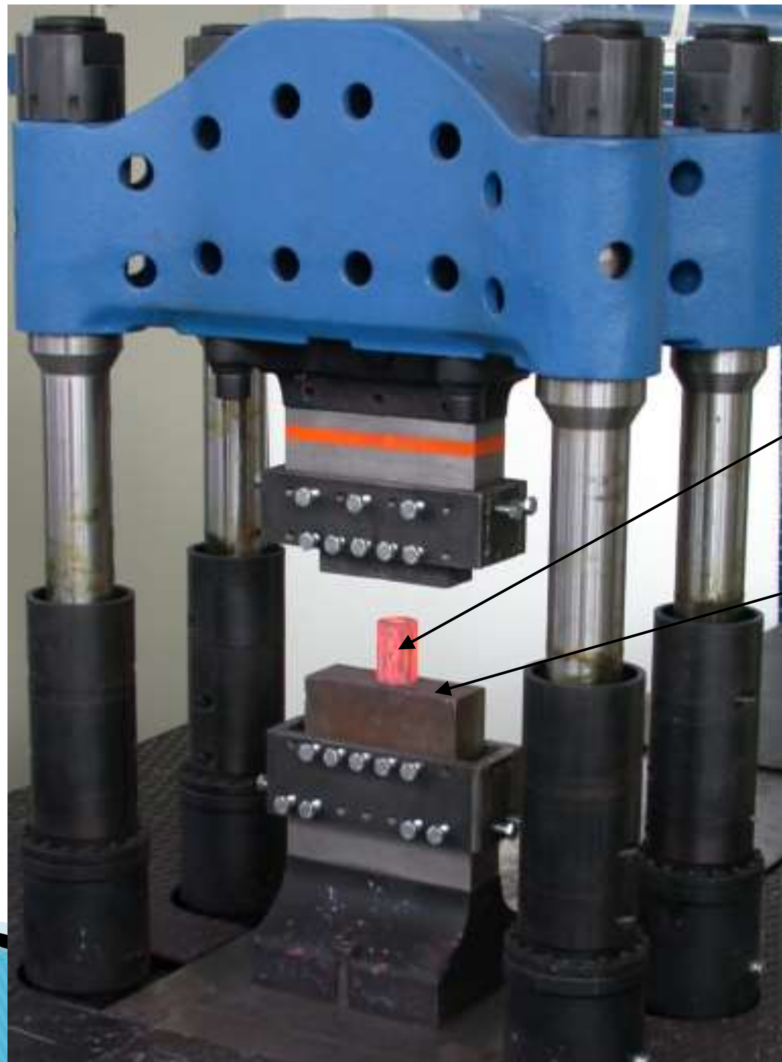
thread rolling machine



Reciprocating flat thread-rolling dies

Forging

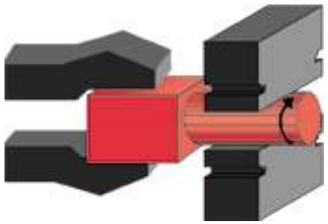
[Heated] metal is beaten with a heavy hammer to give it the required shape



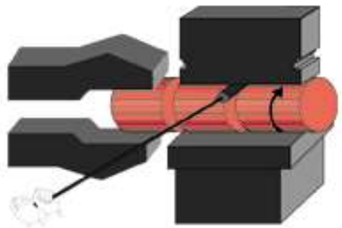
Hot forging,

open-die

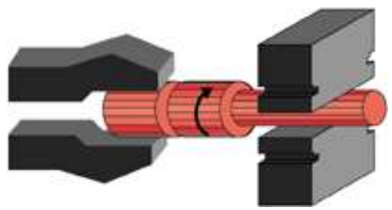
Stages in Open-Die Forging



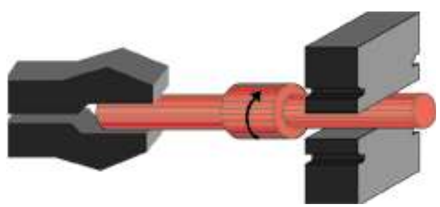
(a) forge hot billet to max diameter



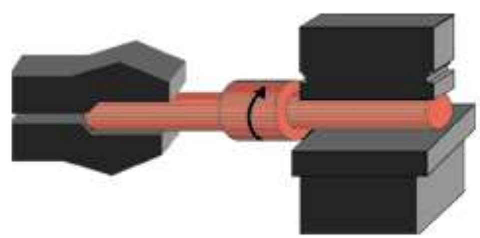
(b) “fuller: tool to mark step-locations



(c) forge right side



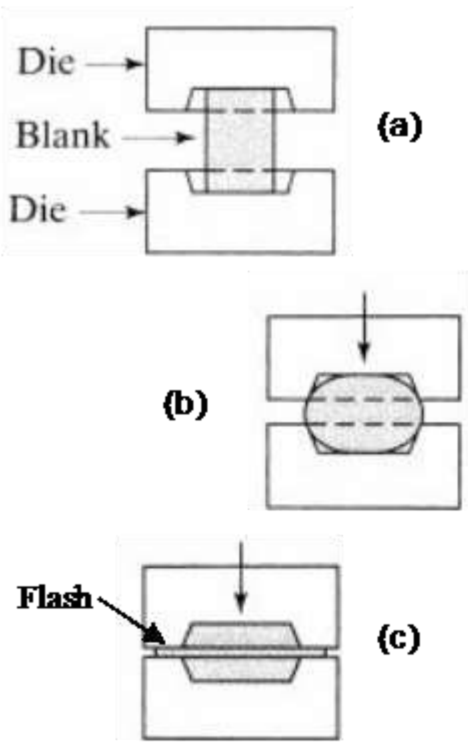
(d) reverse part, forge left side

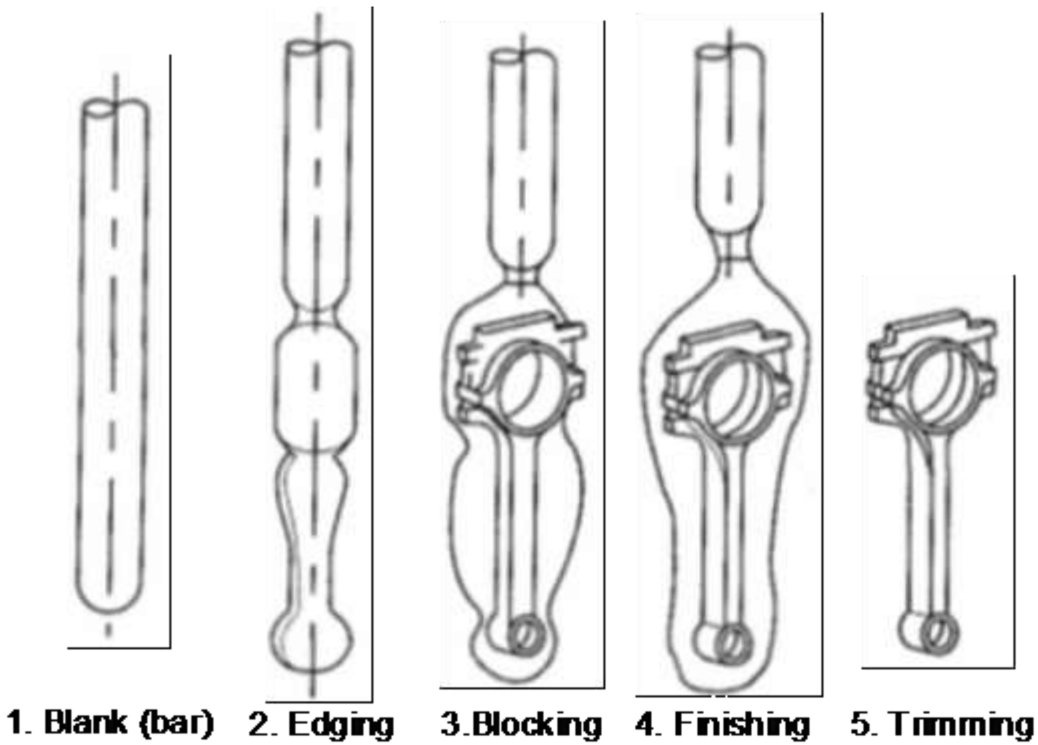


(e) finish (dimension control)

[source:www.scotforge.

Stages in Closed-Die Forging



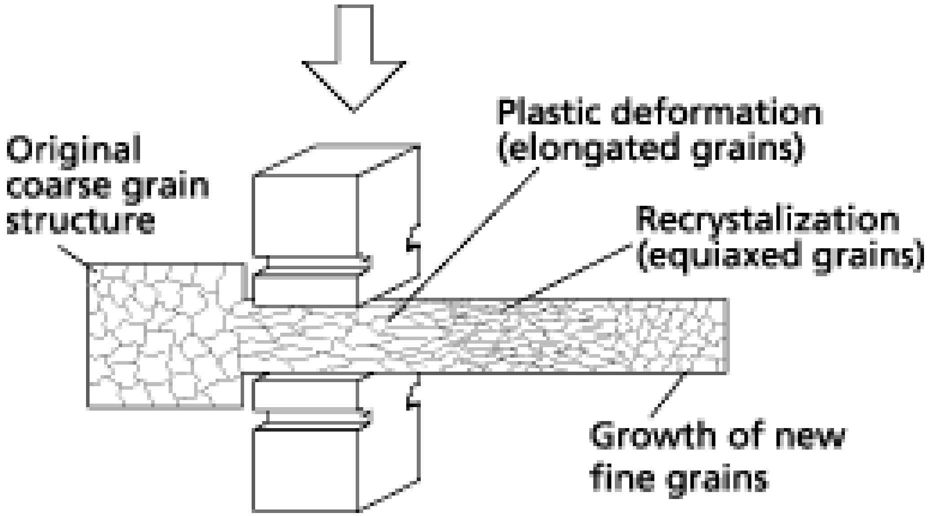


[source:Kalpakjian & Sch

Quality of forged parts

Surface finish/Dimensional control:
Better than casting (typically)

Stronger/tougher than cast/machined parts of same material



[source:www.scot... .om]

Extrusion

[source:www.magnode.com]

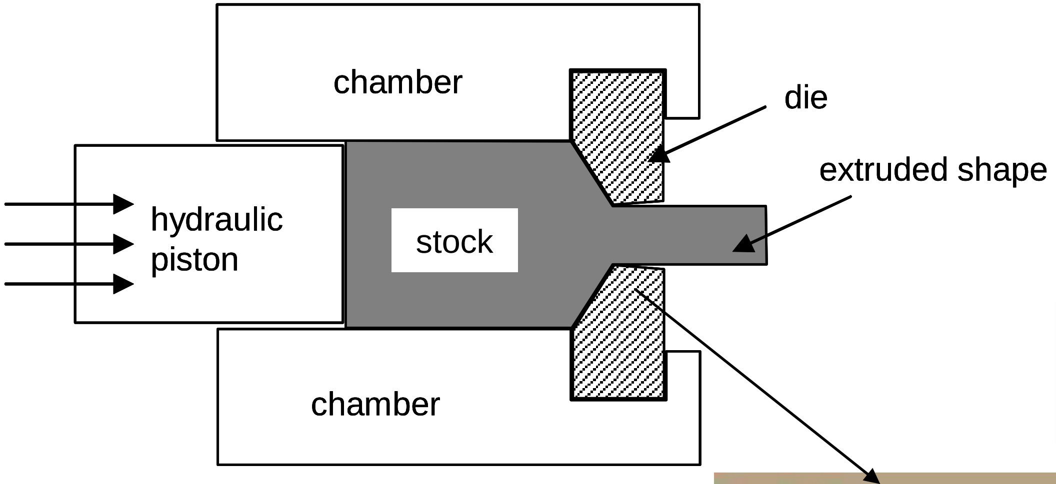
Metal forced/squeezed out through a hole (die)

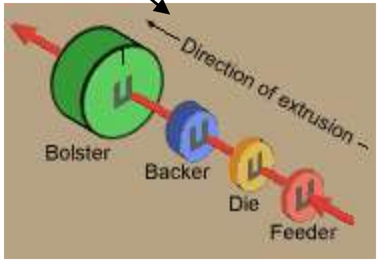
Typical use: ductile metals (Cu, Steel, Al, Mg), Plastics, Rubbers

Common products:

Al frames of white-boards, doors, windows, …

Extrusion: Schematic, Dies

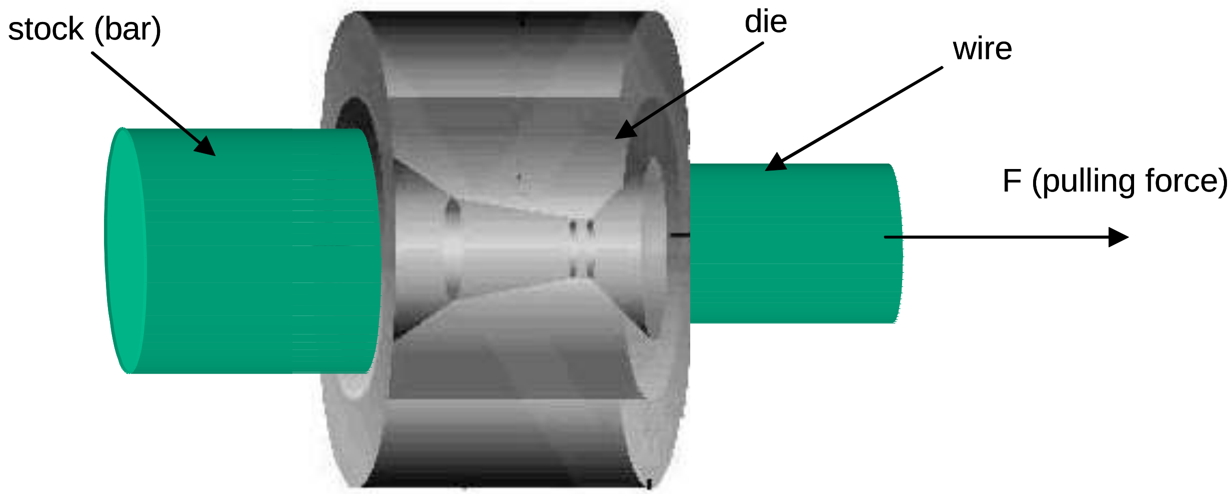




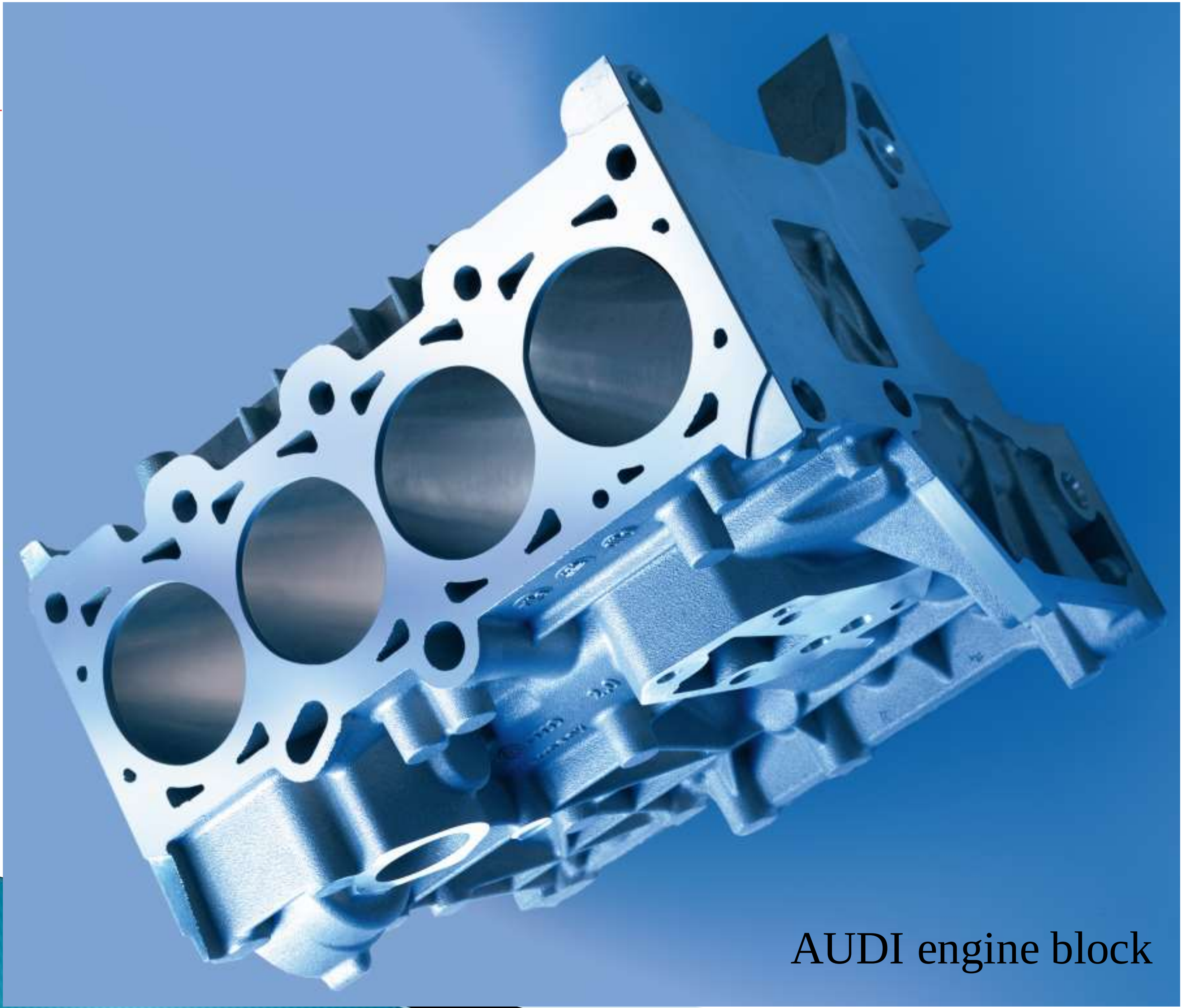
Exercise: how can we get hollow parts?

Drawing

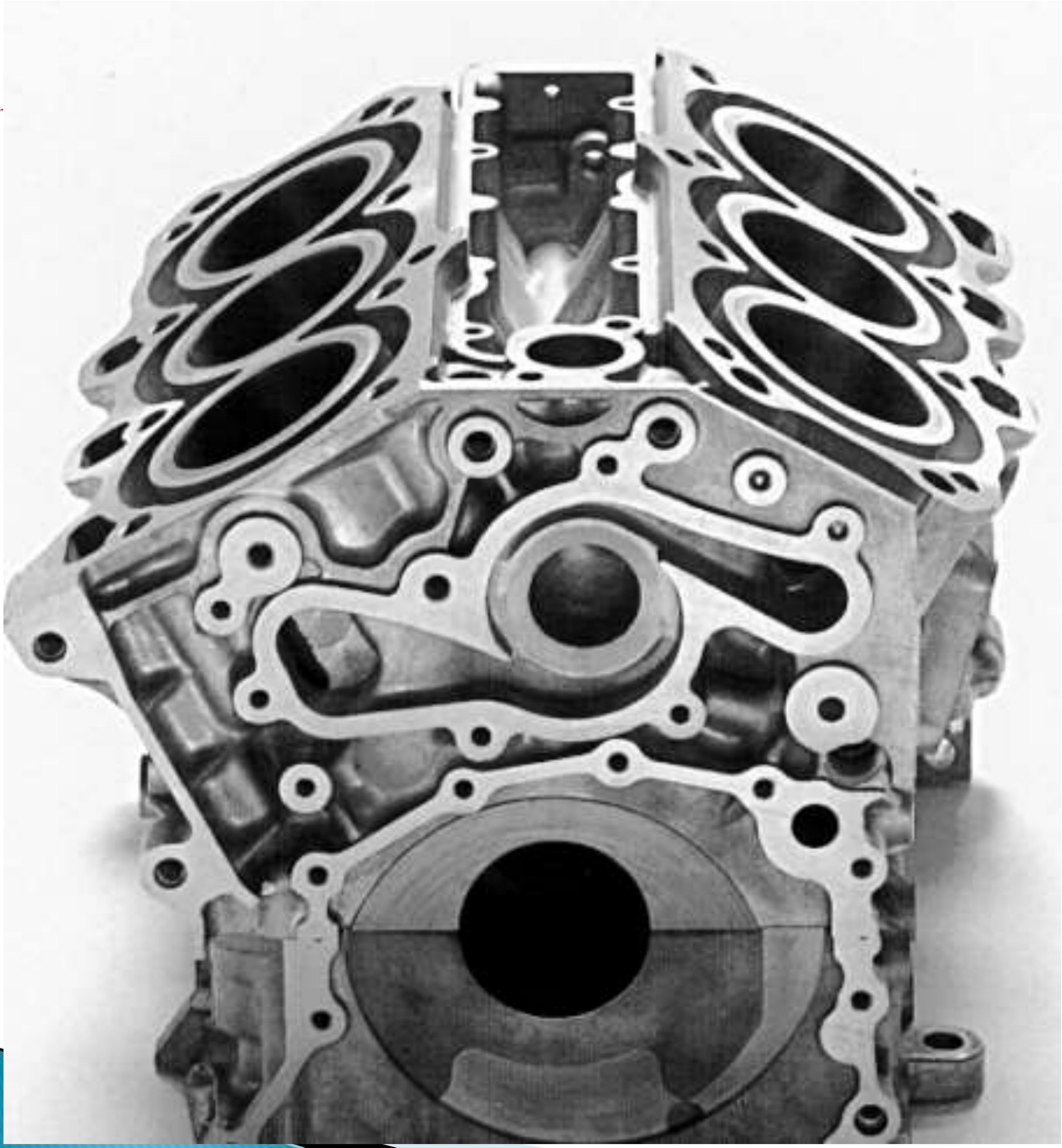
Similar to extrusion, except: ***pulling force*** is applied



Commonly used to make wires from round bars

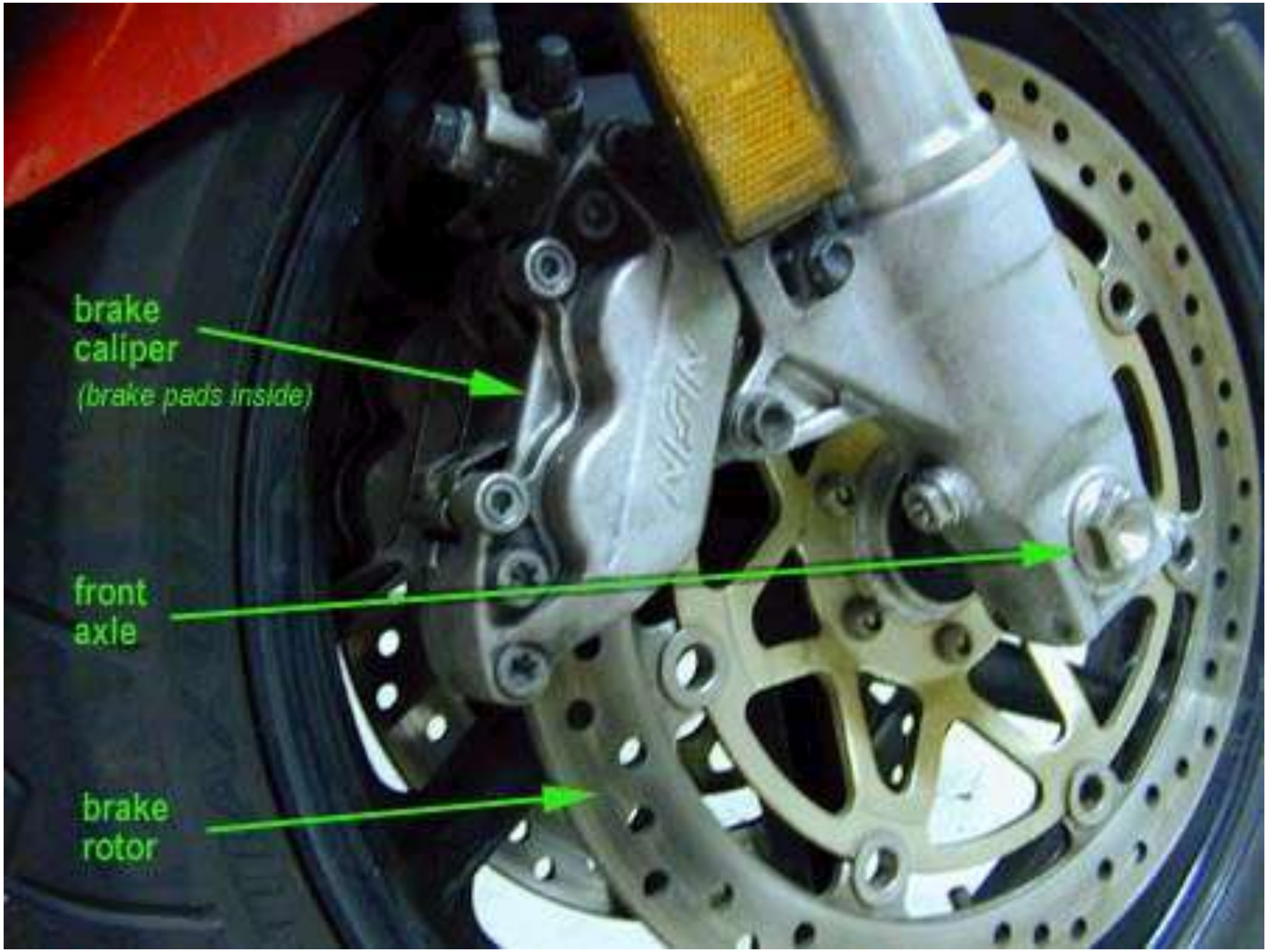


AUDI engine block

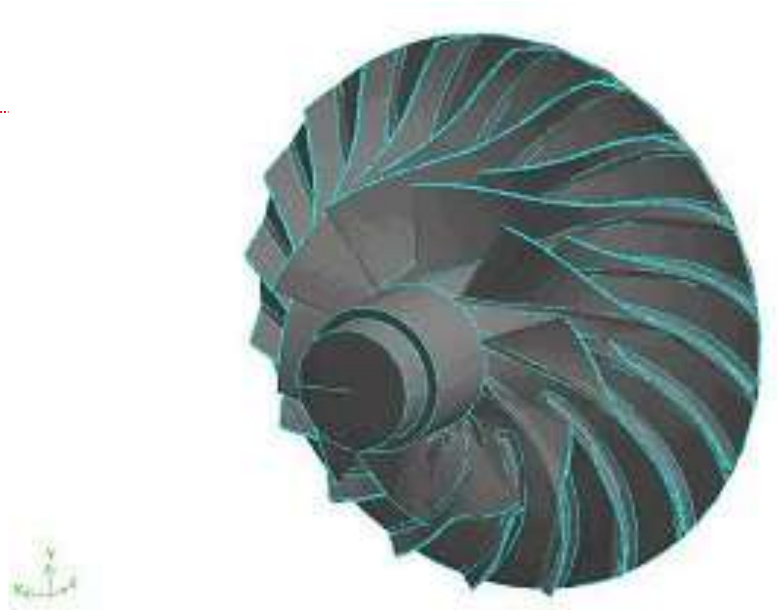


V6 engine block

BMW cylinder head



Brake assembly



Impellers

Crank Shaft

Also see: http://auto.howstuffworks.com/engine7.htm

Traditional Manufacturing Processes

Casting

Forming

Sheet metal processing

Powder- and Ceramics Processing

Plastics processing

Cutting

Joining

Surface treatment

Sheet Metal Processes

Raw material: sheets of metal, rectangular, large

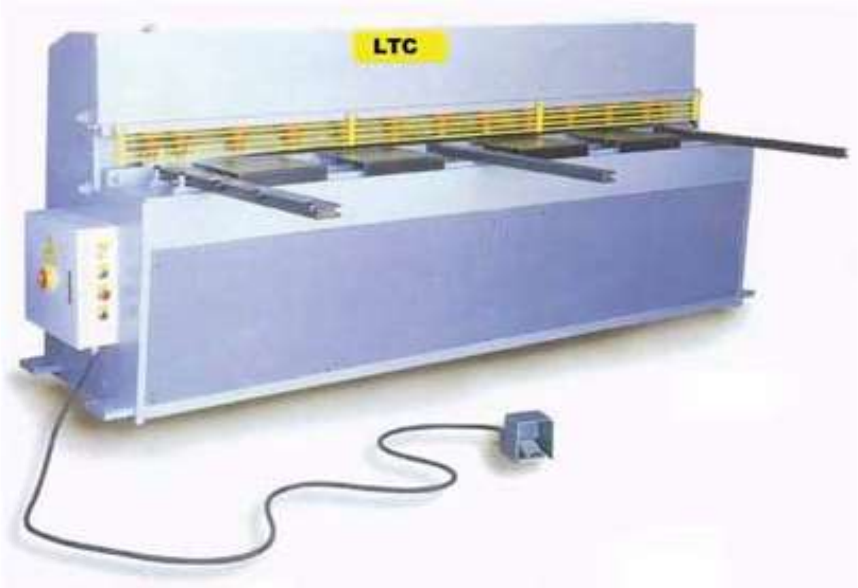
Raw material Processing: Rolling (anisotropic properties)

Processes:

- Shearing
- Punching
- Bending
- Deep drawing

Shearing

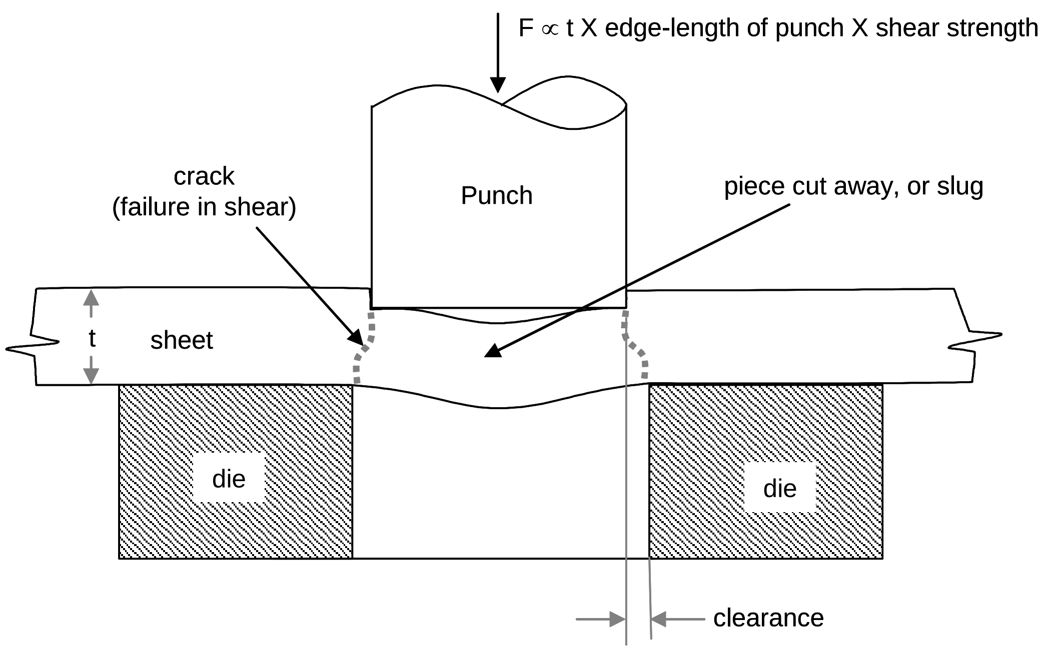
A large scissors action, cutting the sheet along a straight line



Main use: to cut large sheet into smaller sizes for making parts.

Punching

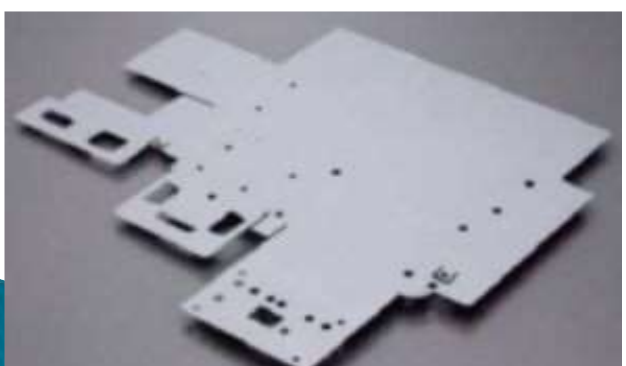
Cutting tool is a round/rectangular punch, that goes through a hole, or die of same shape



Punching

Main uses: cutting holes in sheets; cutting sheet to required shape

nesting of parts

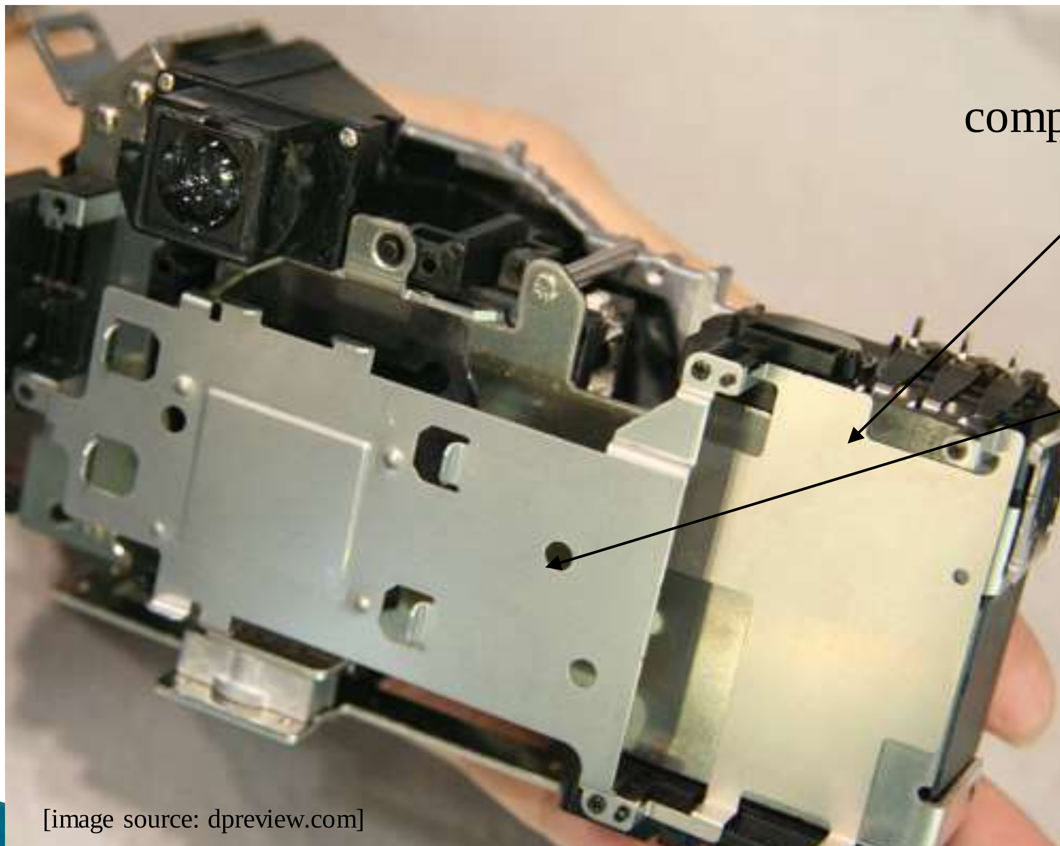


typical punched pa

Exercise: how to determine optimal nesting?

Bending

Body of Olympus E-300 camera

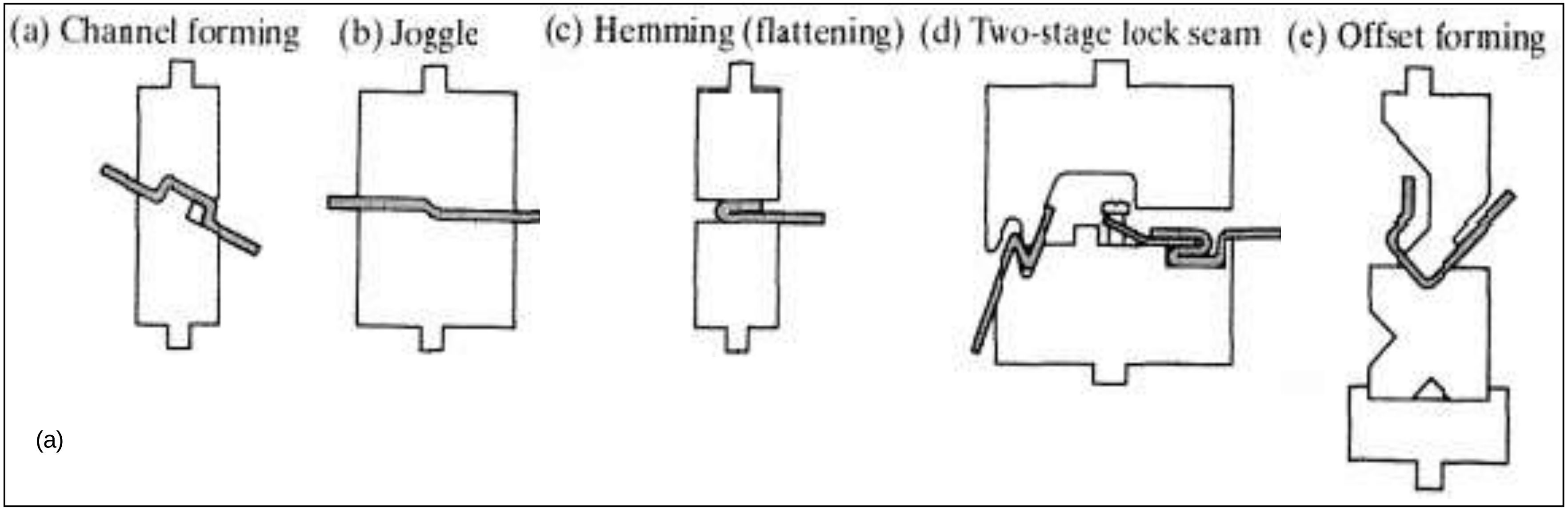


component with multiple bending operations

component with punching,
bending, drawing operations

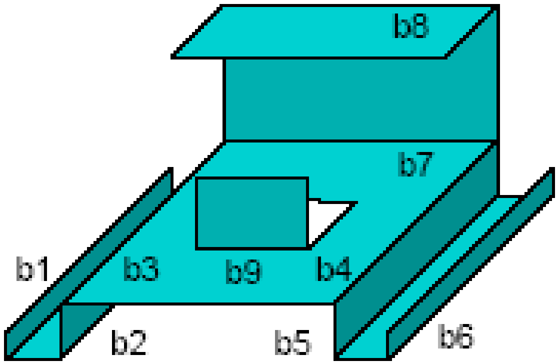
[image source: dpreview.com]

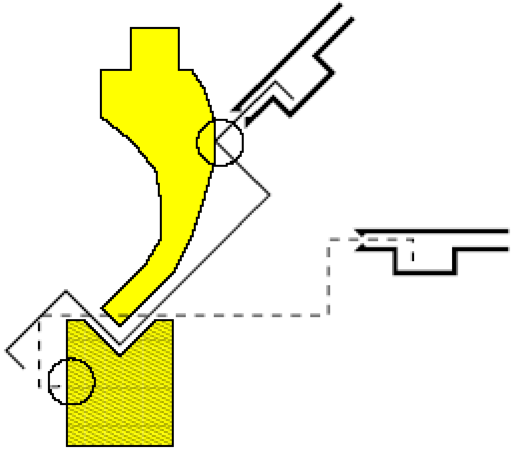
Typical bending operations and shapes



Sheet metal bending

Planning problem: what is the sequence in which we do the bending operations?

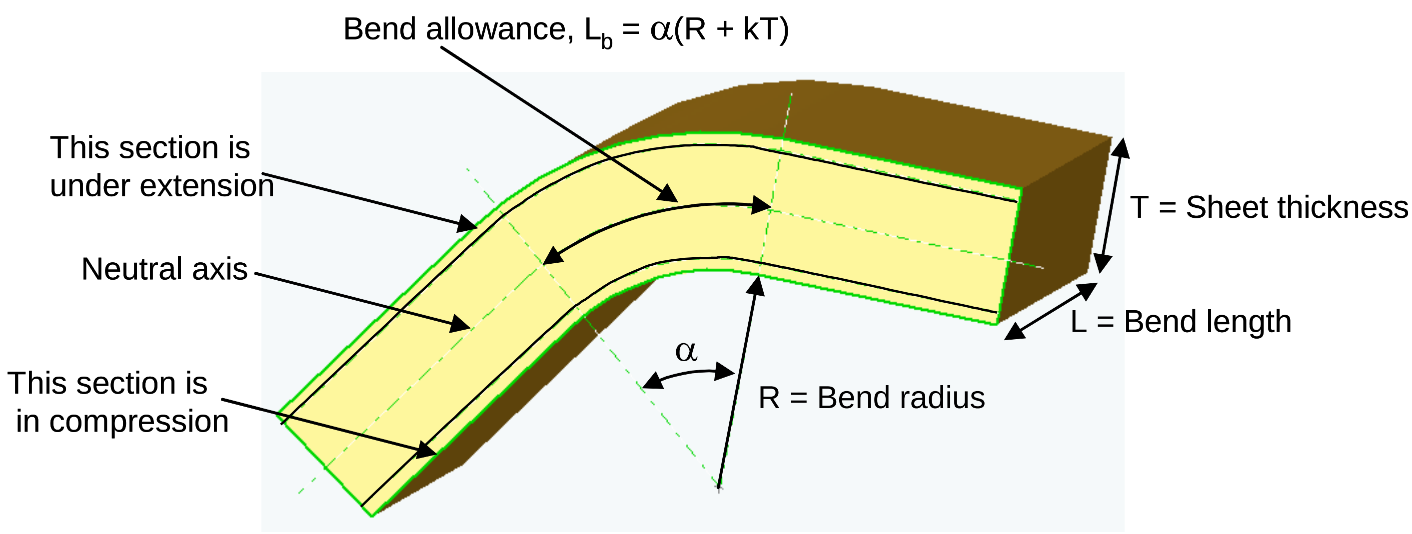




Avoid: part-tool, part-part, part-machine interference

Bending mechanics

Bending Planning ➔ what is the length of blank we must use?



Ideal case: k = 0.5

Real cases: k = 0.33 (R < 2T) ~~ k = 0.5 (R > 2T)

Bending: cracking, anisotropic effects, Poisson effect

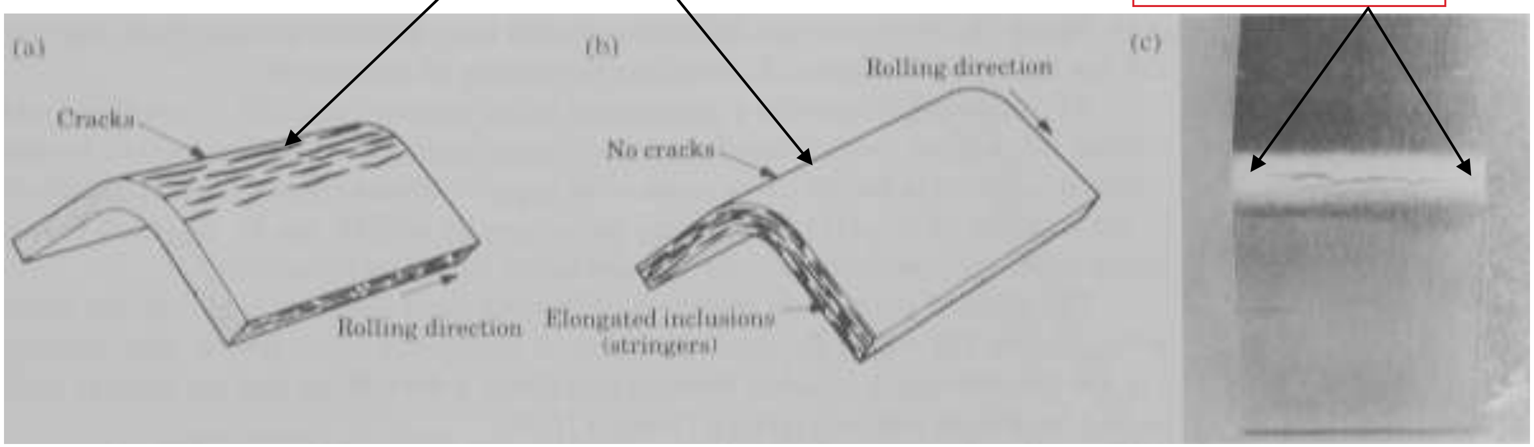
Bending ➔ plastic deformation

Engineering strain in bending = e = 1/(1 + 2R/T)

Bending ➔ disallow failure (cracking) ➔ limits on corner radius: bend radius ≥ 3T

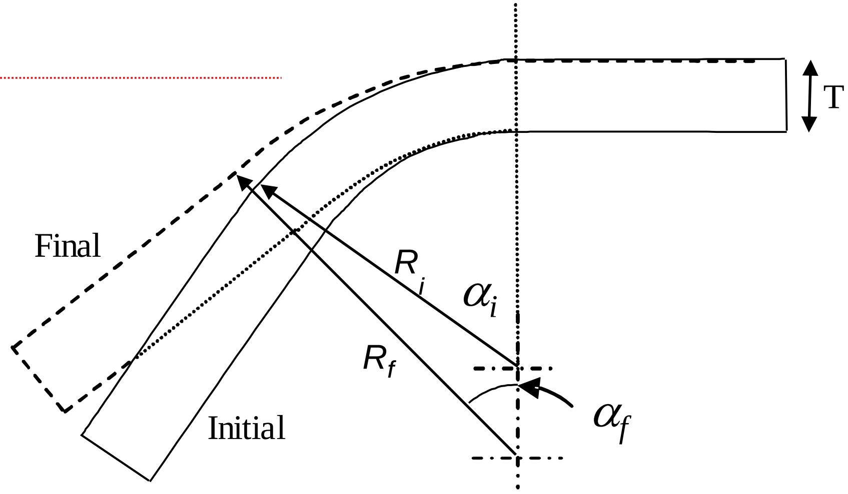
effect of anisotropic stock

Poisson effect



Exercise: how does anisotropic behavior affect planning?

Bending: springback

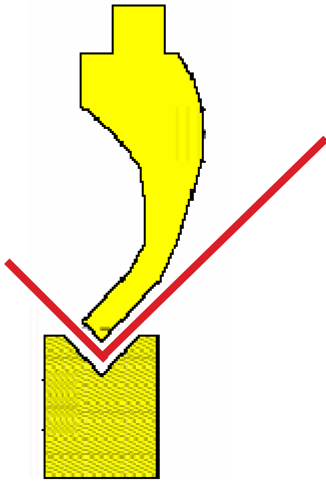


How to handle springback:

(a) Compensation: the metal is bent by a larger angle $\dfrac{R_i}{R_f} = 4\left(\dfrac{R_i Y}{ET}\right)^3 - 3\left(\dfrac{R_i Y}{ET}\right) + 1$

(b) Coining the bend:

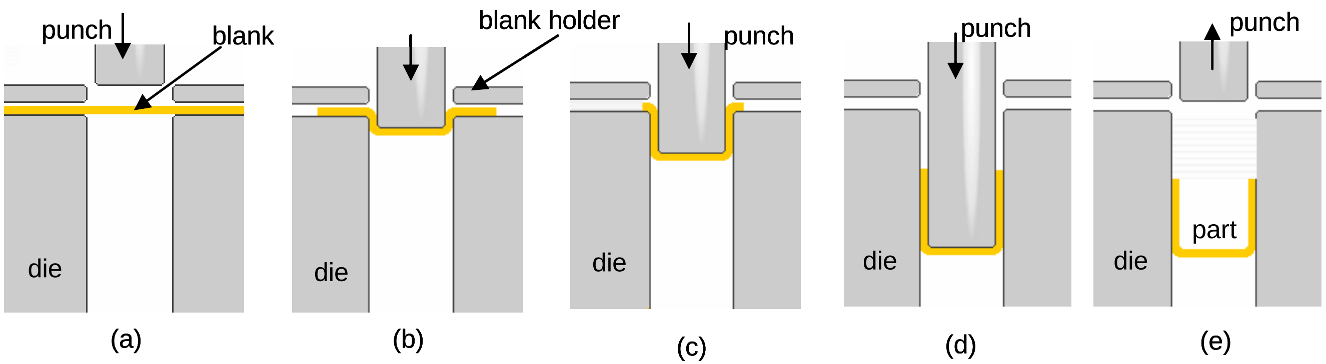
at end of bend cycle, tool exerts large force, dwells



coining: press down hard, wait, release

Deep Drawing

Tooling: similar to punching operation,
Mechanics: similar to bending operation



Examples of deep drawn parts

Common applications: cooking pots, containers, …

Sheet metal parts with combination of operations

Body of Olympus E-300 camera