MODULE 5

SHEET METAL OPERATIONS

SHEET METALWORKING

- Cutting and forming thin sheets of metal usually performed as cold working
- Sheet metal = 0.4 (1/64) to 6 mm (1/4in) thick
- Plate stock > 6 mm thick
- Advantage - High strength, good dimensional accuracy, good surface finish, economical mass production (low cost).
- Cutting, bending, drawing

PARTS MADE BY SHEET METAL FORMING

- Car bodies
- Aircraft fuselages
- Trailers
- Office furniture appliances
- Fuel tanks
- Cookware

Sheet Metalworking Terminology

"Punch-and-die"Tooling to perform cutting, bending, and drawing

"Stamping press" Machine tool that performs most sheet metal operations

"Stampings"Sheet metal products

A set of die and punch

Press working of sheet metal

SHEET METAL OPERATIONS

- SHEARING
- BLANKING
- PUNCHING (PIERCING)
- BENDING
- STAMPING
- DRAWING
- DEEP DRAWING
- EMBOSSING
- SPINNING
- ROLL FORMING

SHEET METAL CHARACTERISTICS

Characteristics of metals important in sheet forming

1. Elongation
2. Yield point elongation
3. Anisotropy ⟹ Crystallographic anisotropy
   Mechanical fibering
4. Grain Size
5. Residual stresses
6. Spring back
7. Wrinkling
8. Quality of sheared edges
9. Surface condition of sheet

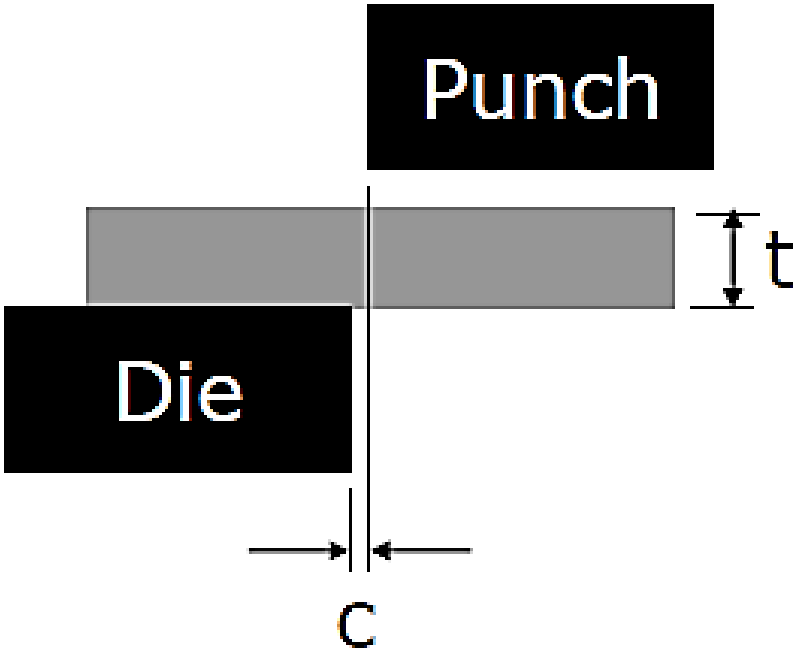
Cutting Operation

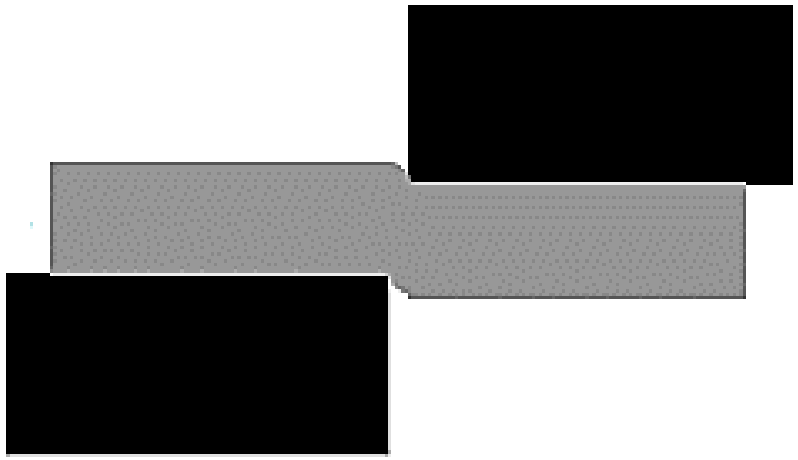
- **Shearing -** using a machine called power shear or square shear.

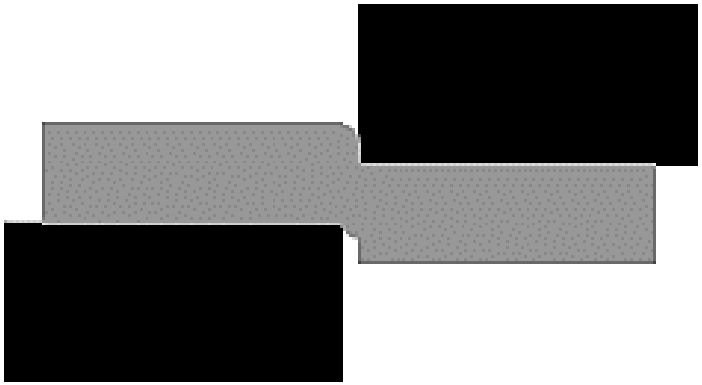
- **Blanking –** shearing a closed outline (desired part called blank)

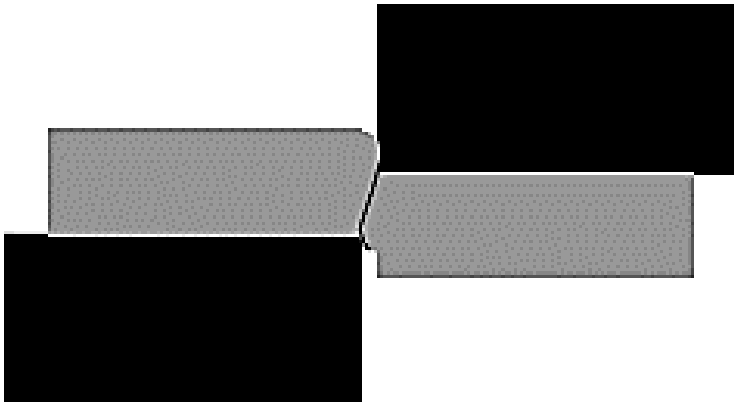
- **Punching –** sheared part is slag (or scrap) and remaining stock is a desired part

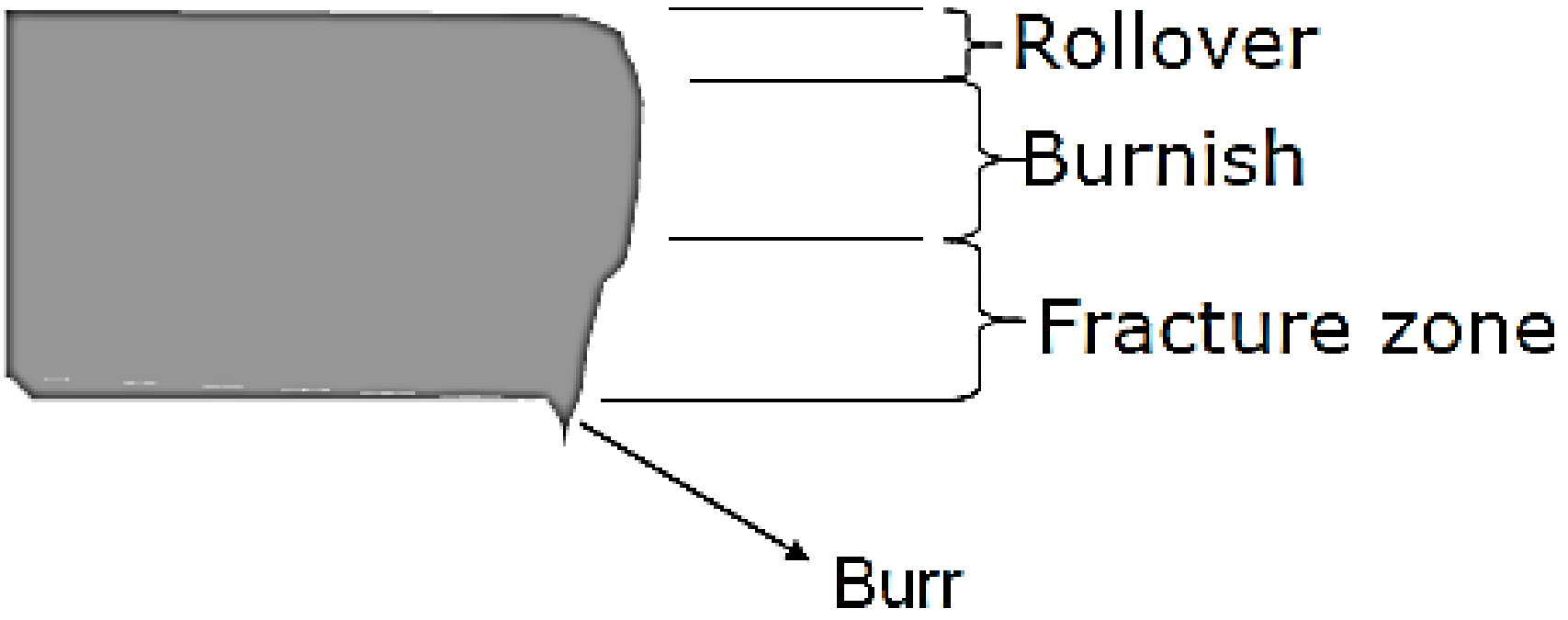
CUTTING OPERATION



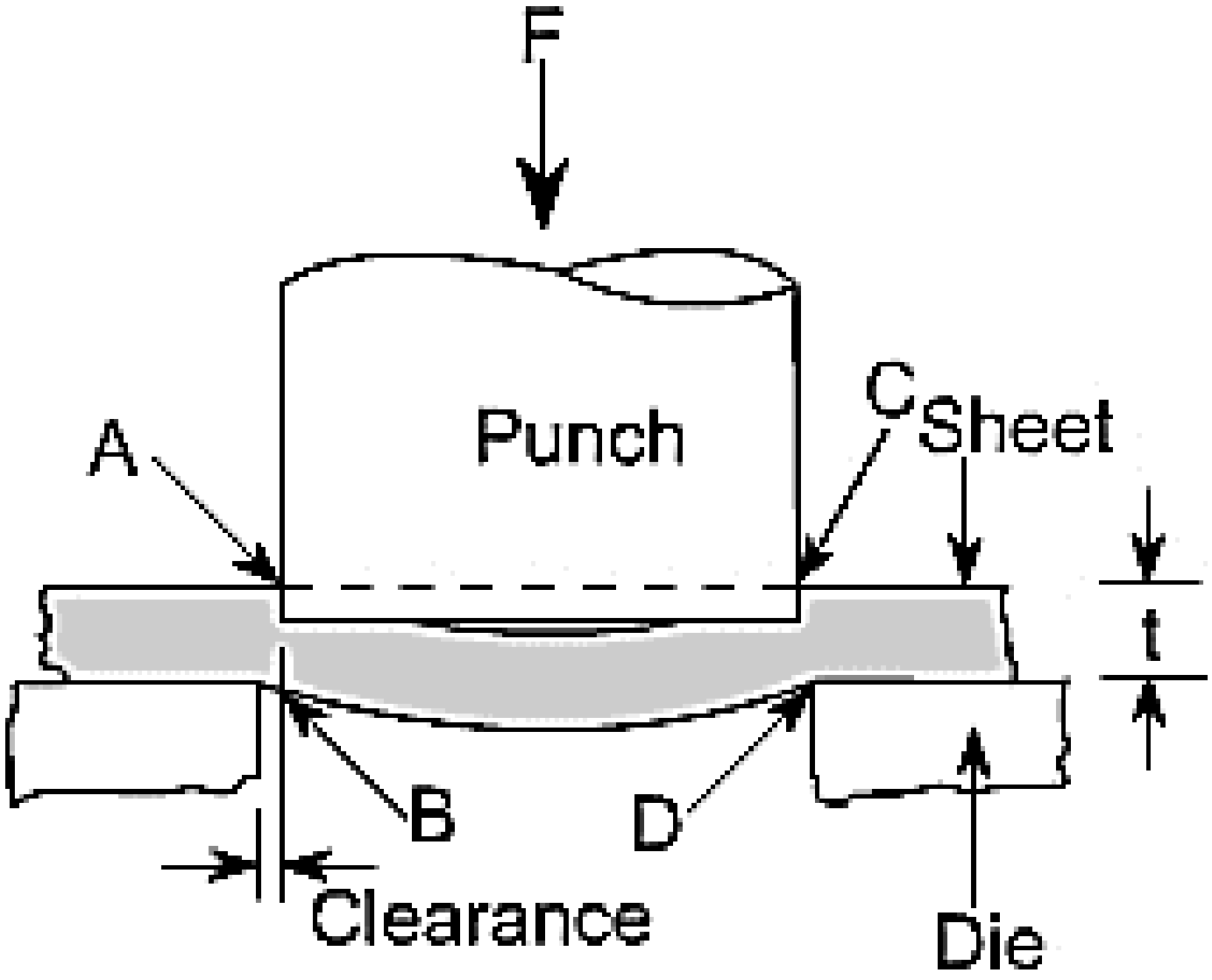







Rollover
Burnish
Fracture zone
Burr

SHEARING



Analysis

Clearance -4-8% but sometime 1% of thickness

Too small –fracture does not occur requiring more force.
Too large –Get pinched and cause an excessive burr

Clearance: c=a*t

Metal group	a
▪ 1100S and 5052S aluminum alloys, all tempers	0.045
2024ST and 6061ST aluminum alloys;	
▪ brass, soft cold rolled steel, soft stainless steel	0.060
▪ Cold rolled steel, half hard; stainless steel, half hard and full hard	0.075

Factors affecting shearing operation

- Shape and material of the punch
- Die, speed of punching, lubrication
- Clearance between punch & die

Die, blank and punch size

- For a round blank,

Blank punch diameter=D_b-2c

Blank die diameter = D_b

- For a round hole,

Hole punch diameter=D_h

Hole die diameter = D_h+2c

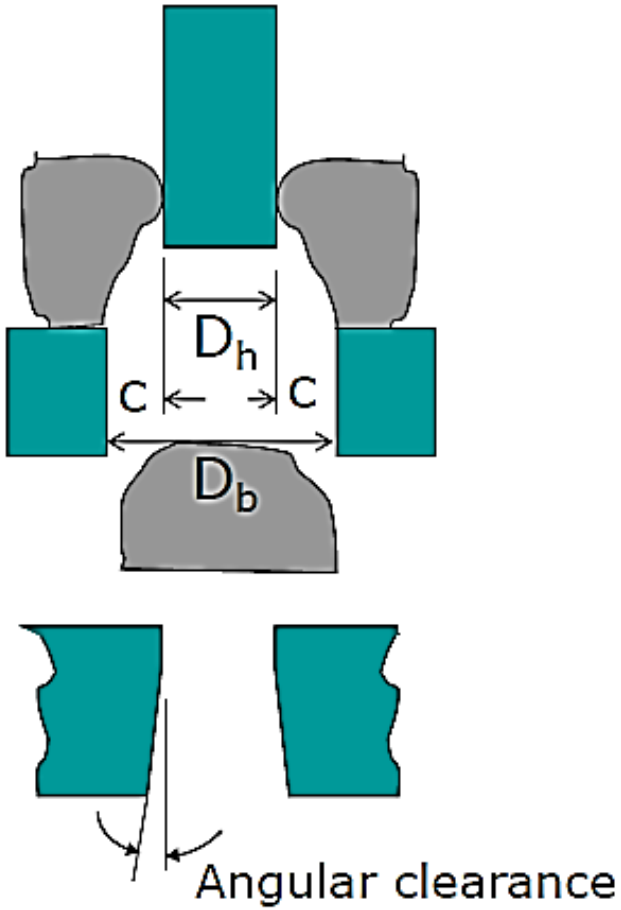
- Angular clearance of 0.25°to 1.5°
- Cutting forces: $F=S\times t\times L=0.7\times TS\times t\times L$

where S= Shear strength

t=thickness

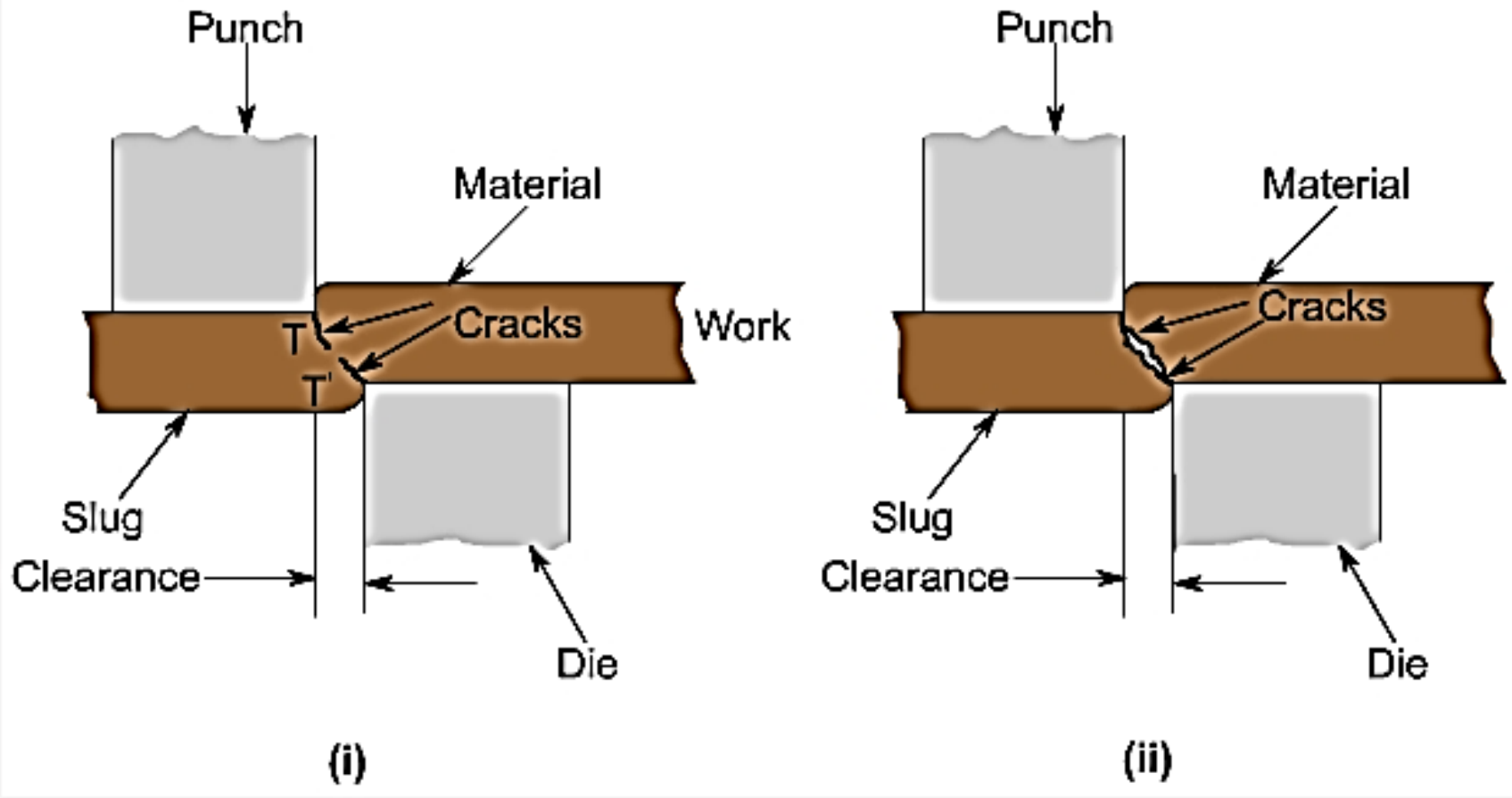
L=length of cutting edge

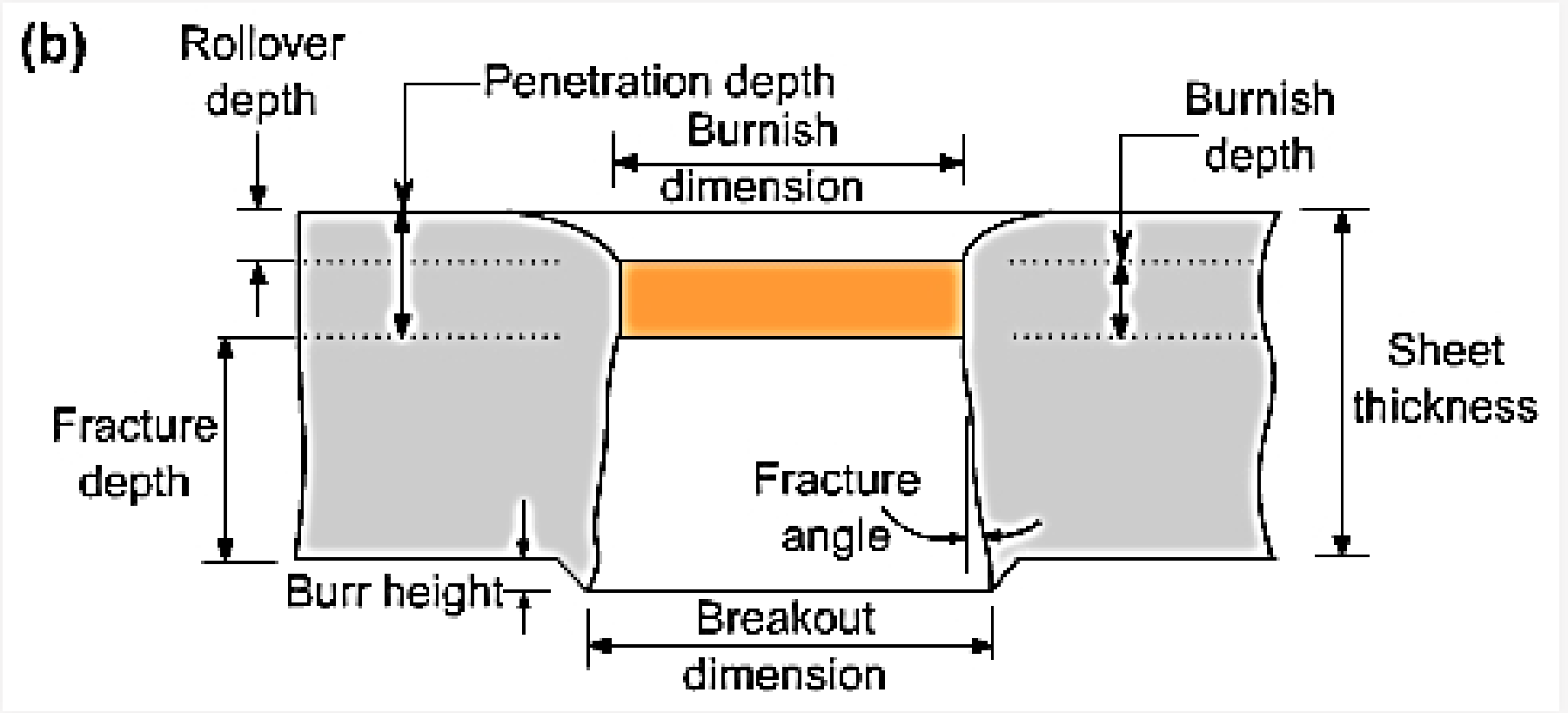
TS =Ultimate tensile strength



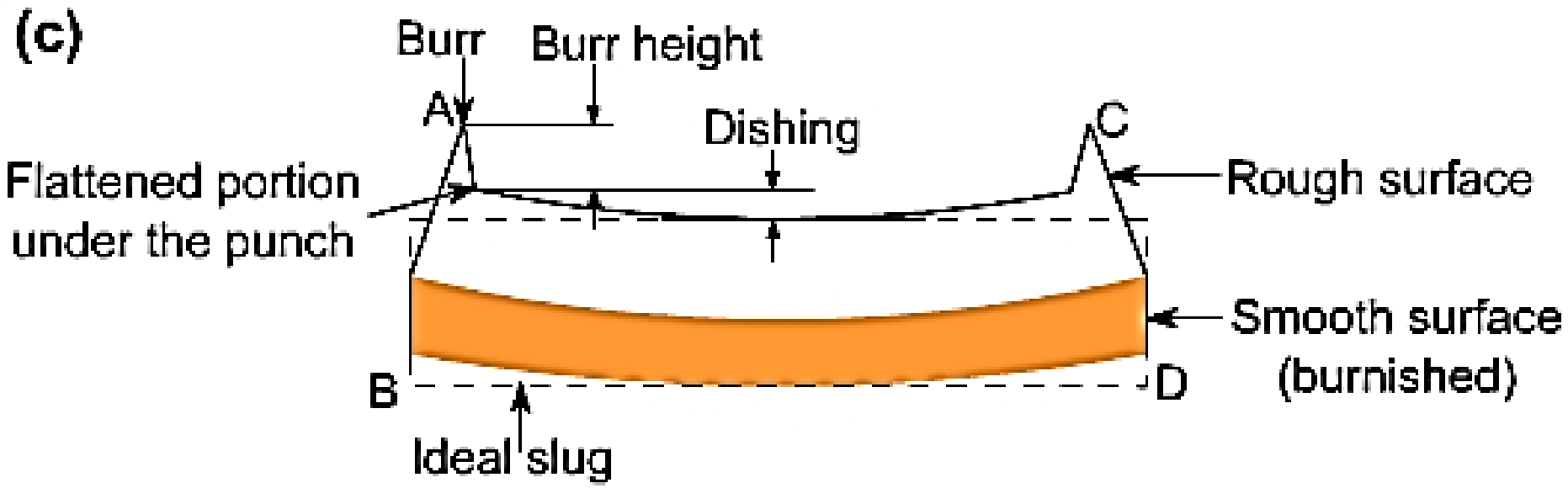
STAGES IN SHEARING ACTION

1. Plastic Deformation
2. Fracture
3. Shear

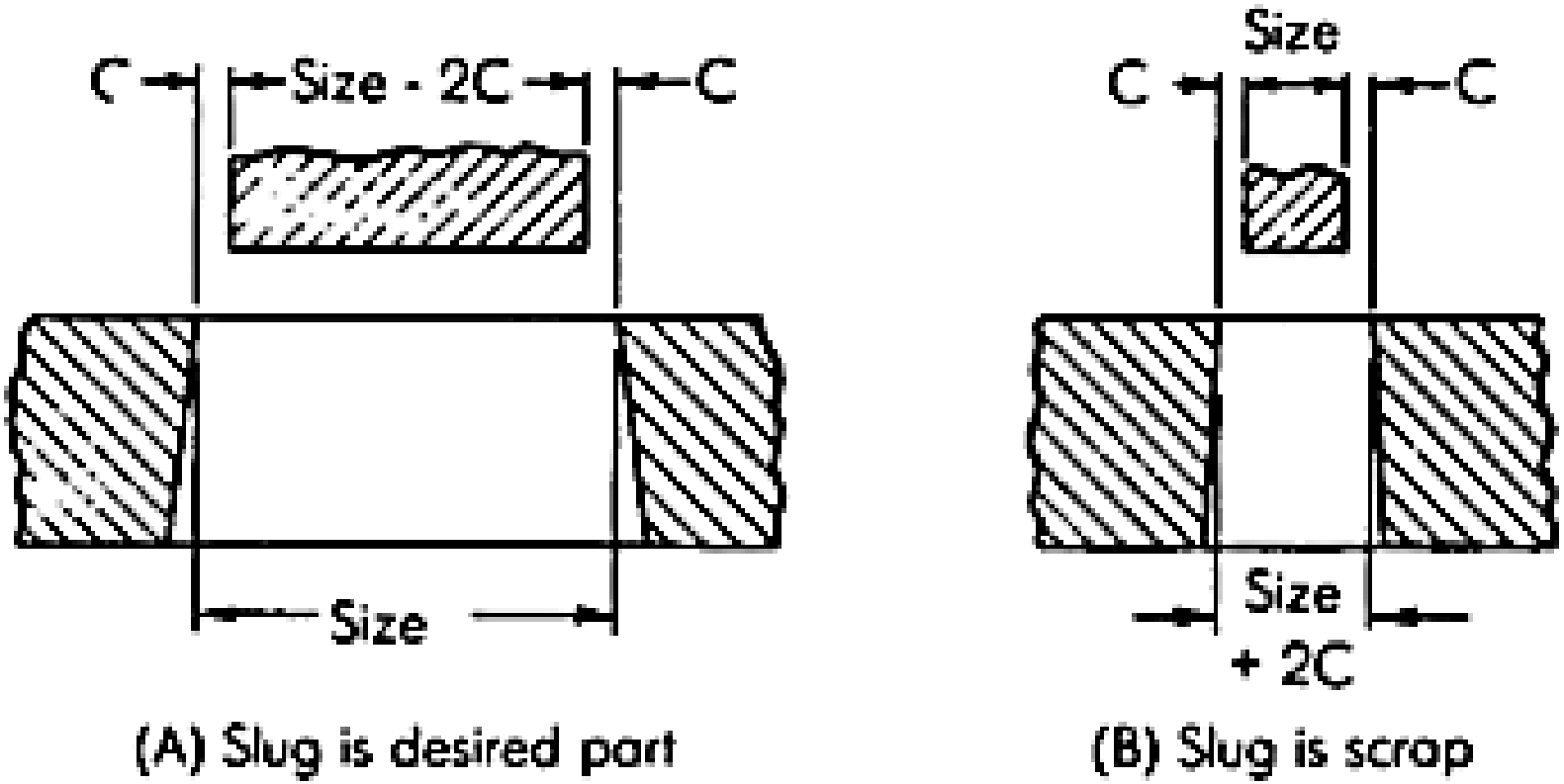

Punch
Material
Cracks
Work
T
T'
Slug
Clearance
Die
(i)
Punch
Material
Cracks
Slug
Clearance
Die
(ii)



FEATURES OF PUNCHED HOLE

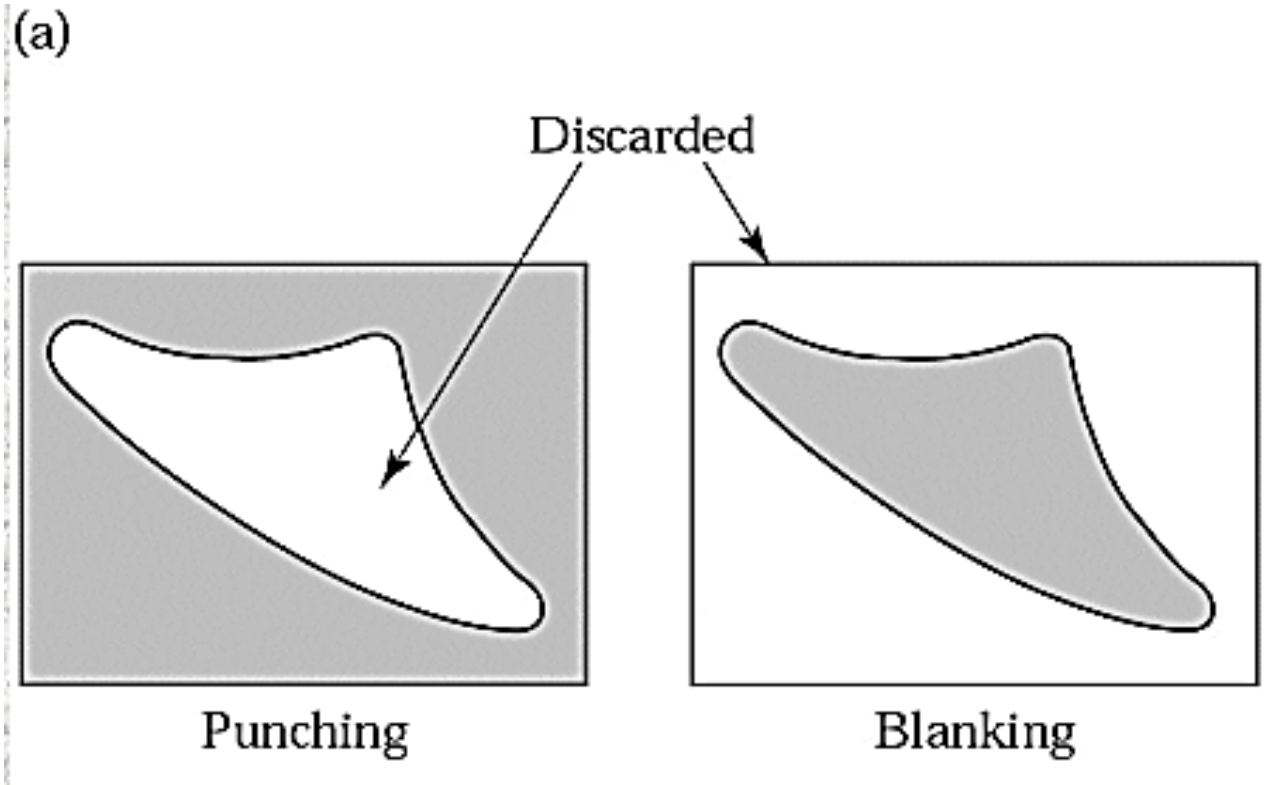


FEATURES OF SLUG

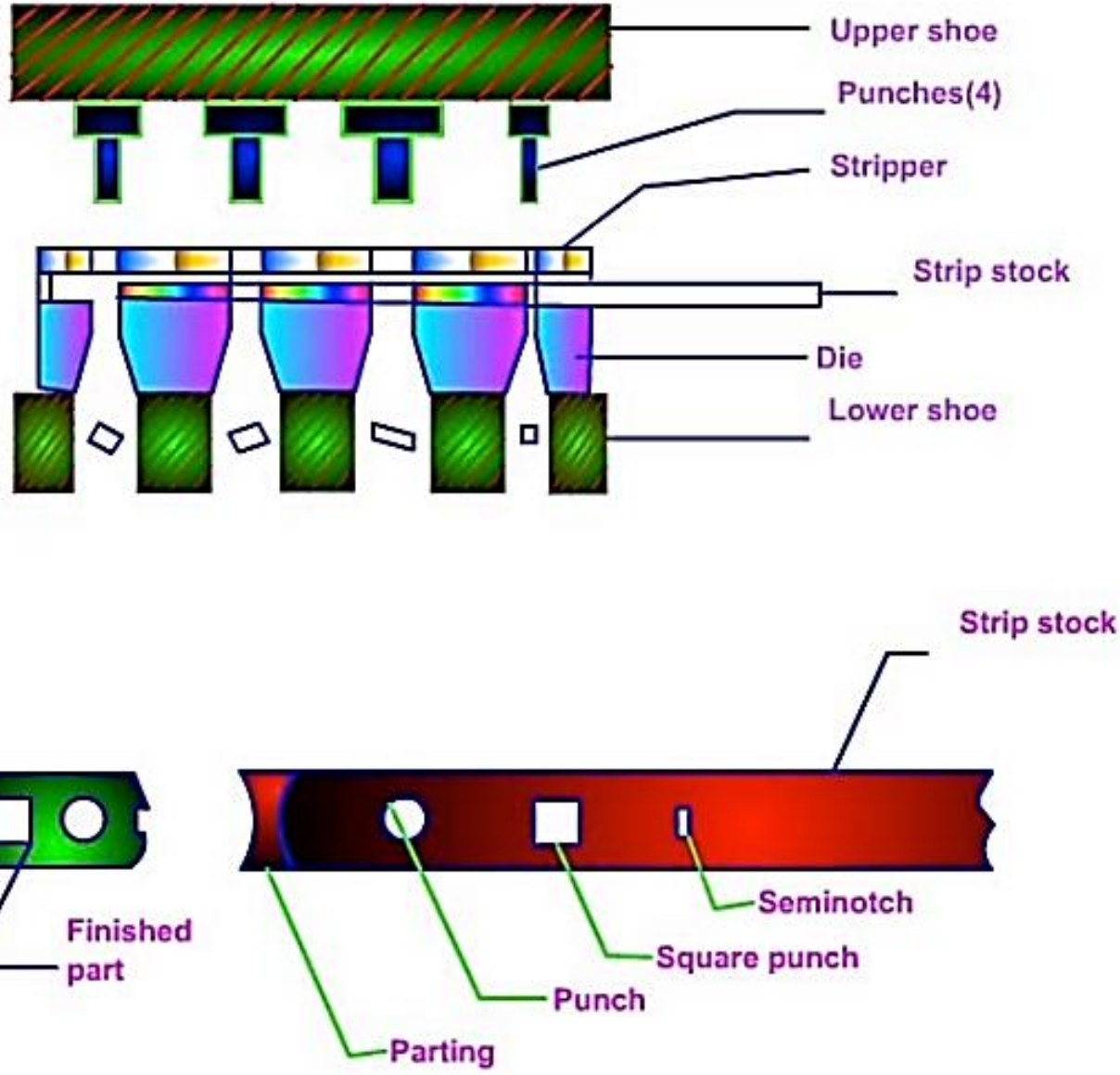


Control of hole and blank sizes by clearance location.

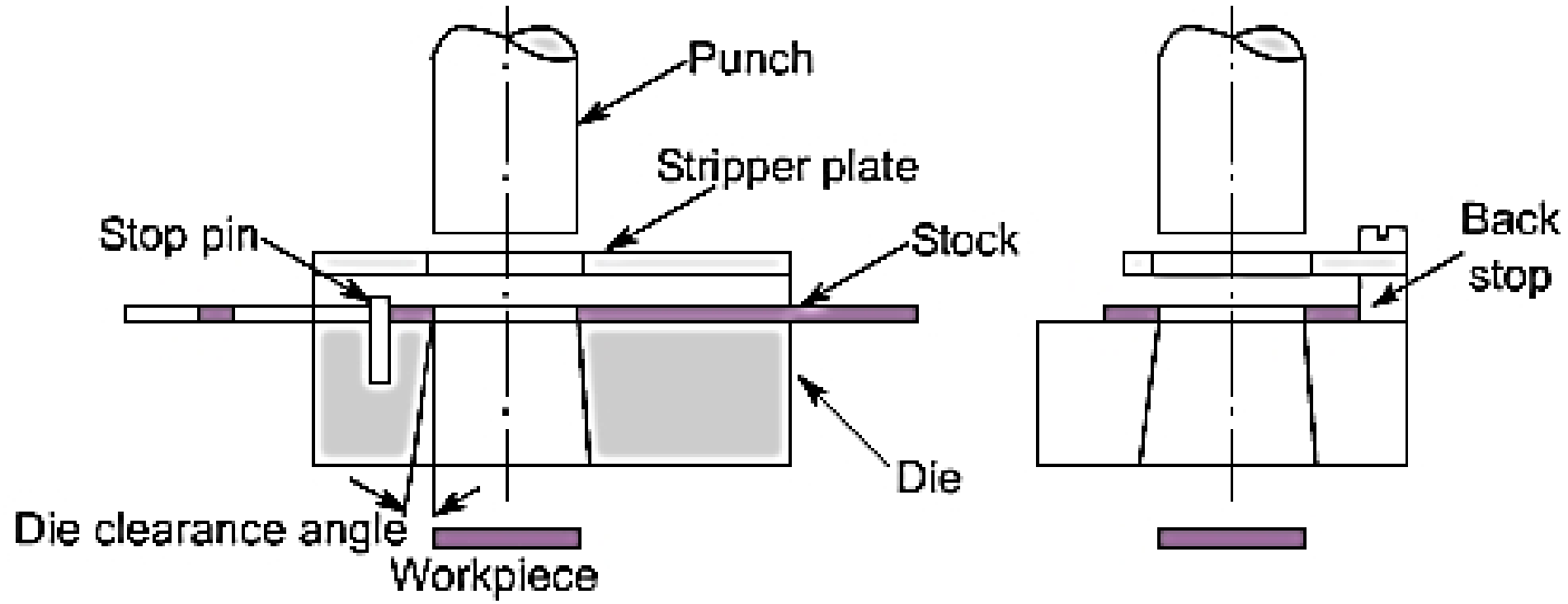
Shearing Operations



Punching (piercing) and blanking.



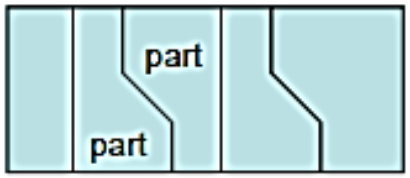
Blanking and punching

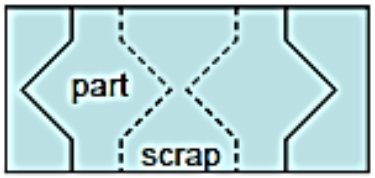


Blanking punch and die

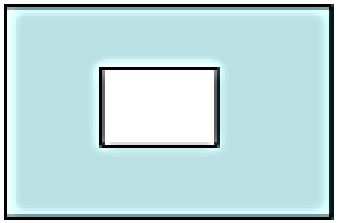
Other Cutting Operations

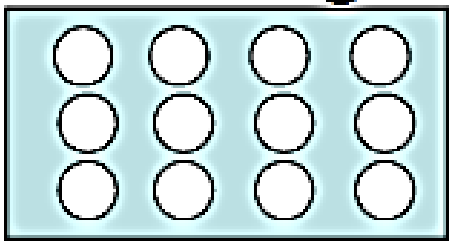
- Cutoff and Parting

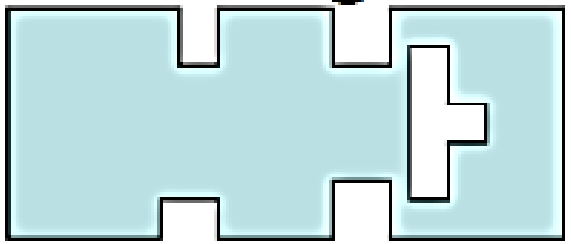




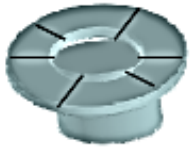
- Slotting, Perforating and Notching





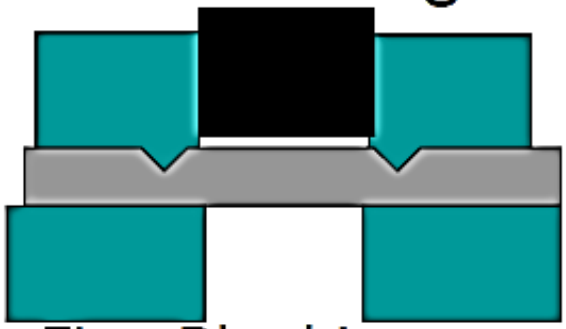


- Trimming, Shaving and Fine Blanking

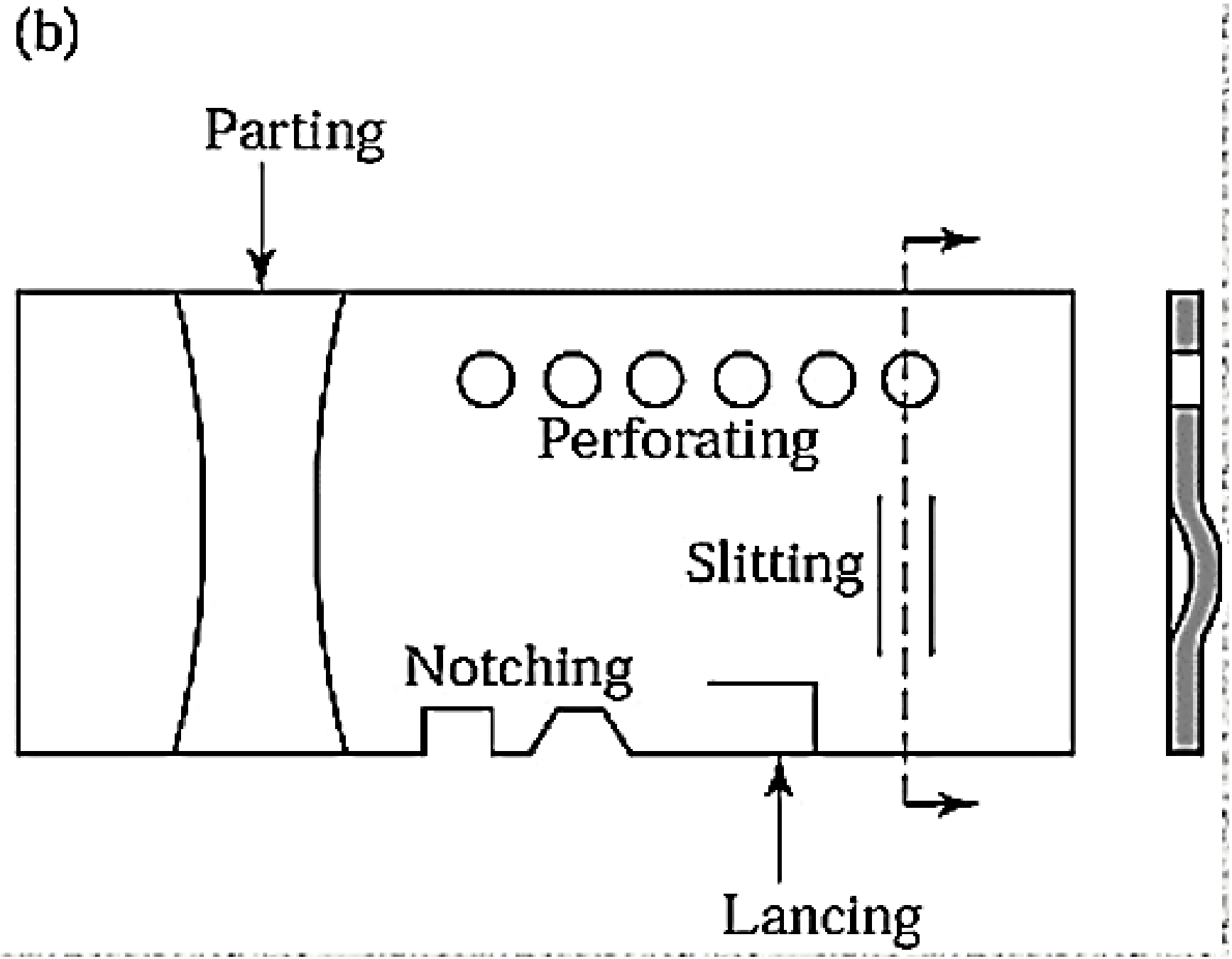


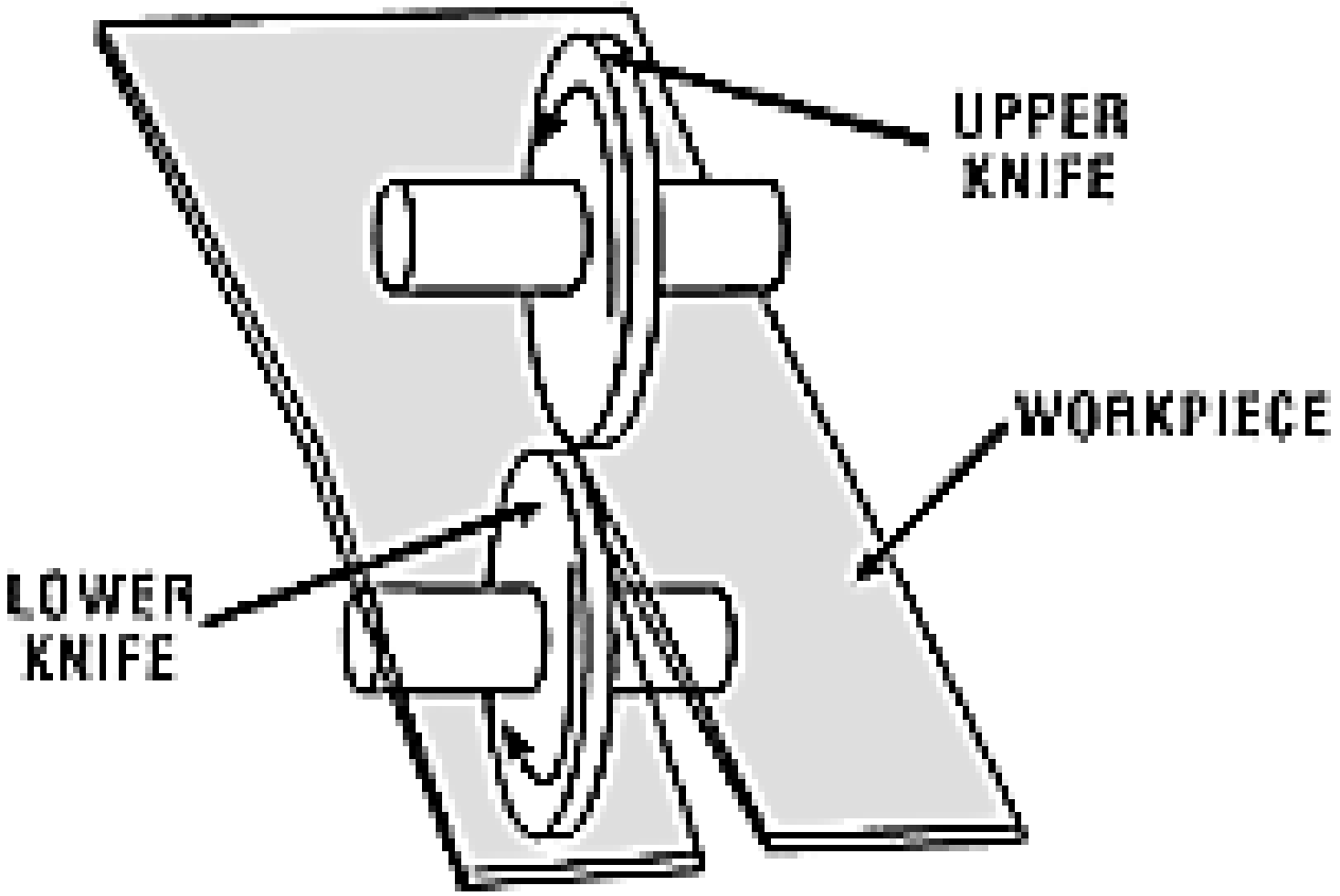
Trimming

Shaving

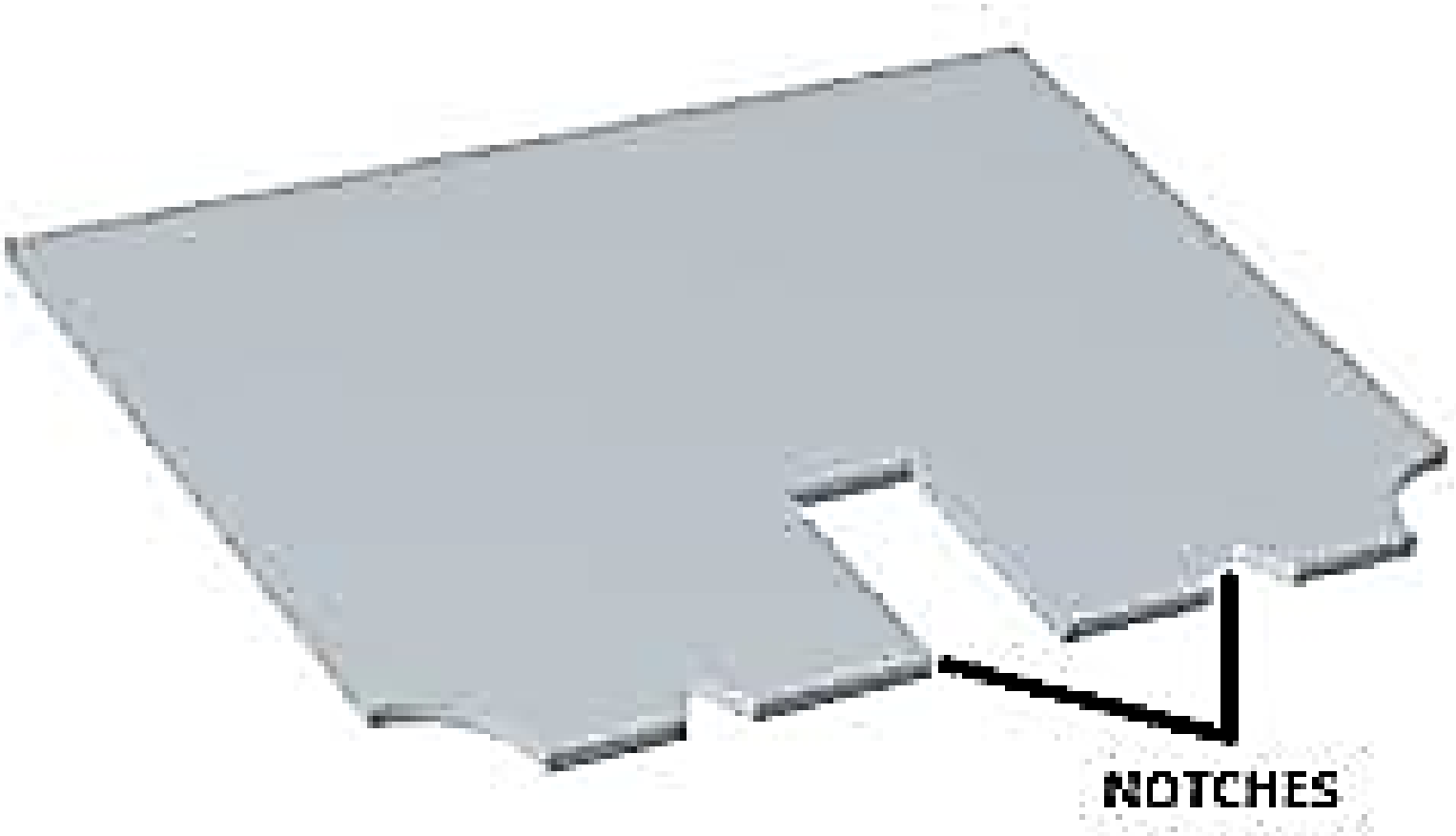


Fine Blanking


(b)
Parting
Perforating
Slitting
Notching
Lancing



SLITTING PROCESS



NOTCHING OPERATION

LANCING OPERATION

Maximum force, P required to be exerted by the punch to shear out a blank from the sheet can be estimated as

$$\mathbf{P = t.L.\tau}$$

t – Sheet thickness

L – Total length sheared

τ - Shear strength of the sheet material

Shearing force, **SF = 0.02 Lt**

SF – Shearing force in KN

L – Length of cut in mm

t – Thickness of material in mm

Clearance between die and punch,

$$\mathbf{c = 0.003t.\tau}$$

Example: A circular blank of 30 mm diameter is to be cut from 2 mm thick 0.1 C steel sheet. Determine the die and punch sizes. Also estimate the punch force and the stripping force needed. You may assume the following for the steel : Tensile strength: 410 MPa ; shear strength : 310 MPa

Solution:- For cutting a blank, die size = blank size

$\therefore$ Die size = 30mm

Clearance = $0.003 \times t \times \tau = 0.003 \times 2 \times 310$

$= 1.86$ mm

Punch size = blank size – 2 clearance

$= 30 - 2 \times 1.86 = 26.28$ mm

Punch force needed = L. t. $\boldsymbol{\tau} = \pi \times 30 \times 2 \times 310$

$= 58.5$ kN

Stripping force needed = 0.02 L.t

$= 0.02 \times \pi \times 30 \times 2$

$= 3.77$ kN

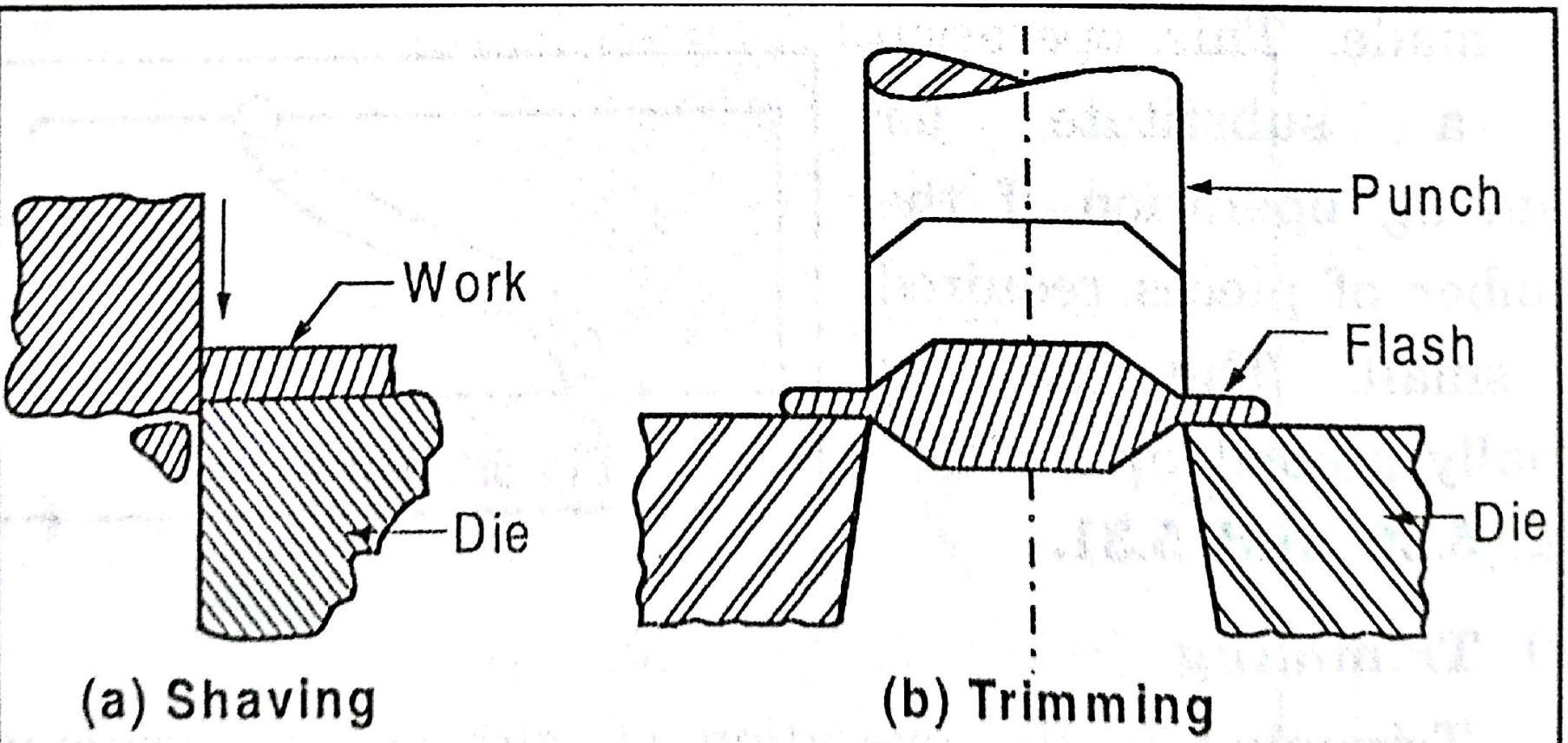
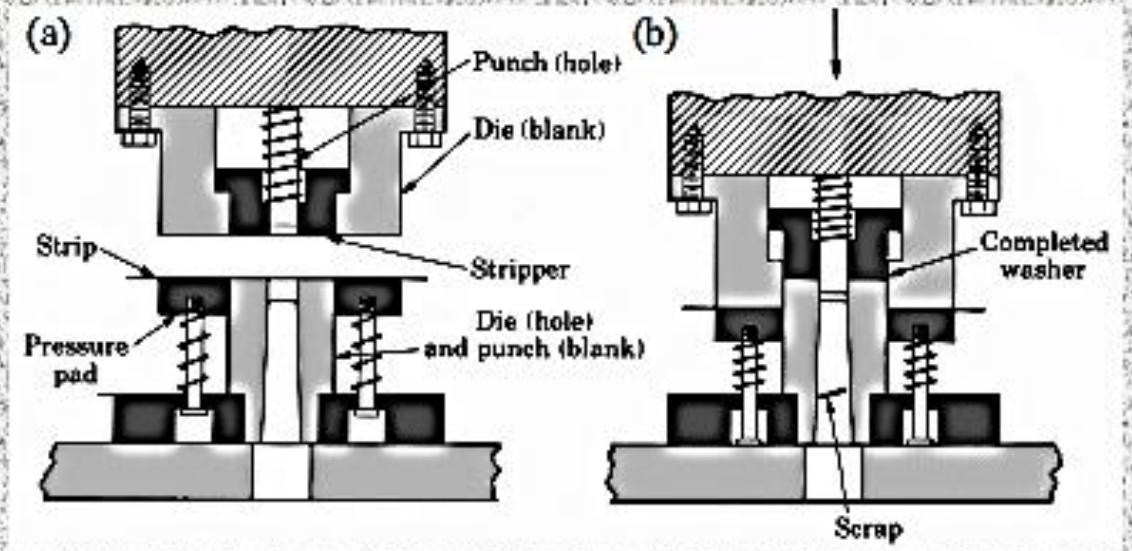
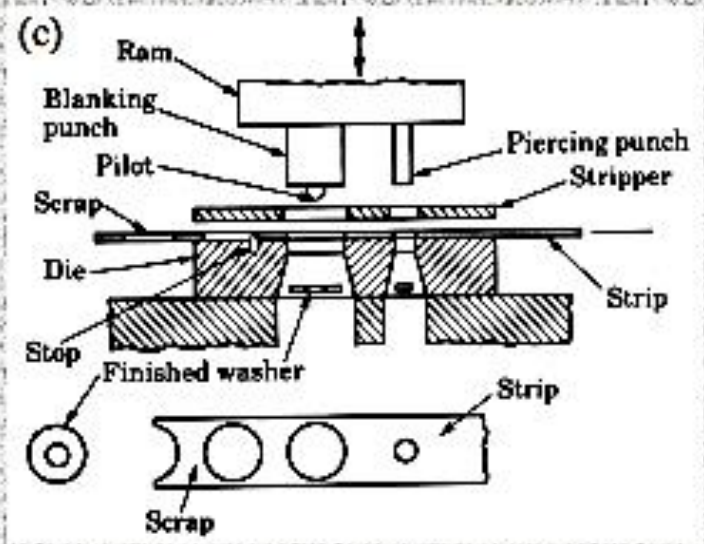


Fig 5.33 Shaving and Trimming Operations

PROGRESSIVE AND COMPOUND DIES

Compound and Progressive Die





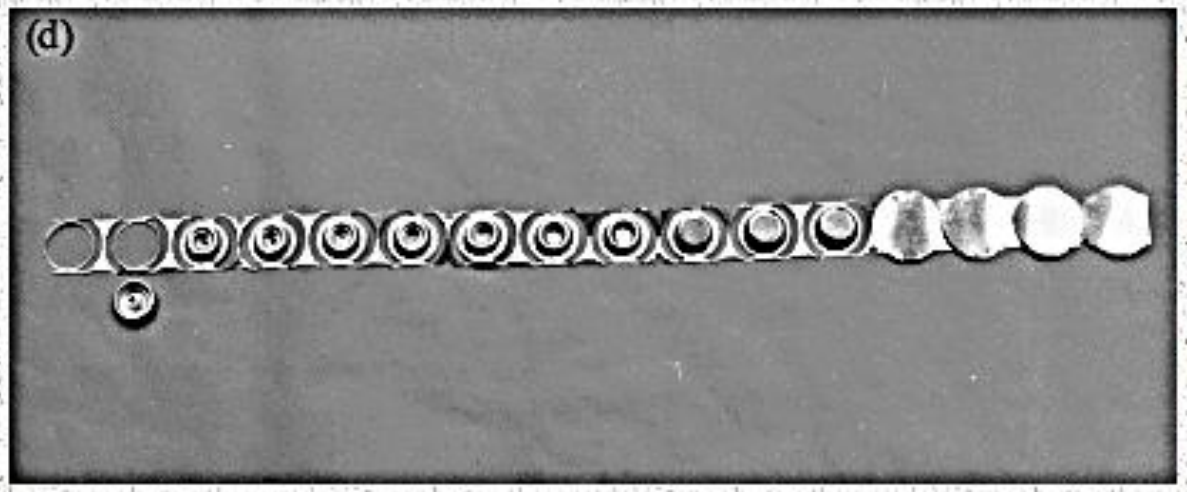
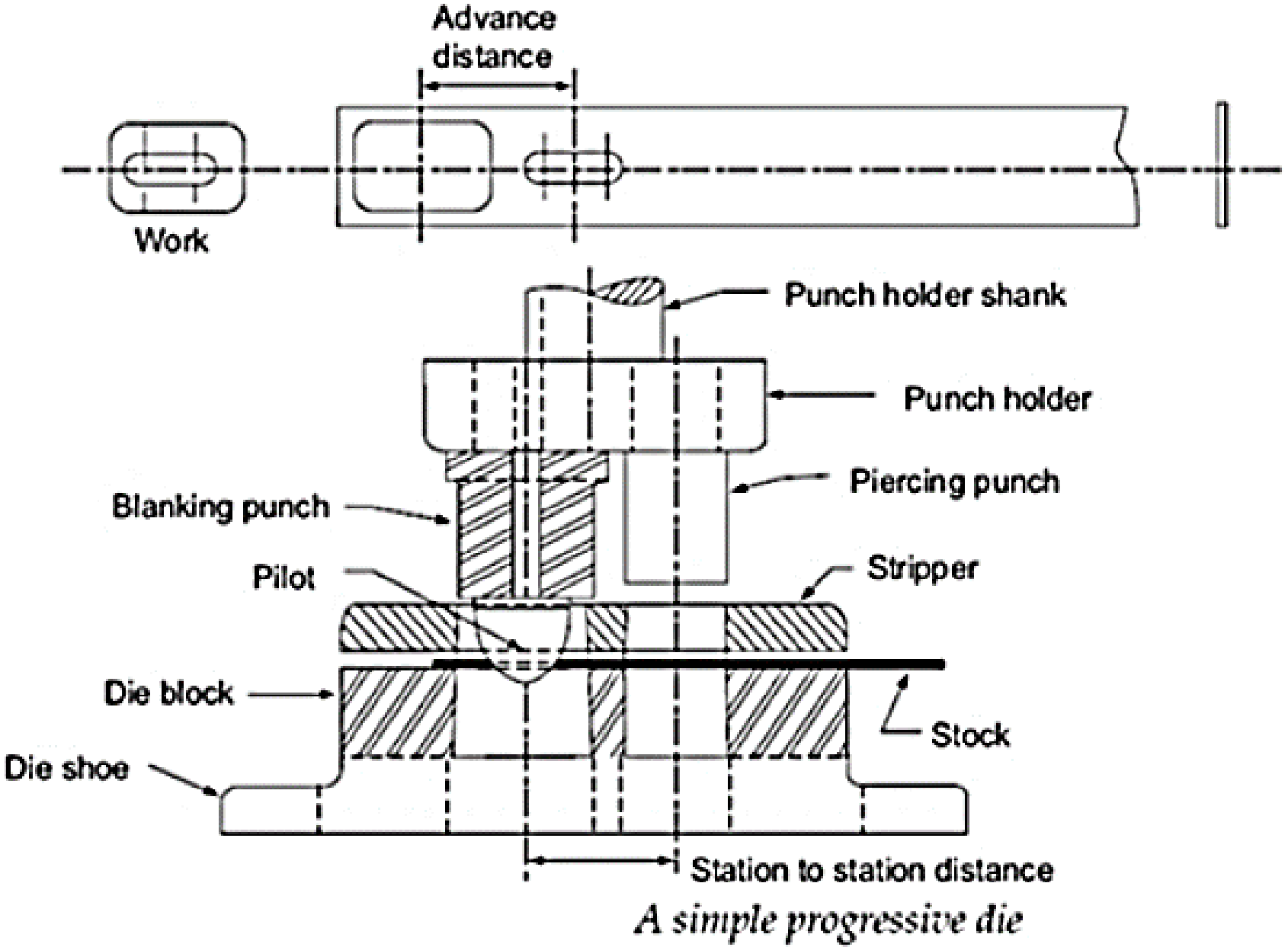


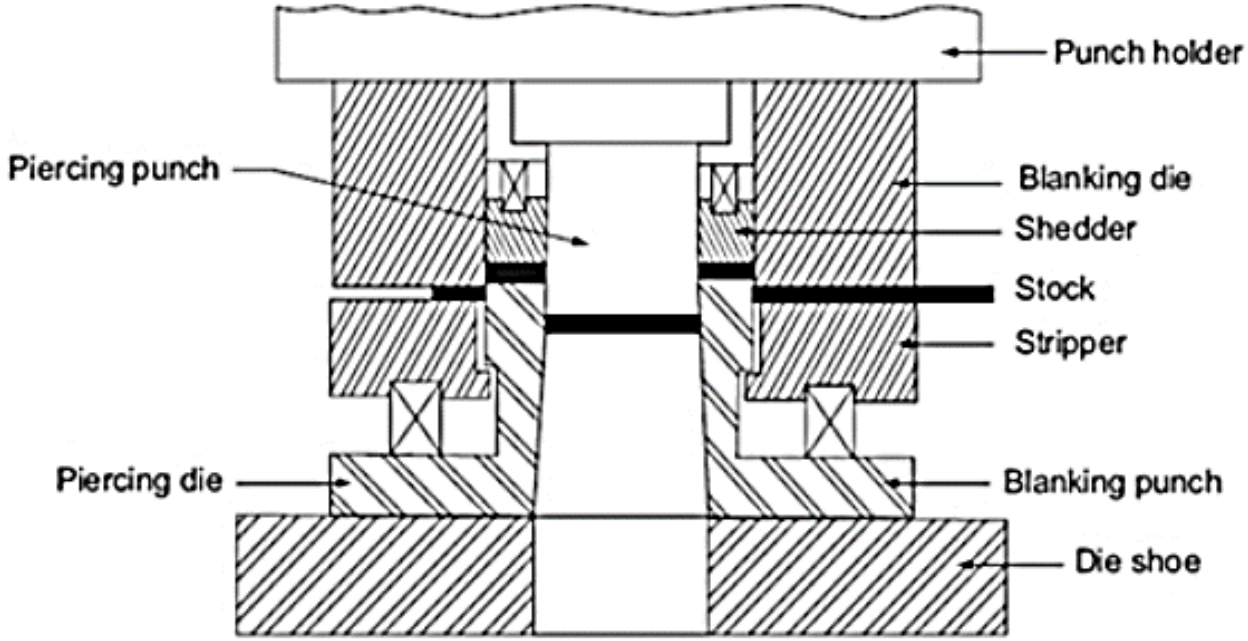
Figure 16.11 Schematic illustrations: (a) before and (b) after blanking a common washer in a compound die. Note the separate movements of the die (for blanking) and the punch (for punching the hole in the washer). (c) Schematic illustration of making a washer in a progressive die. (d) Forming of the top piece of an aerosol spray can in a progressive die. Note that the part is attached to the strip until the last operation is completed.

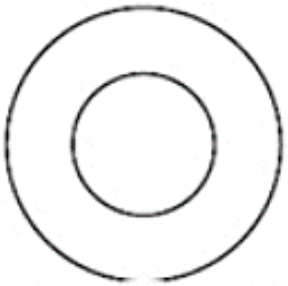
PROGRESSIVE DIE



A simple progressive die

COMPOUND DIE





Component

Compound die for making a washer

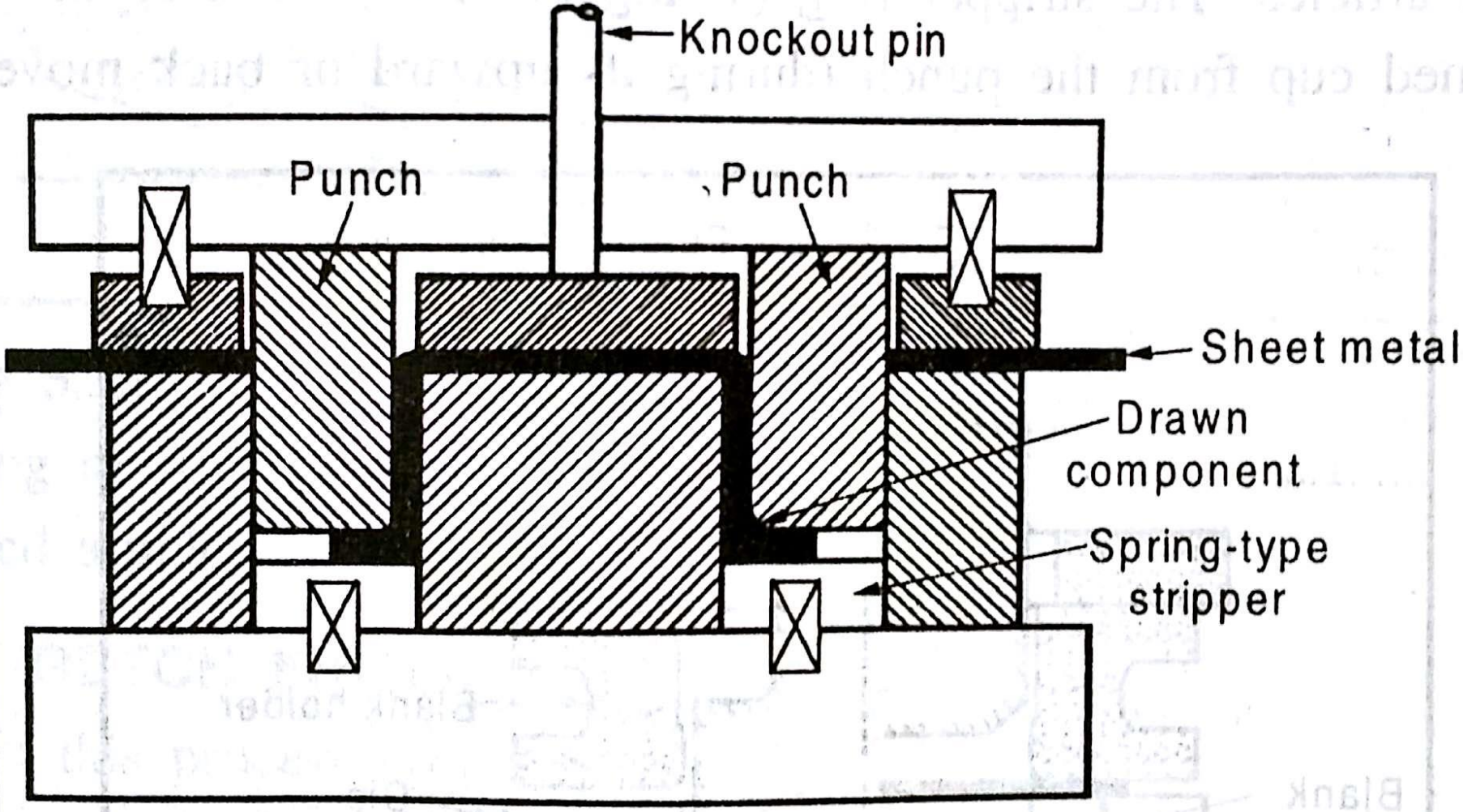
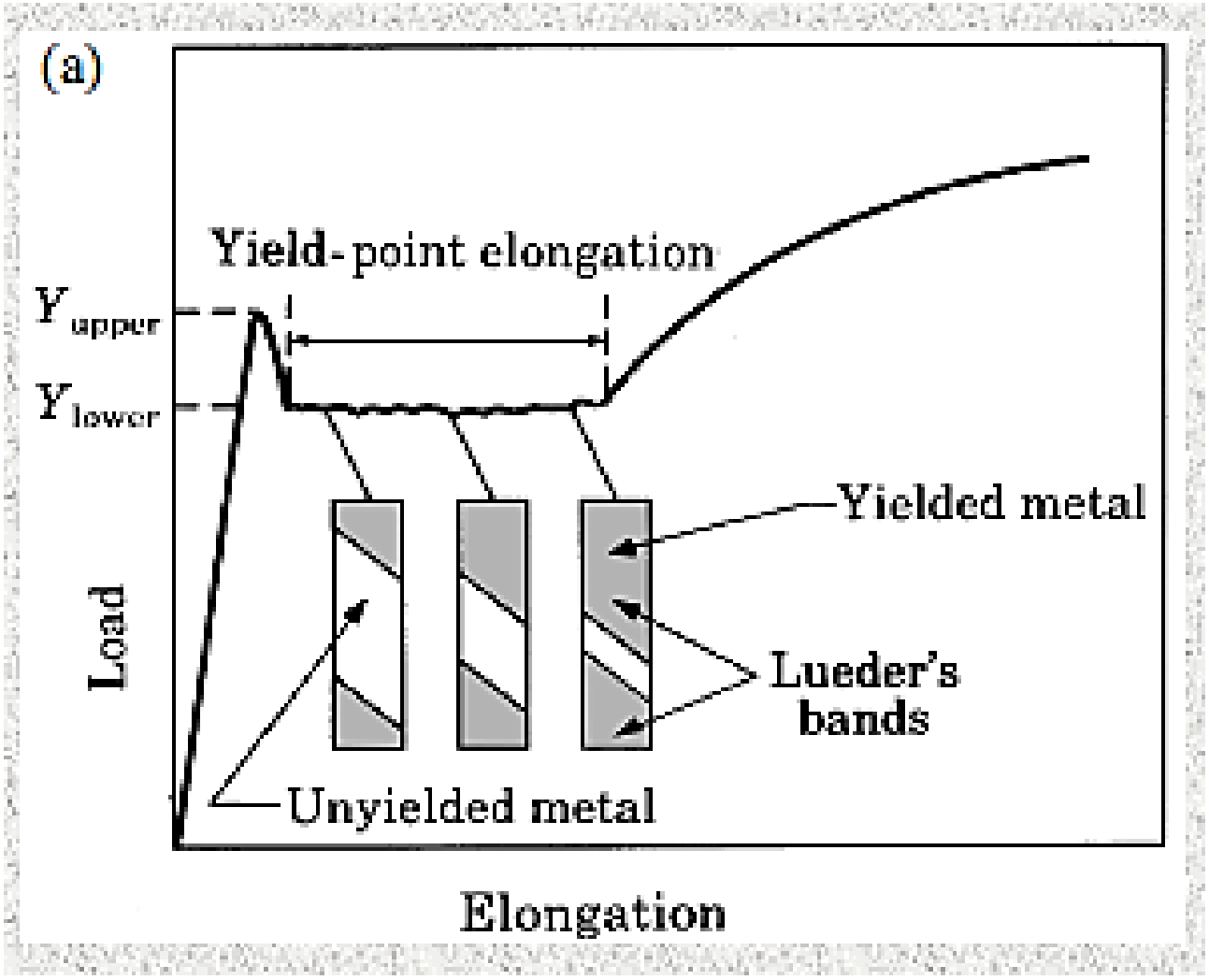


Fig 5.21 Compound Die for blanking & drawing operation in one go of the press

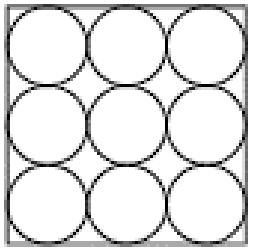
Yield-Point Elongation

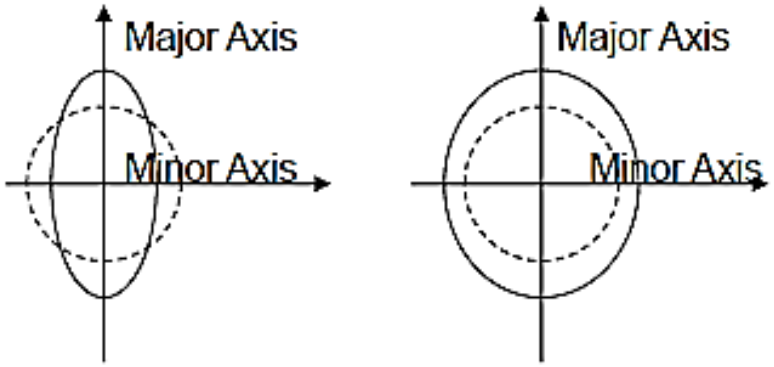


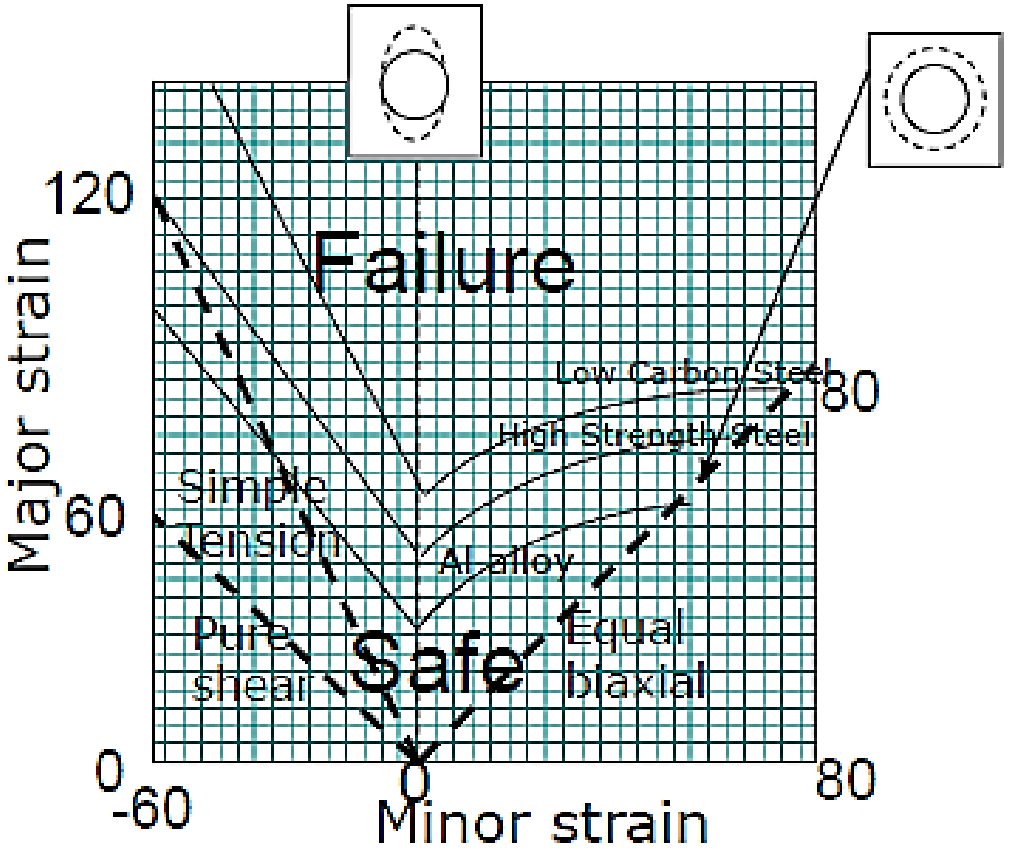
Forming-Limit Diagram

A grid pattern of circles, typically 2.5 to 5mm in diameter, produced by electrochemical or photoprinting.

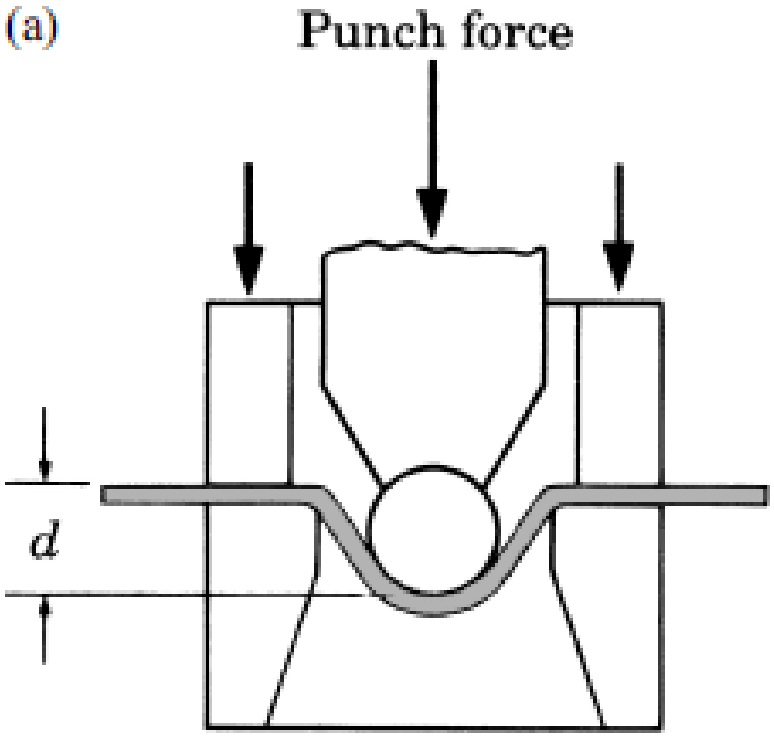
After drawing, the circles are observed for failure. The major strain is on the major direction and magnitude of strain



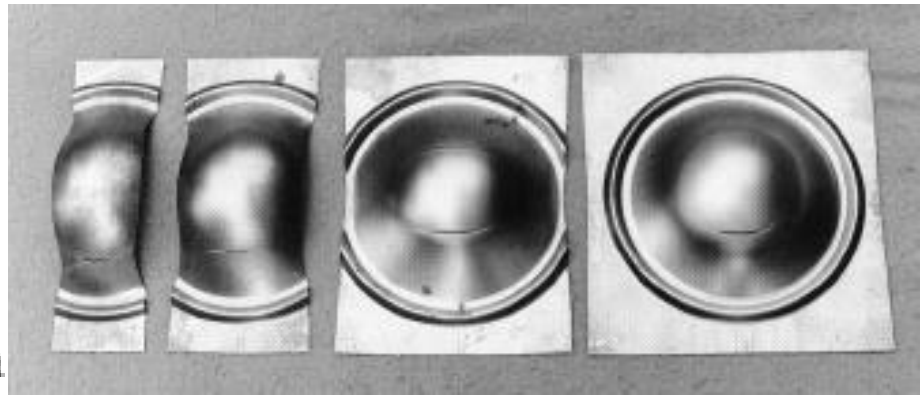

Major Axis
Minor Axis
Major Axis
Minor Axis


Failure
Safe
Low Carbon Steel
High Strength Steel
Al alloy
Simple tension
Pure shear
Equal biaxial
Major strain
Minor strain
120
60
0
-60
0
80
80

Erichsen and Bulge-Tests

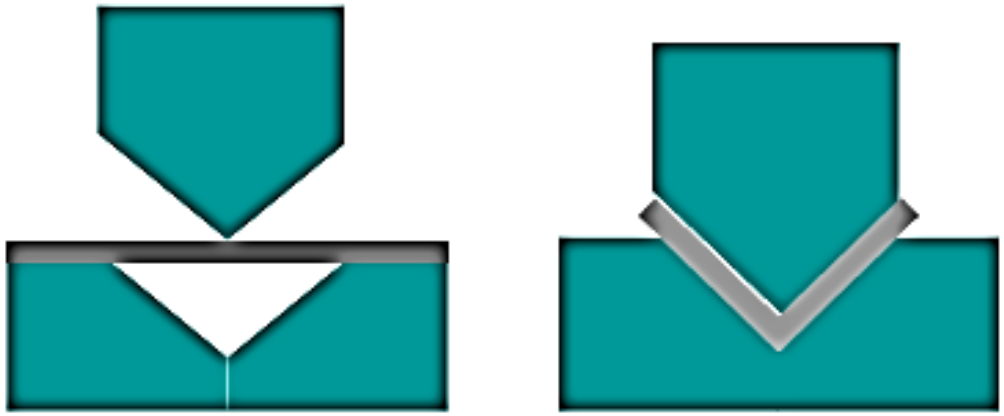


Sheet specimen

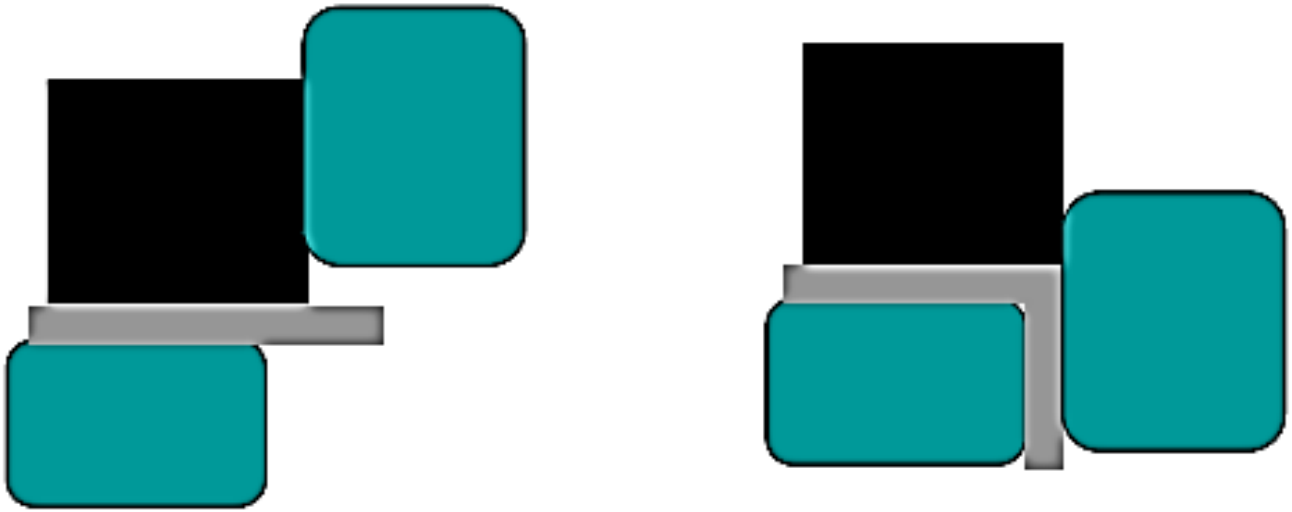


Bending Operations

- V-bending



- Edge Bending

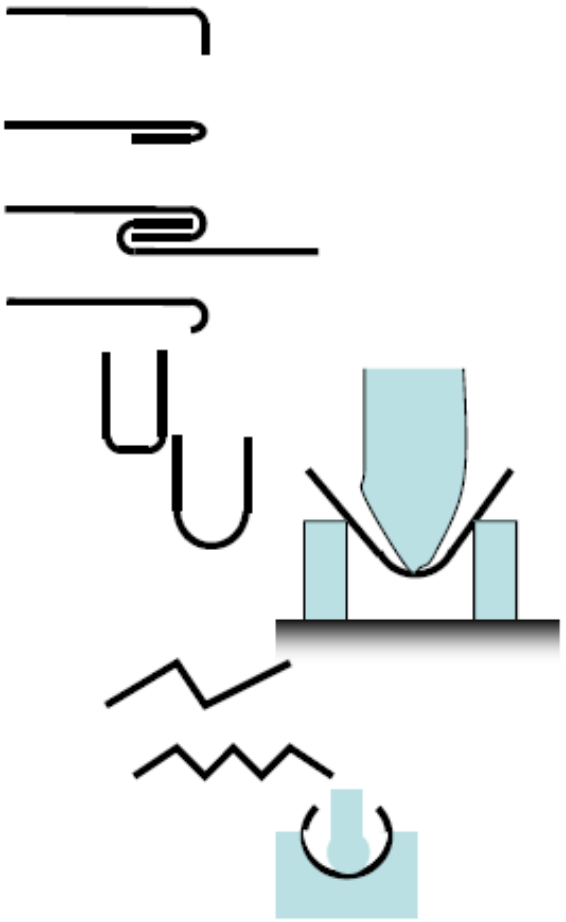


In V-bending, the sheet metal is bent between a V-shaped punch and die set up. The included angles range from very obtuse to very acute values.

In edge bending, cantilever loading of the sheet is seen. A pressure pad is used to apply a force to hold the sheet against the die, while the punch forces the sheet to yield and bend over the edge of the die.

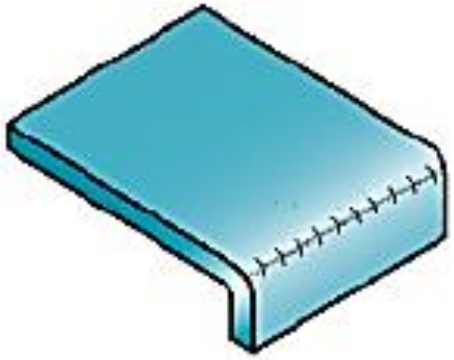
Other Bending Operations

- ✓ Flanging
- ✓ Hemming
- ✓ Seaming
- ✓ Curling
- ✓ Channel,



- ✓ U-bending
  Offset bending,
  and Tube forming

Air bending,
Corrugating

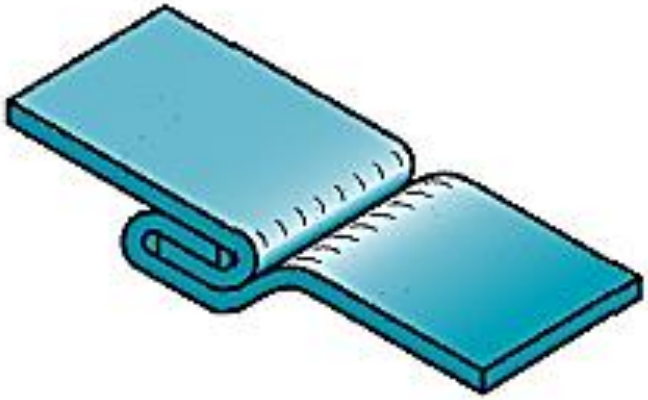


Straight flanging

stretch flanging

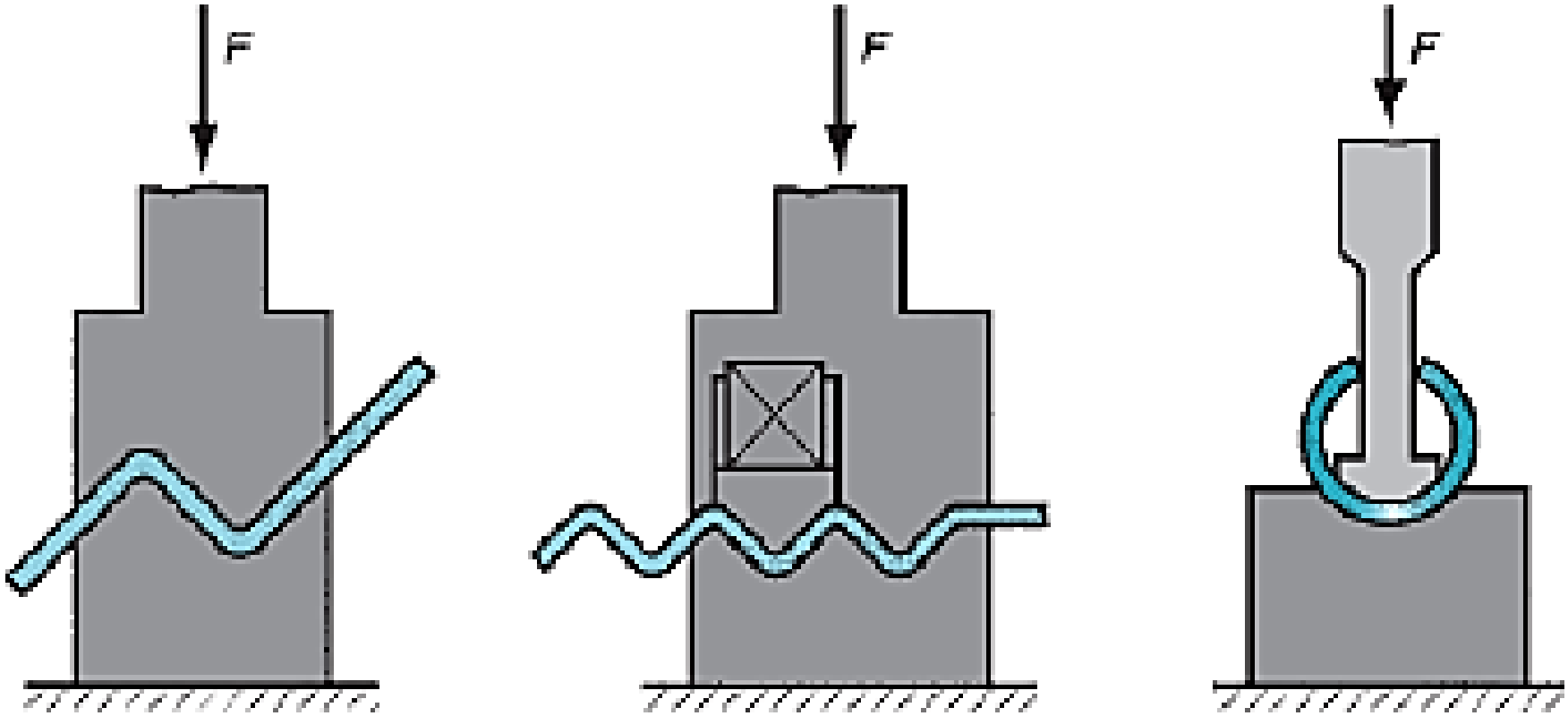
shrink flanging

Hemming



seaming

curling



Other bending operations

BENDING OPERATION

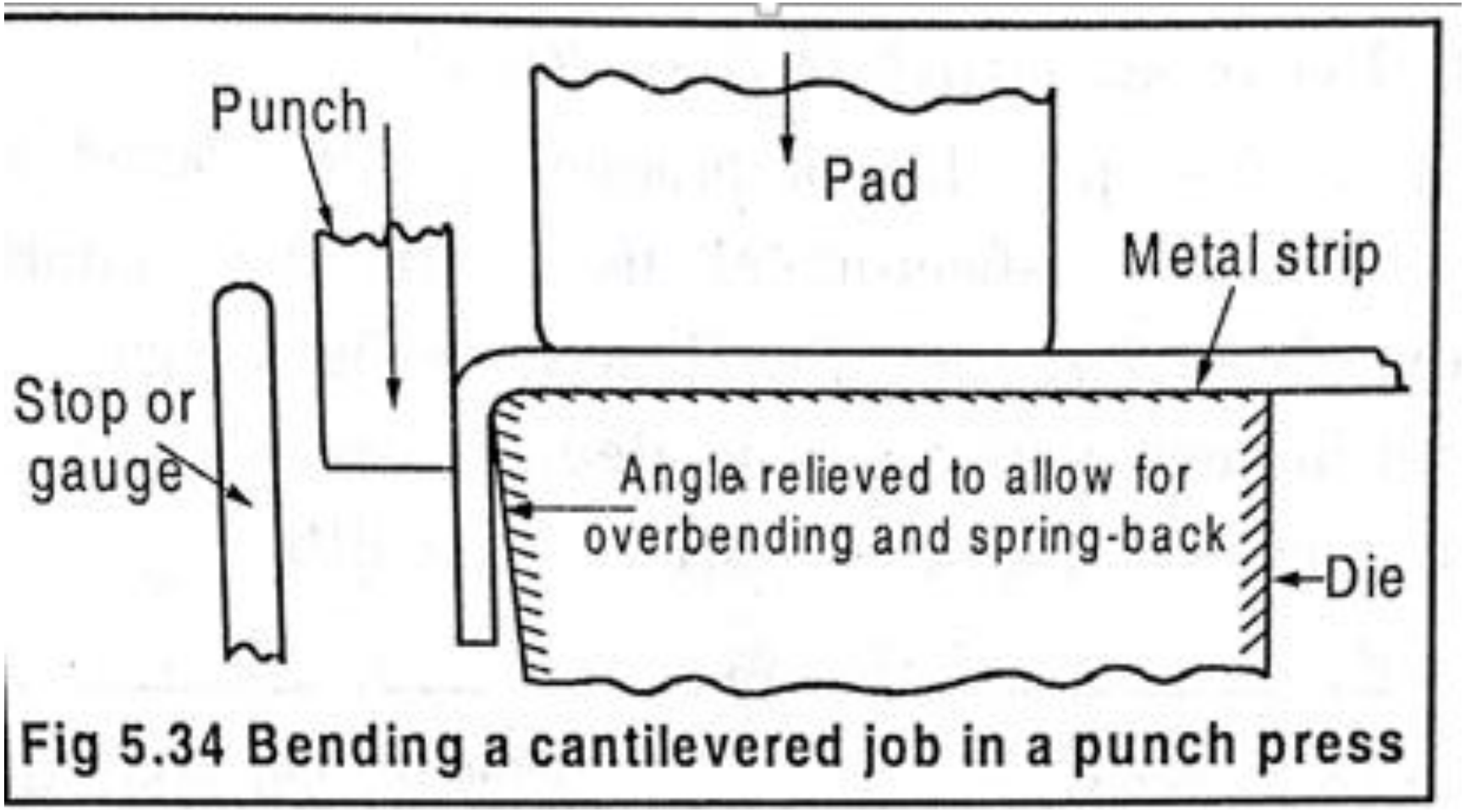


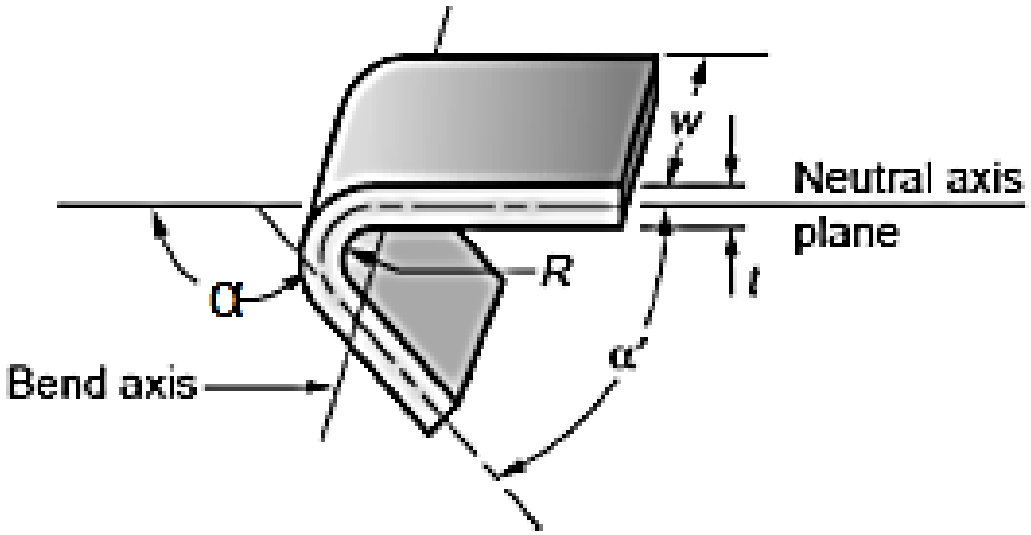
Fig 5.34 Bending a cantilevered job in a punch press

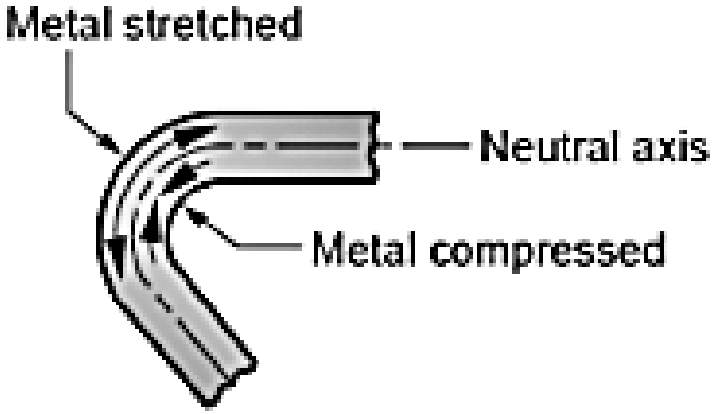
Sheet bending

Sheet bending is defined as the straining of the metal around a straight axis.

During bending operation, the metal on the inner side of the neutral plane is compressed, and the metal on the outer side of the neutral plane is stretched.

Bending causes no change in the thickness of the sheet metal.


w
Neutral axis
plane
R
t
α
Bend axis
α'


Metal stretched
Neutral axis
Metal compressed

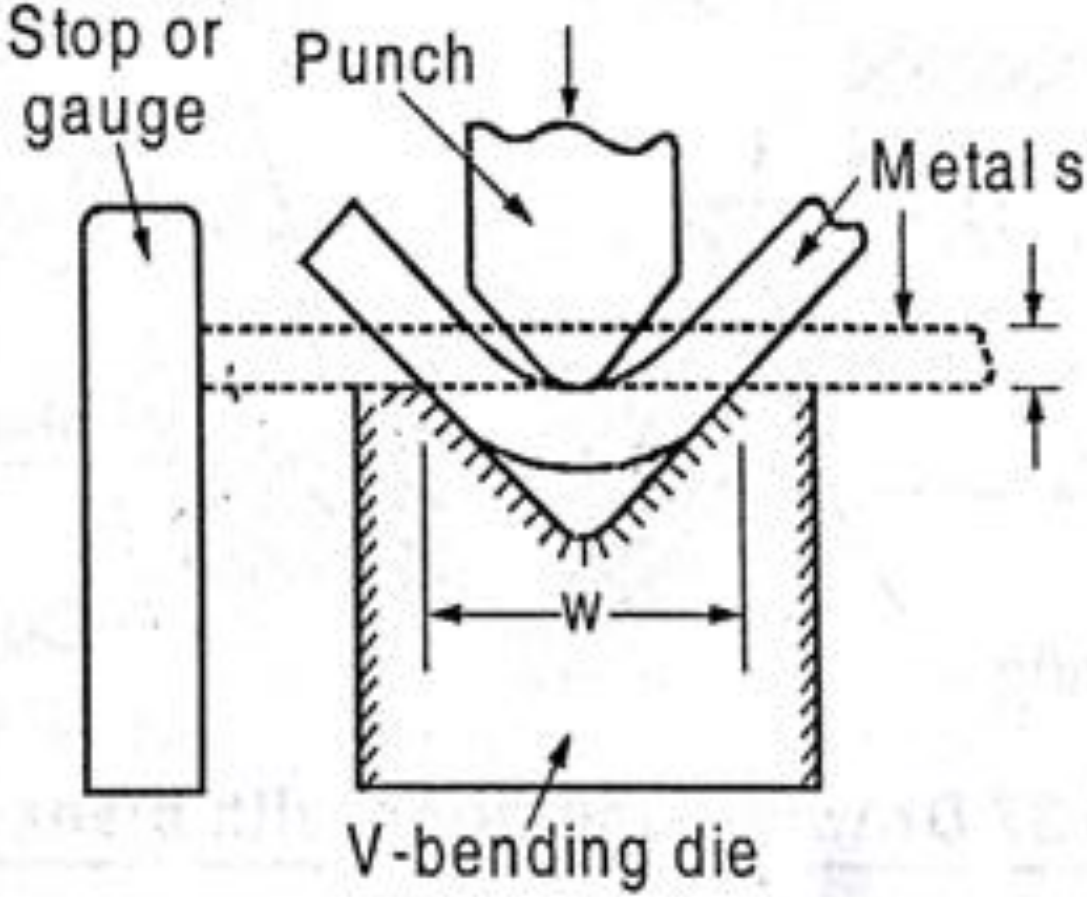


Fig 5.35 Making a 90° bend in a V die and press

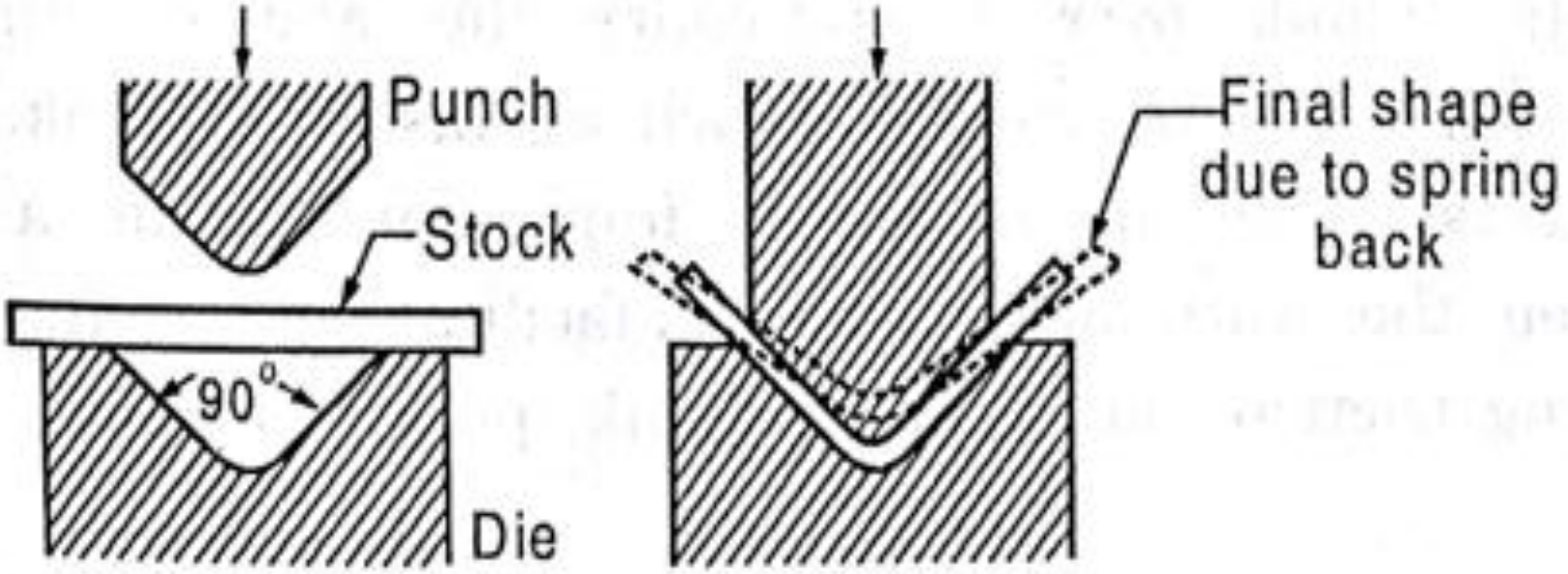


Fig. 5.36 Bending operation (showing spring back)

SPRING BACK

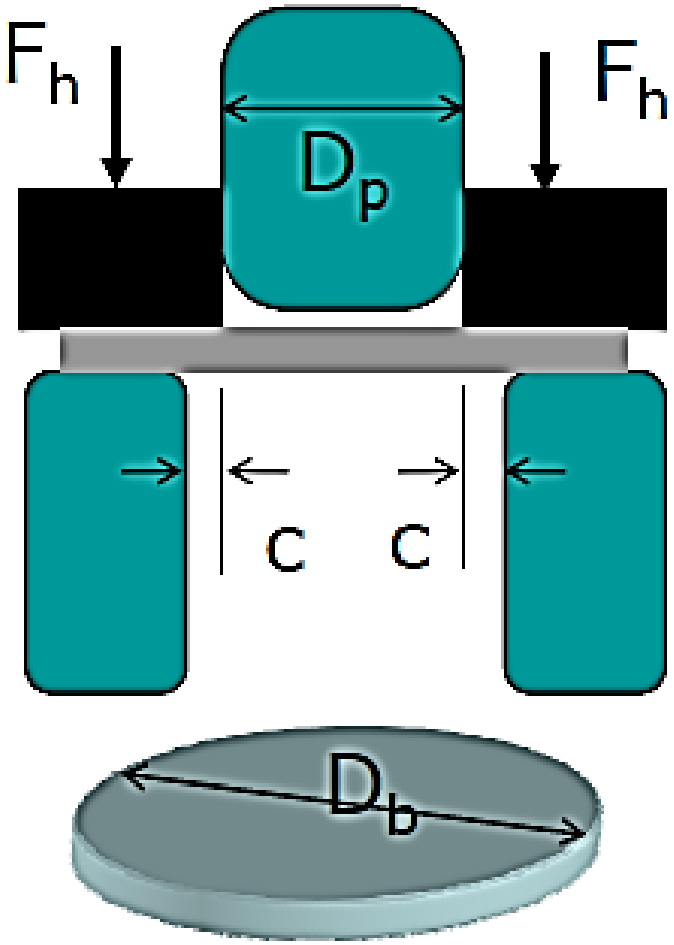
At the end of the bending operation, the bent part retains some of its elasticity which is recovered after the punch is removed.

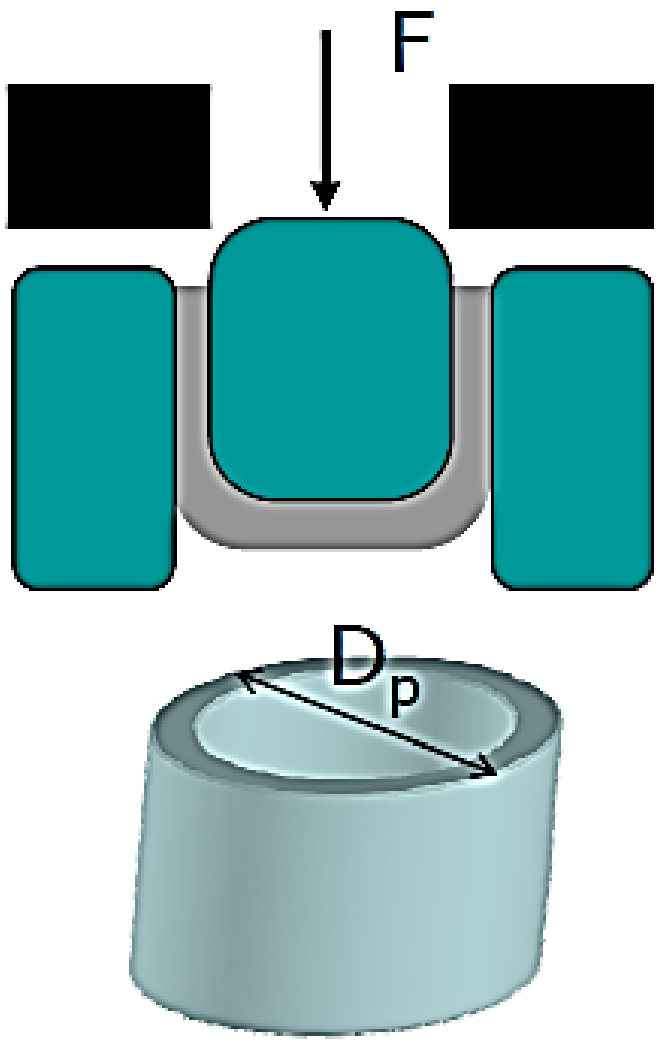
PREVENTING METHODS

1. Stretch forming
2. Overbending
3. Bottoming
4. Ironing

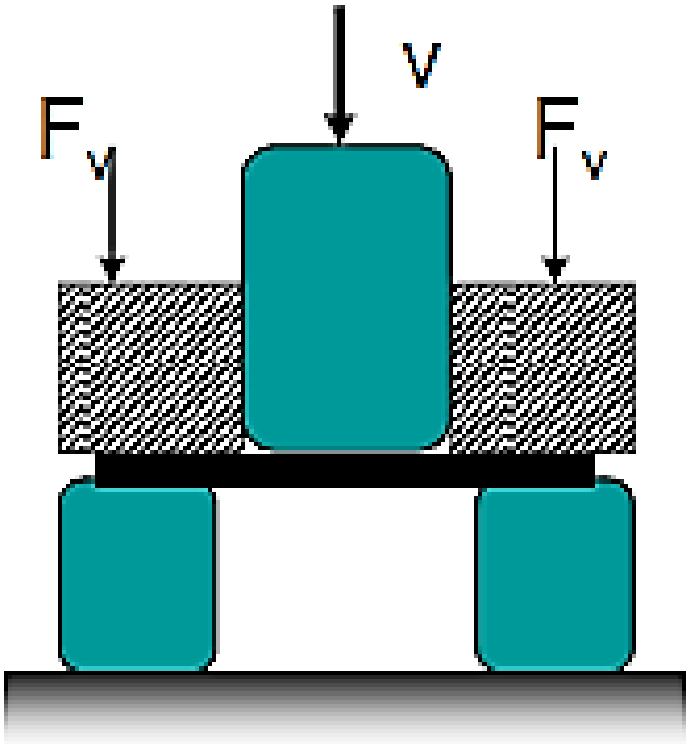
Drawing

Basic drawing operation –a cup-shape part

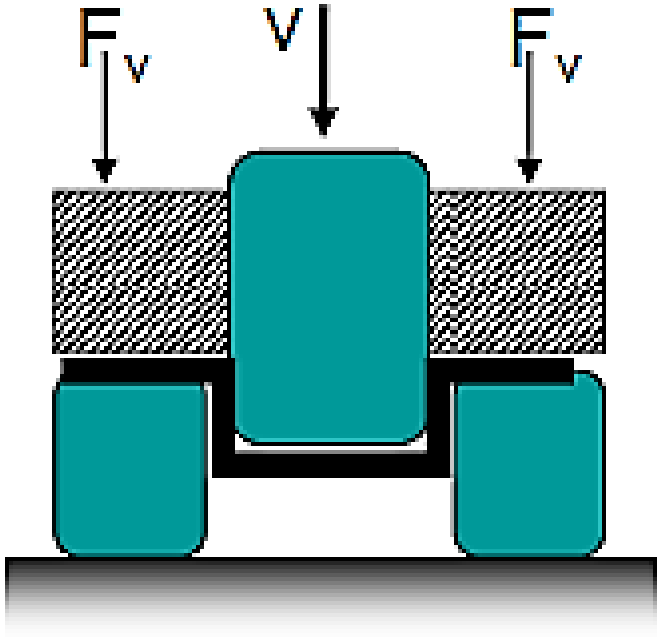




Detail Steps of Drawing

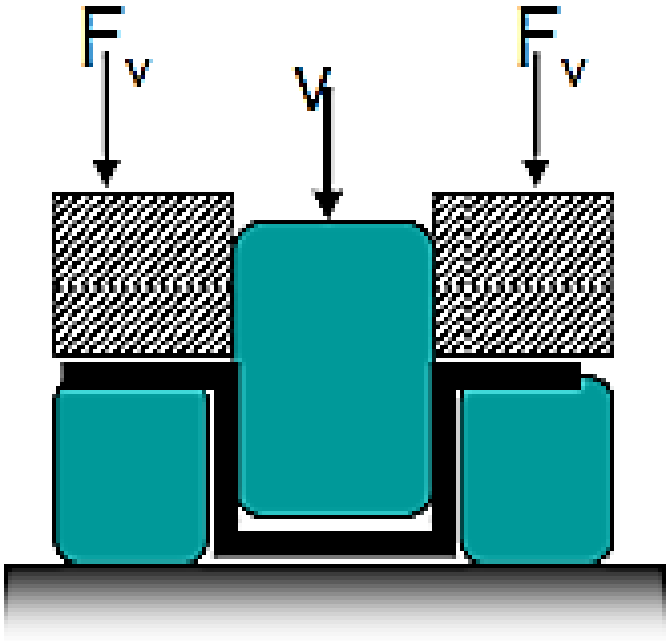


1. Initial Contact

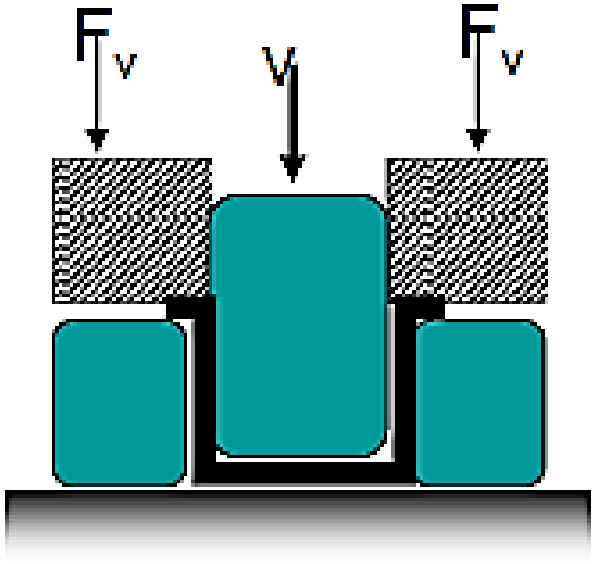


2. Bending

Detail Steps of Drawing....

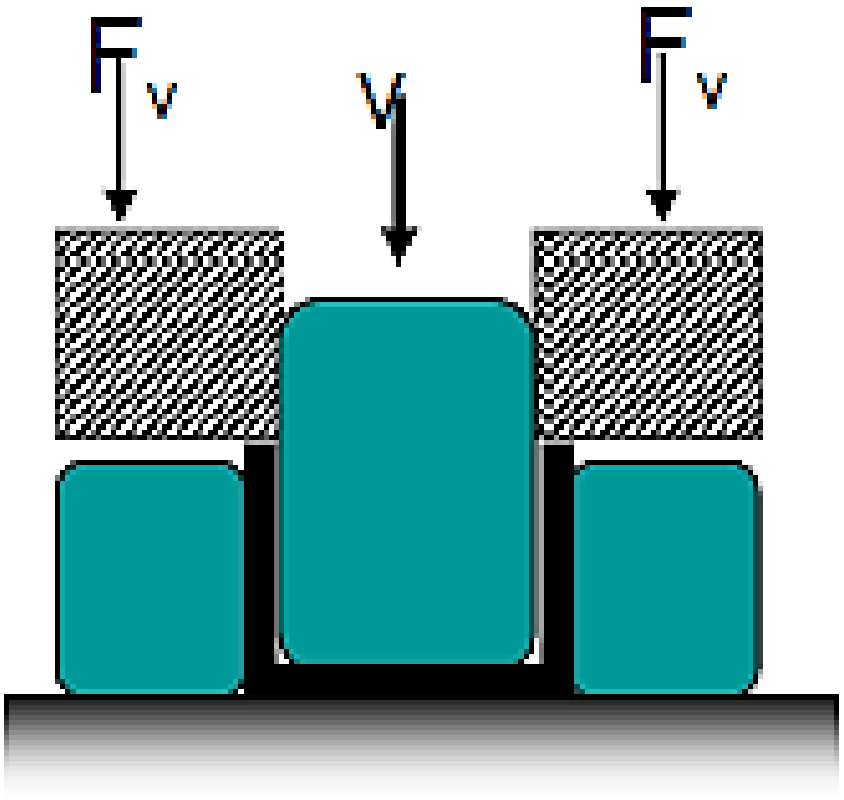


3. Straightening



4. Friction & Compression

Detail Steps of Drawing...



5. Final Shape

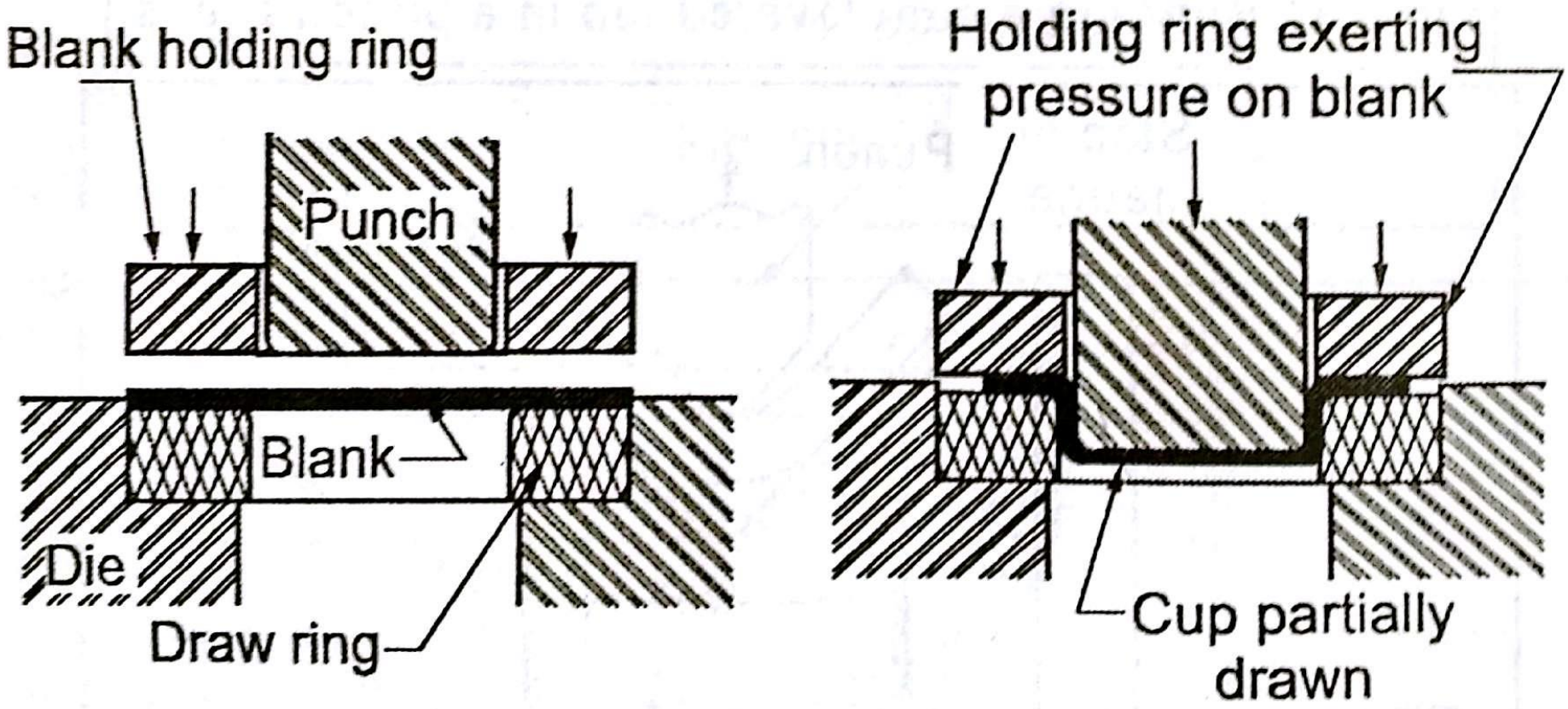
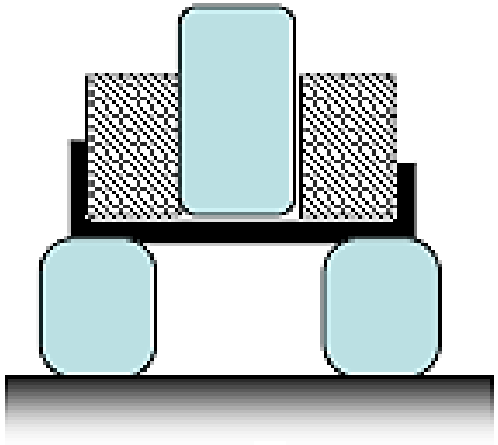
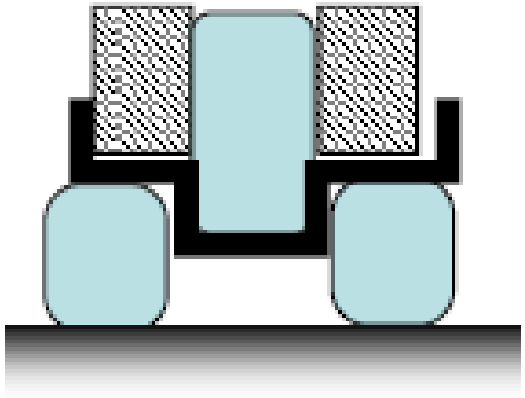


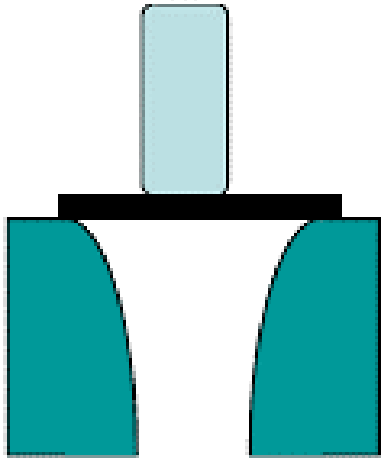
Fig. 5.37 Drawing operation with blank holder

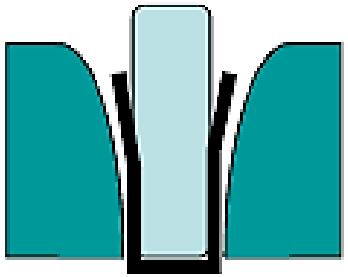
Other Drawing Operation

- Redrawing
- Drawing without a Blankholder









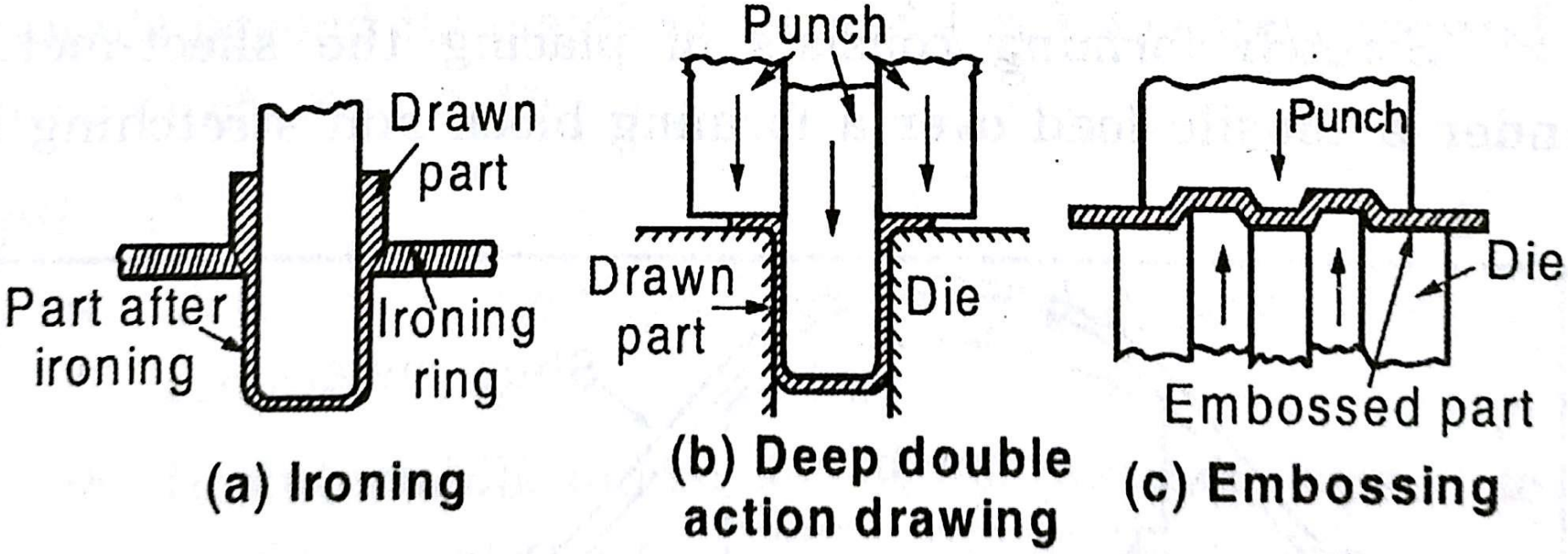


Fig. 5.38 Sheet-metal drawing operations, (a) ironing is the operation in which wall thickness of a drawn part is made constant by pushing the drawn part through ironing rings, (b) deep drawing with double action drawing, (c) embossing is stretching the sheet-metal blank into desired shape under a punch and die.

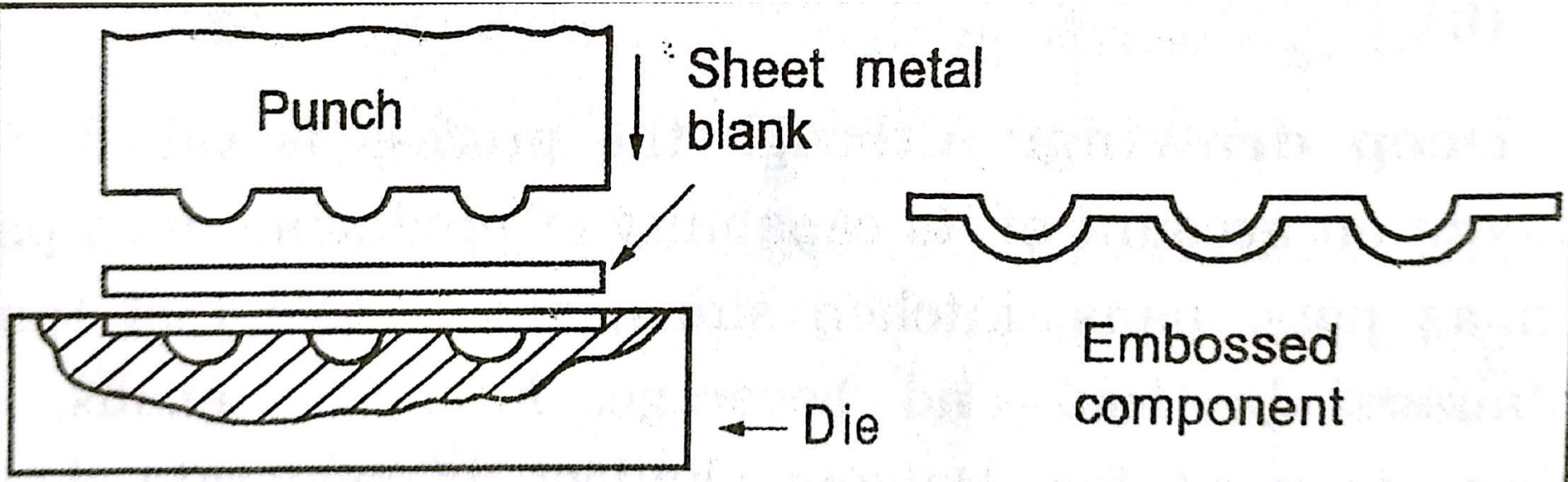
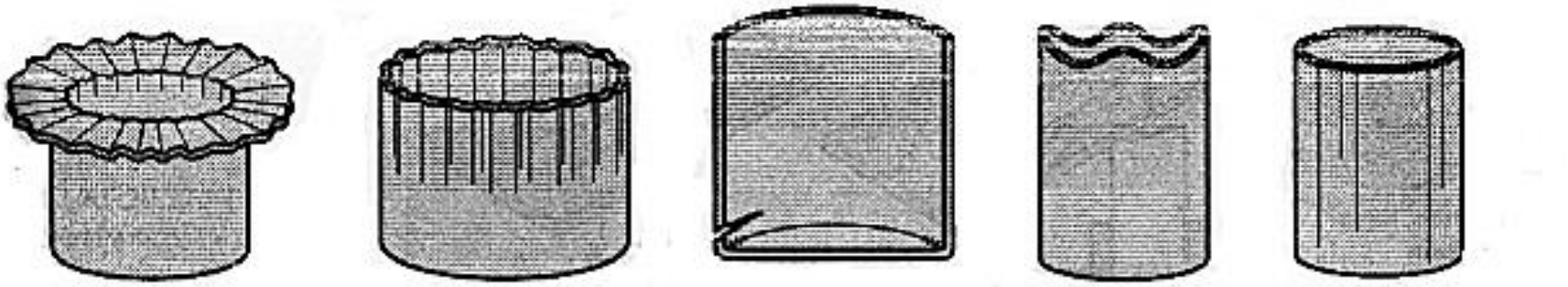


Fig. 5.39. Embossing

Defects in drawing

- Wrinkling in the flange
- Wrinkling in the wall
- Tearing
- Earing –Anistropy in sheet metal
- Surface scratch



- Wrinkling in flange and cup wall: This is like ups and downs or waviness that is developed on the flange. If the flange is drawn into the die hole, it will be retained in cup wall region.

- Tearing: It is a crack in the cup, near the base, happening due to high tensile stresses causing thinning and failure of the metal at this place. This can also occur due to sharp die corner.

- Earing: The height of the walls of drawn cups have peaks and valleys called as earing. There may be more than four ears. Earing results from planar anisotropy (ΔR), and ear height and angular position correlate well with the angular variation of R.

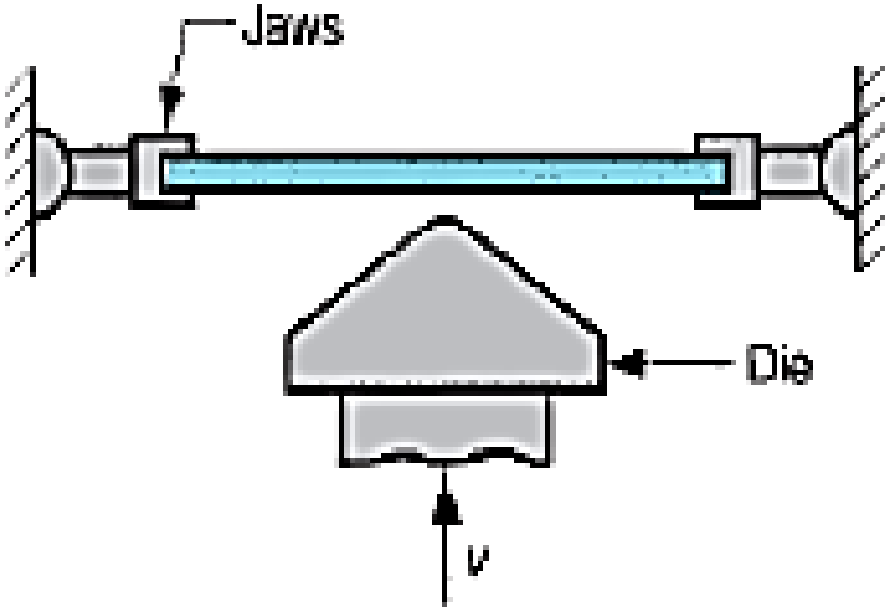
- Surface scratches: Usage of rough punch, dies and poor lubrication cause scratches in a drawn cup.

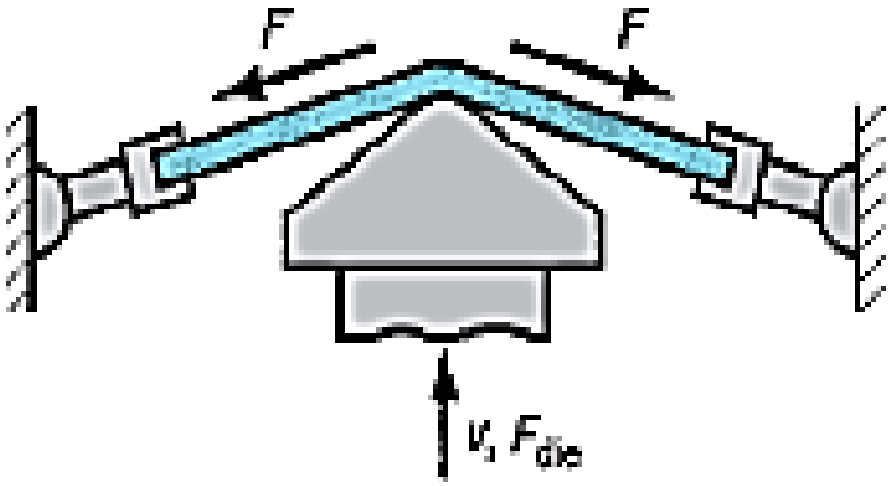
Stretching/stretch forming

Stretch forming is a sheet metal forming process in which the sheet metal is intentionally stretched and simultaneously bent to have the shape change.

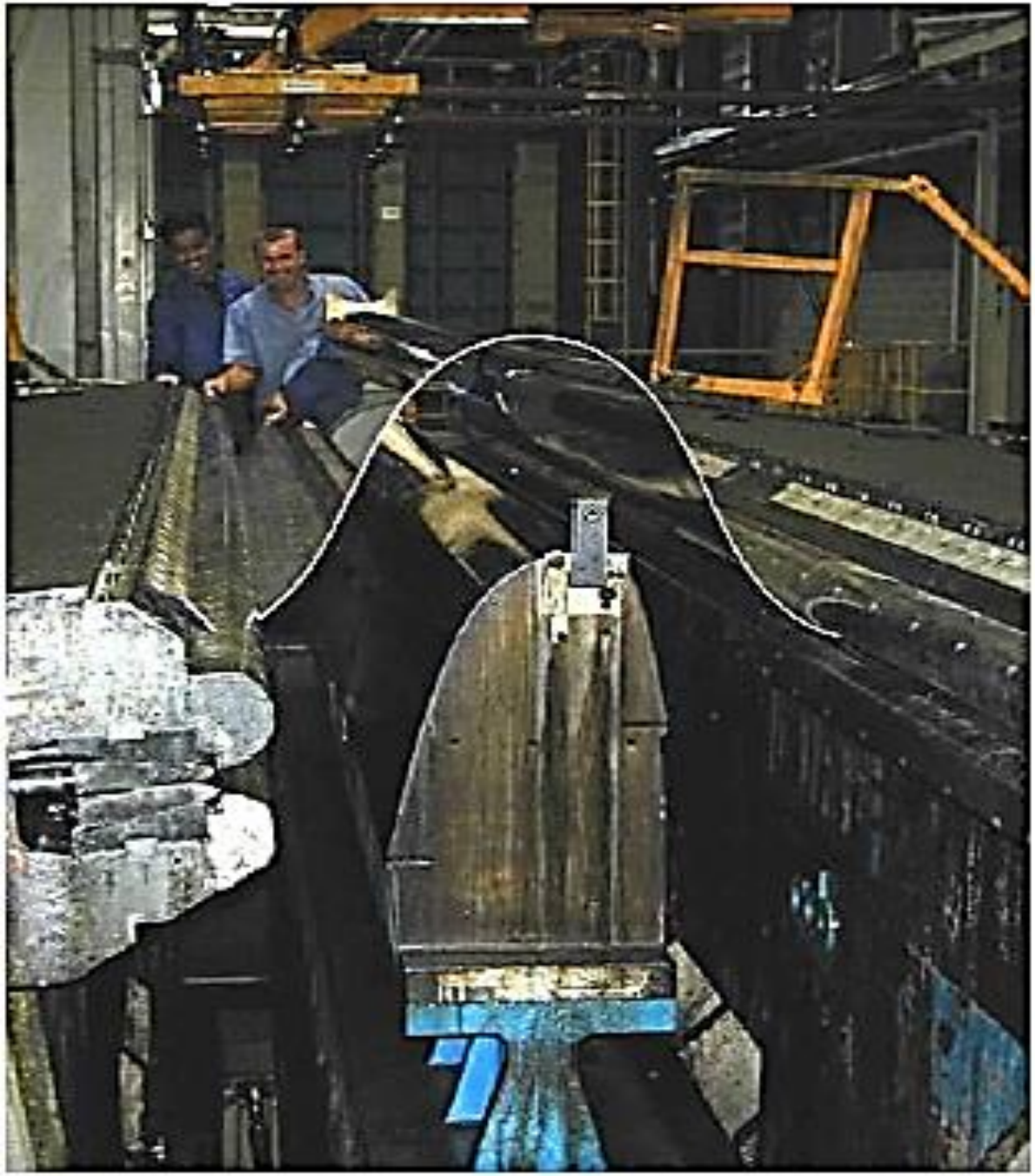
Sheet is held by jaws or drawbeads at both the ends and then stretched by punch, such that the sheet is stressed above yield strength.

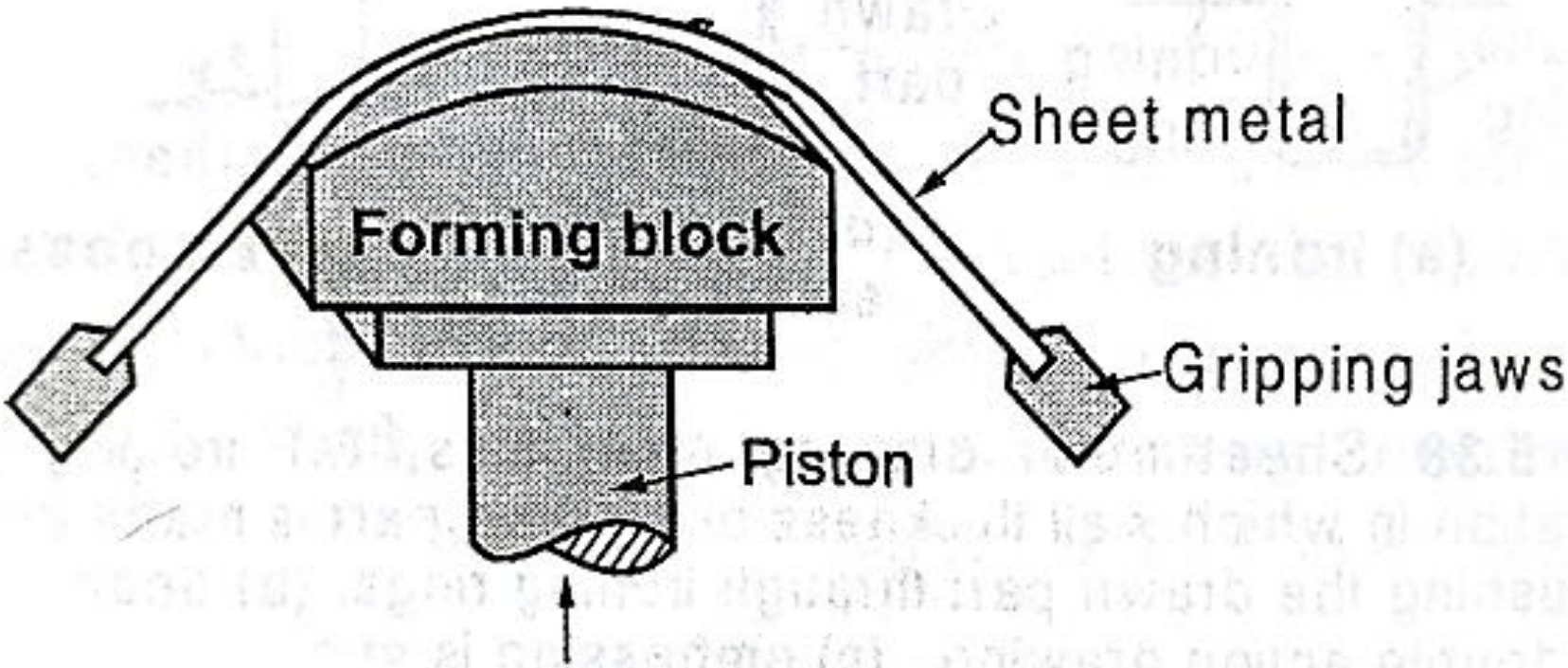
When the tension is released, the metal has been plastically deformed. The combined effect of stretching and bending results in relatively less springback in the part.



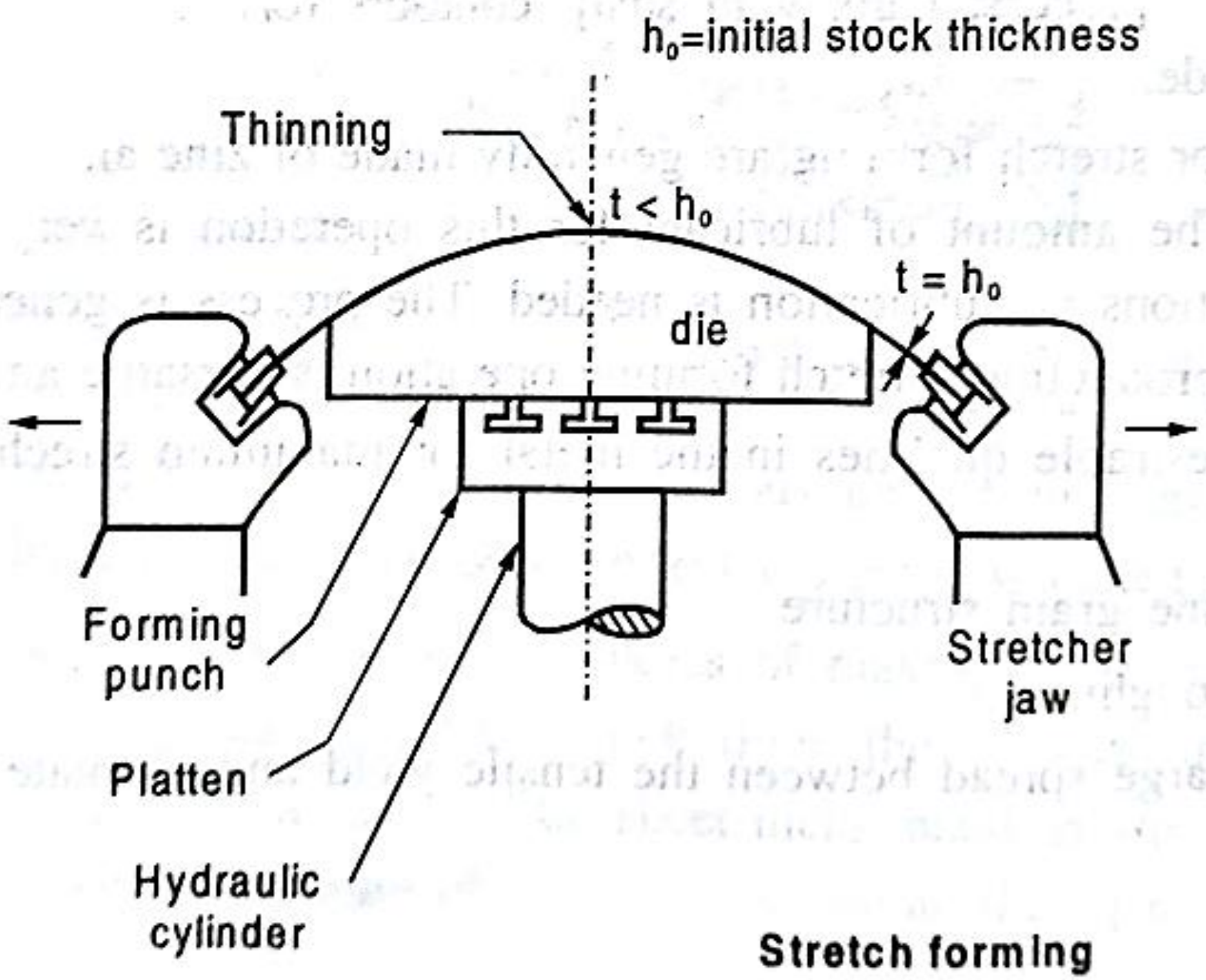


Stretching/ stretch forming

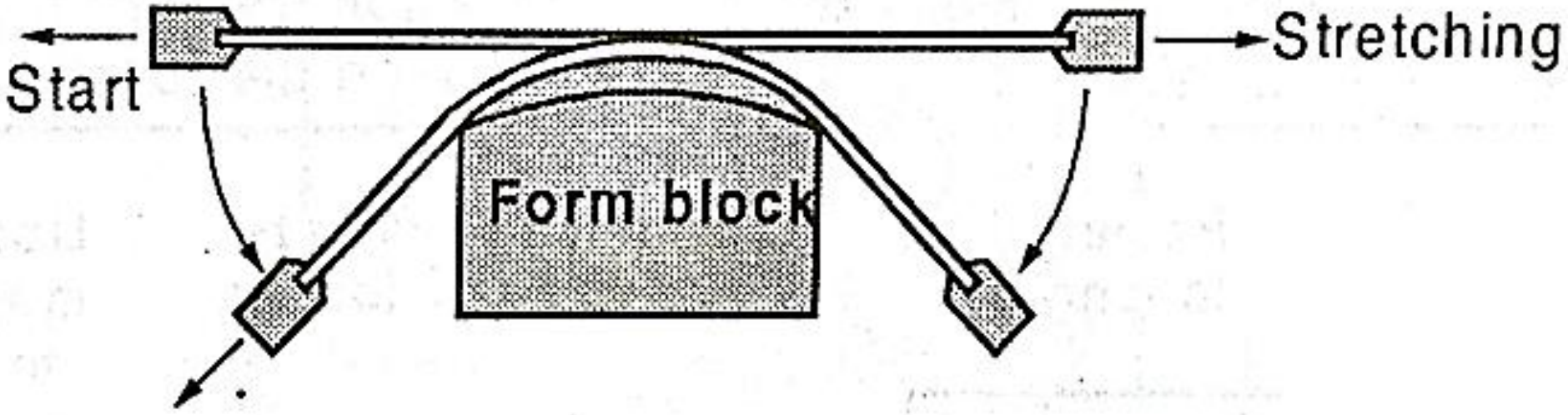




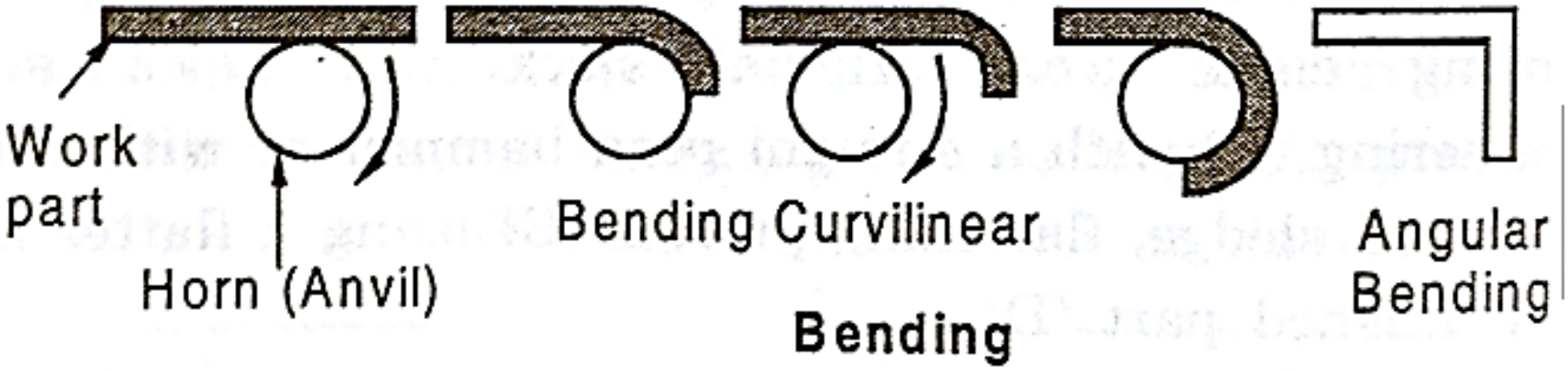
Stretch forming



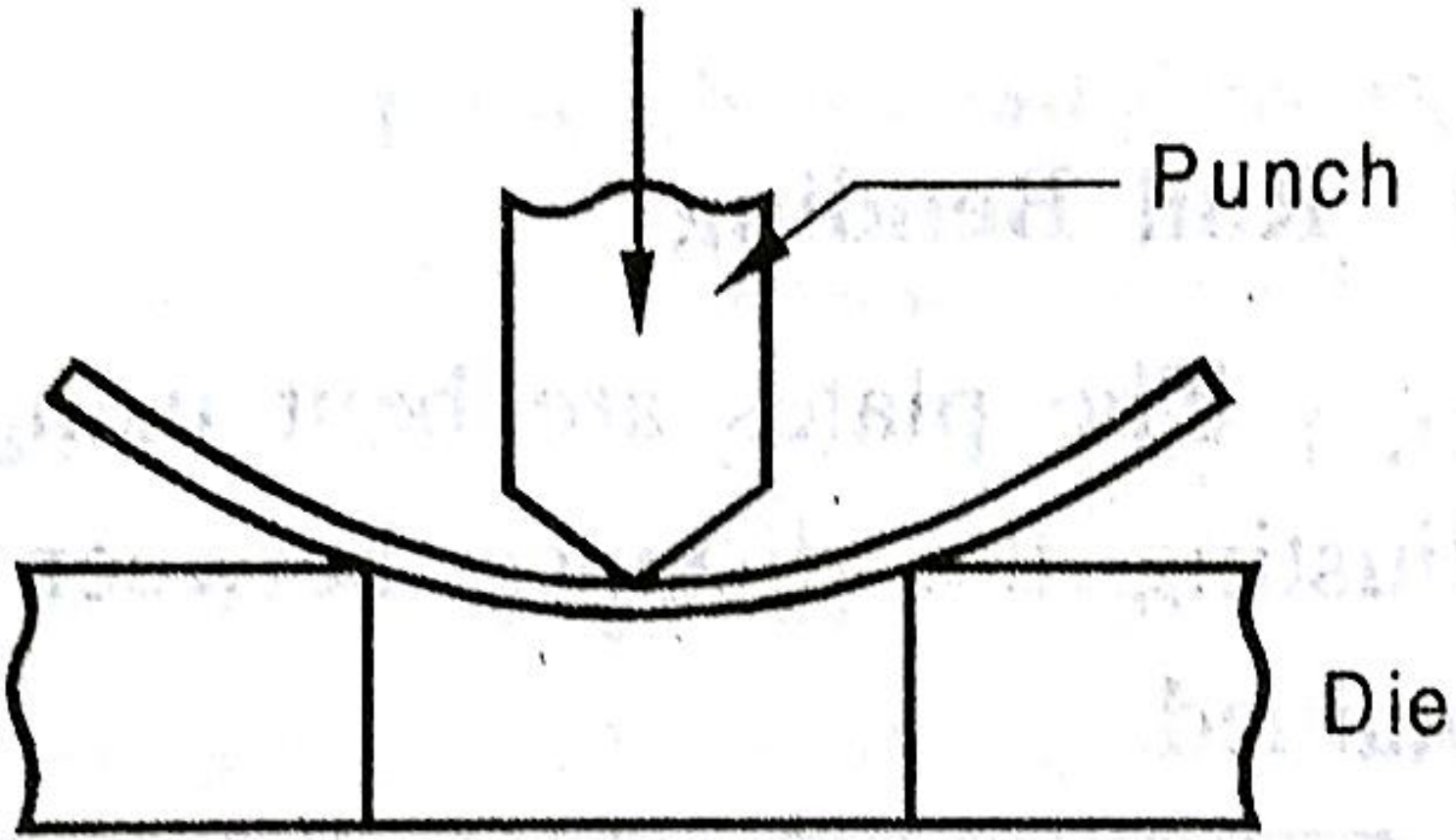
Stretch forming



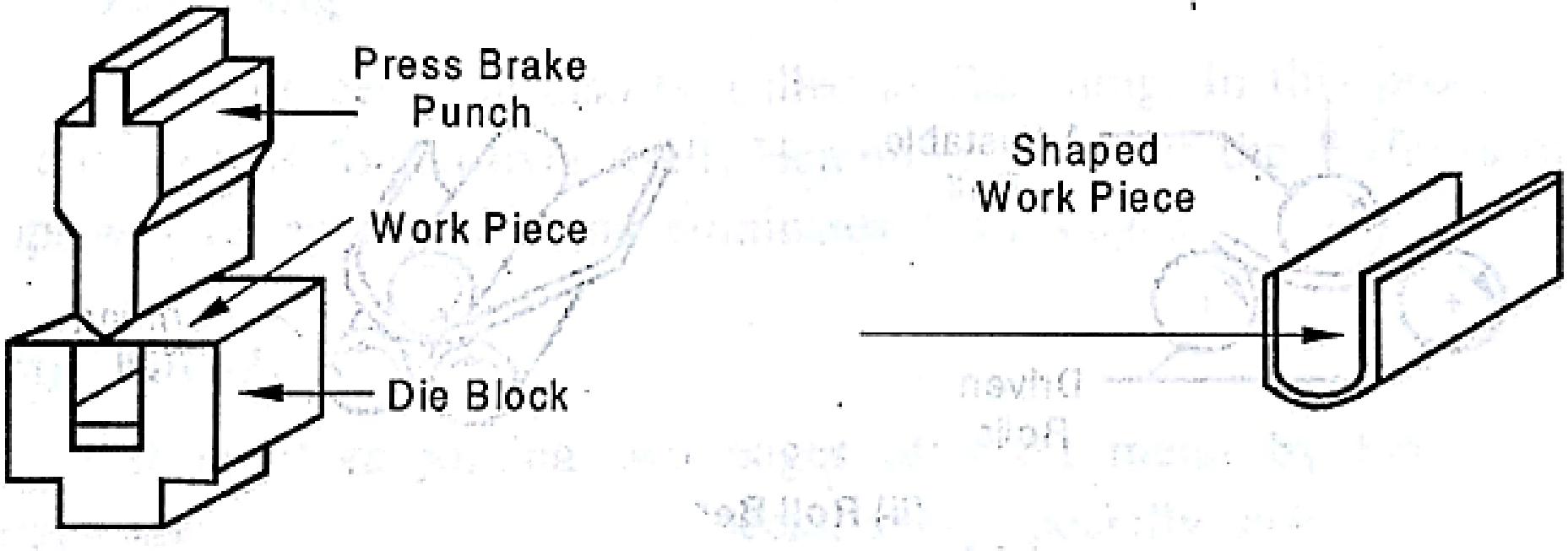
Stretch-wrap forming



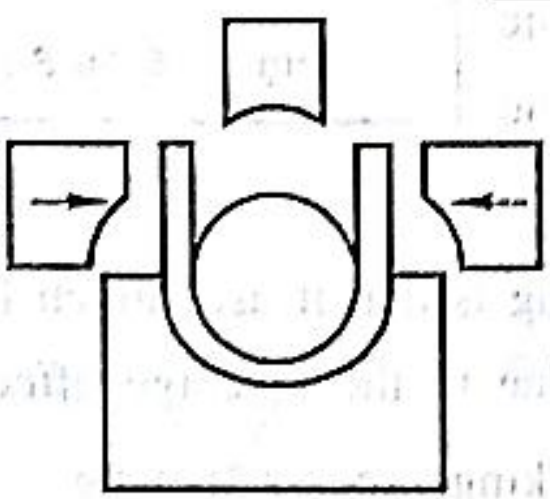
Bending



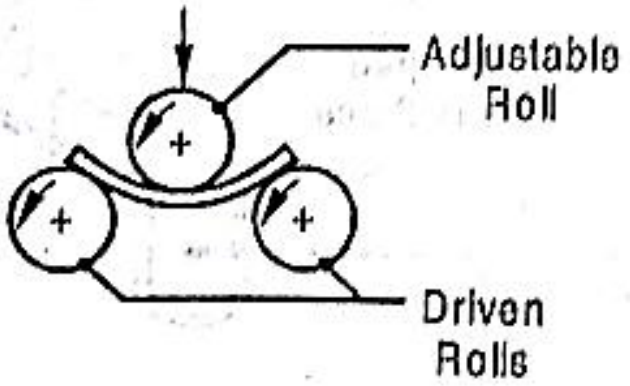
Air Bending

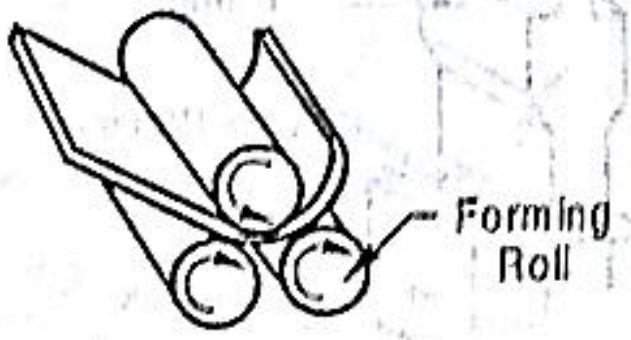


Press Braking

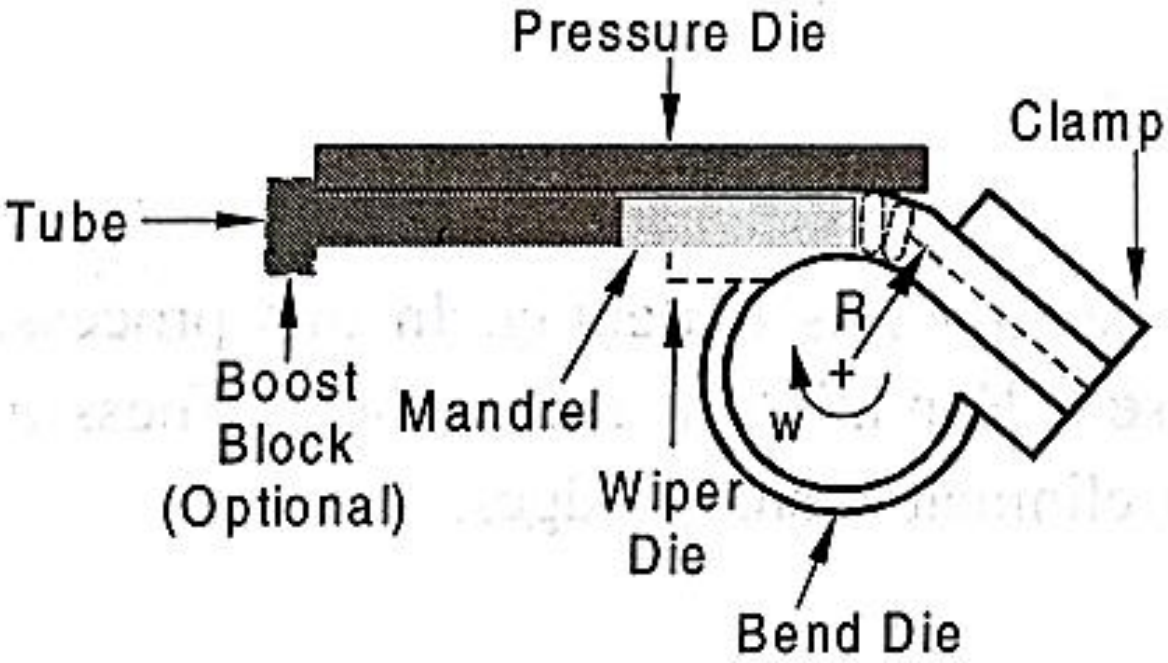


(I) Bonding in a 4-slide machine

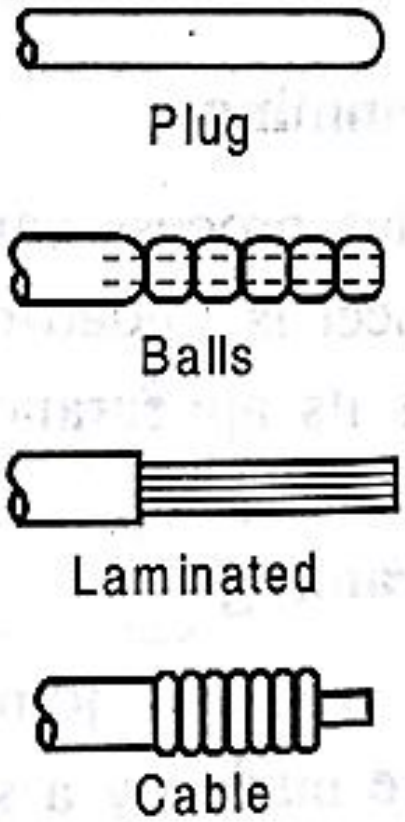




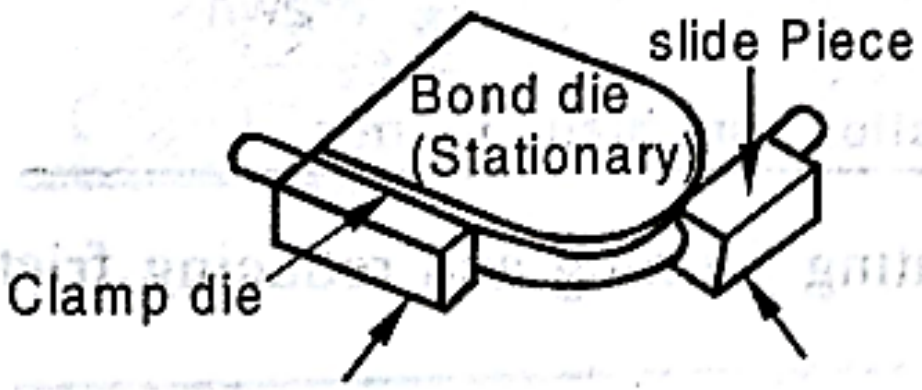
(II) Roll Bonding



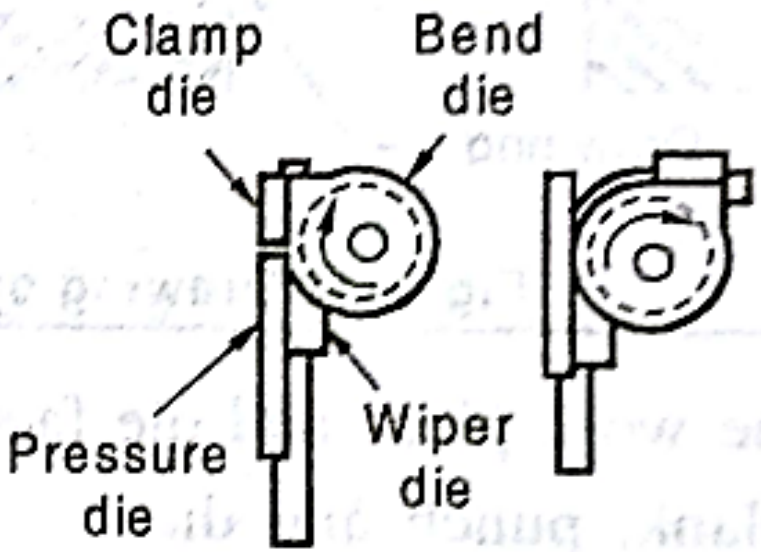
Mandrels for tube bending



Tube Bending



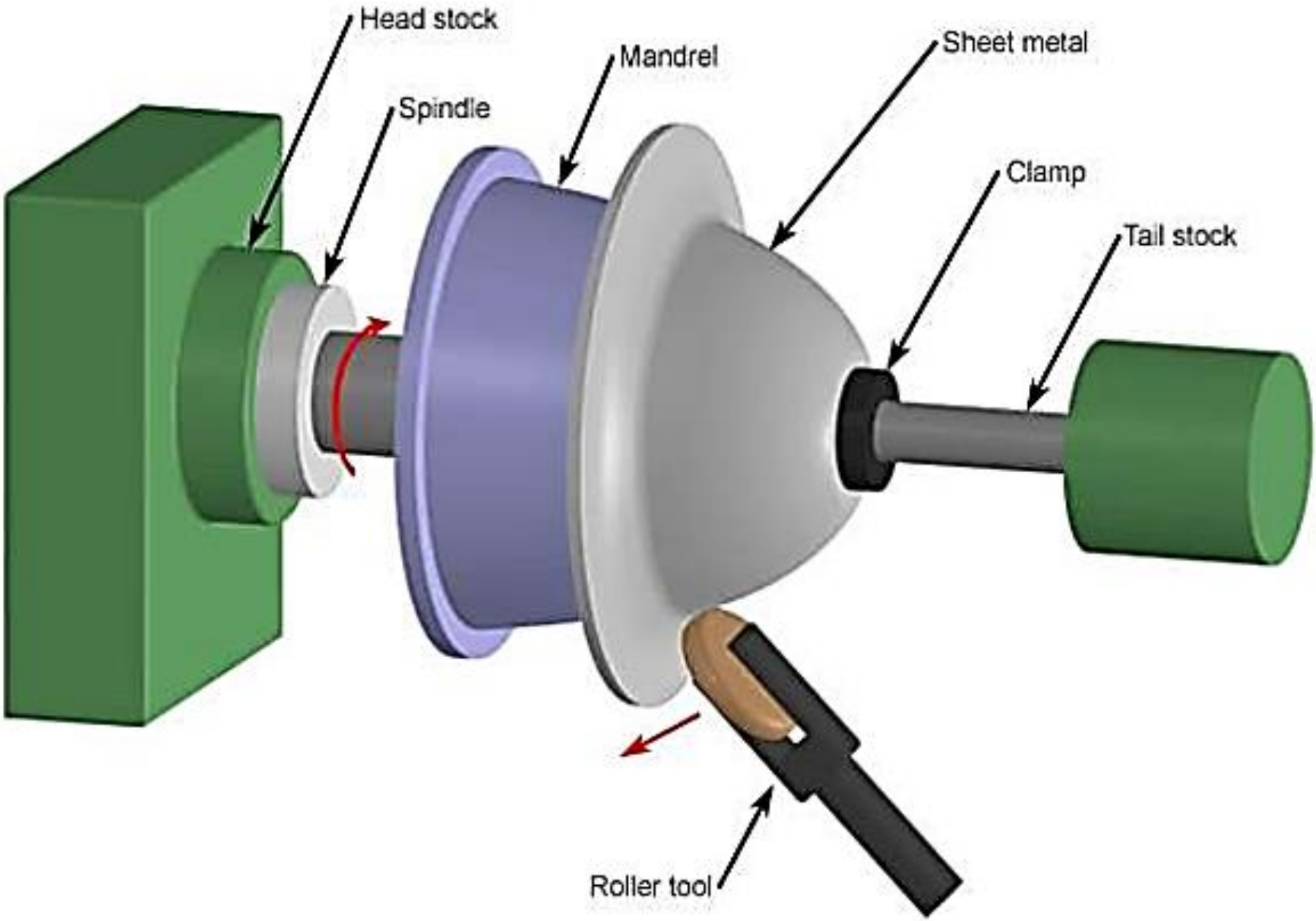
Compression Bending



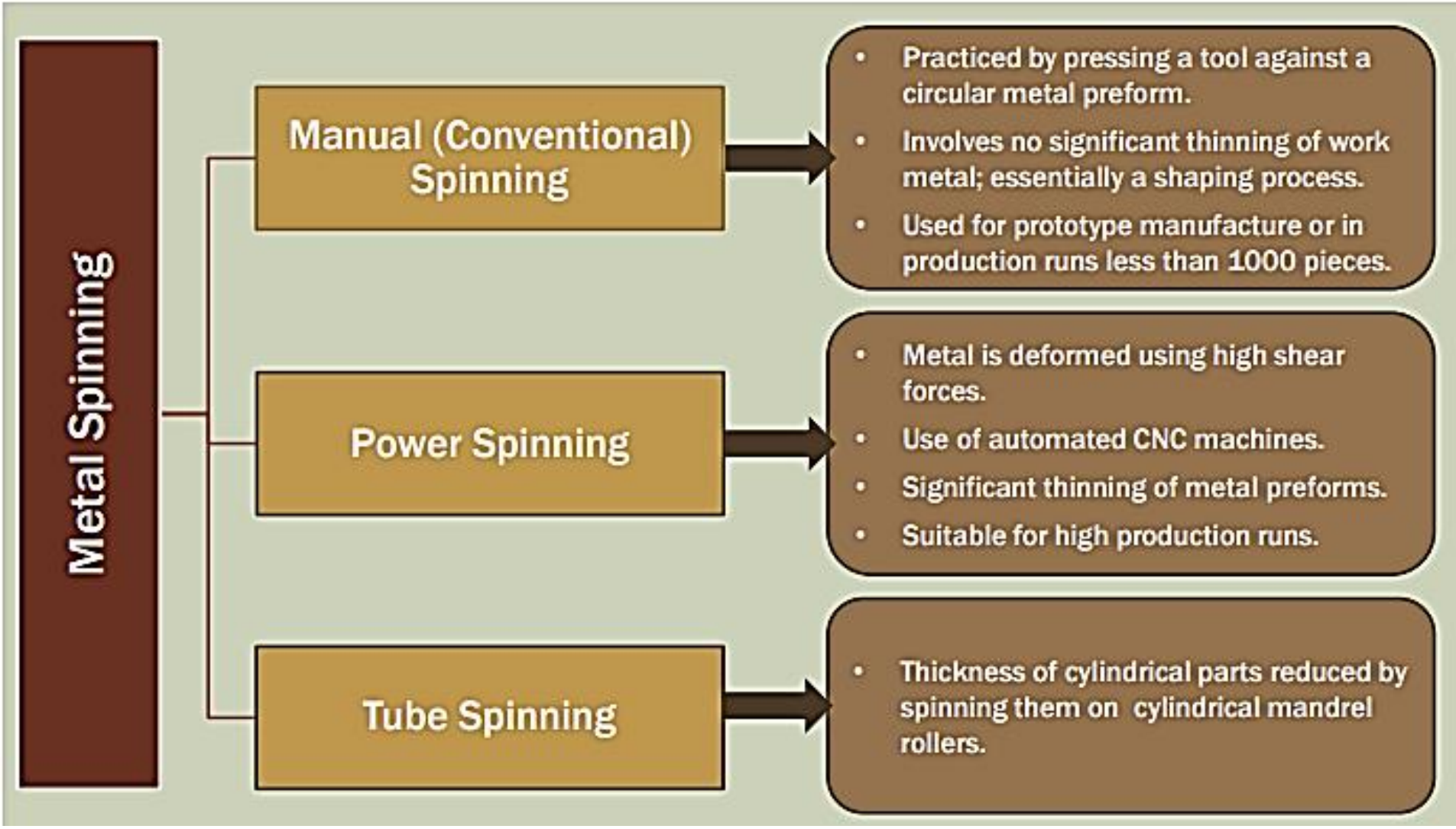
Rotary Draw Bending

METAL SPINNING

Metal Spinning process is a cold forming process in which the blank metal appears to flow somewhat like a piece of clay on a potter's wheel.


Head stock
Spindle
Mandrel
Sheet metal
Clamp
Tail stock
Roller tool

CLASSIFICATION OF METAL SPINNING TECHNIQUES



PROCESS OF METAL SPINNING

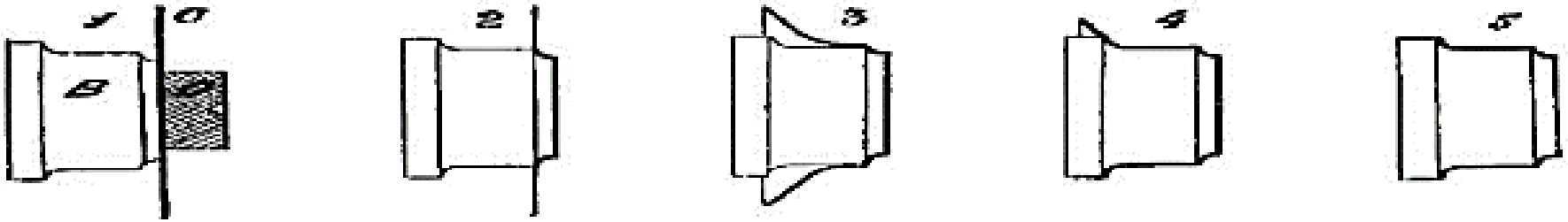
External shape of the mandrel corresponds to the internal contour of the part to be produced.

- The blank is clamped between spinning mandrel and a follower on the tailstock spindle.
- The mandrel, blank, and follower are then set in rotation at controlled speeds.

STEPS IN SPINNING PROCESS

Step 1 : Metal Forming

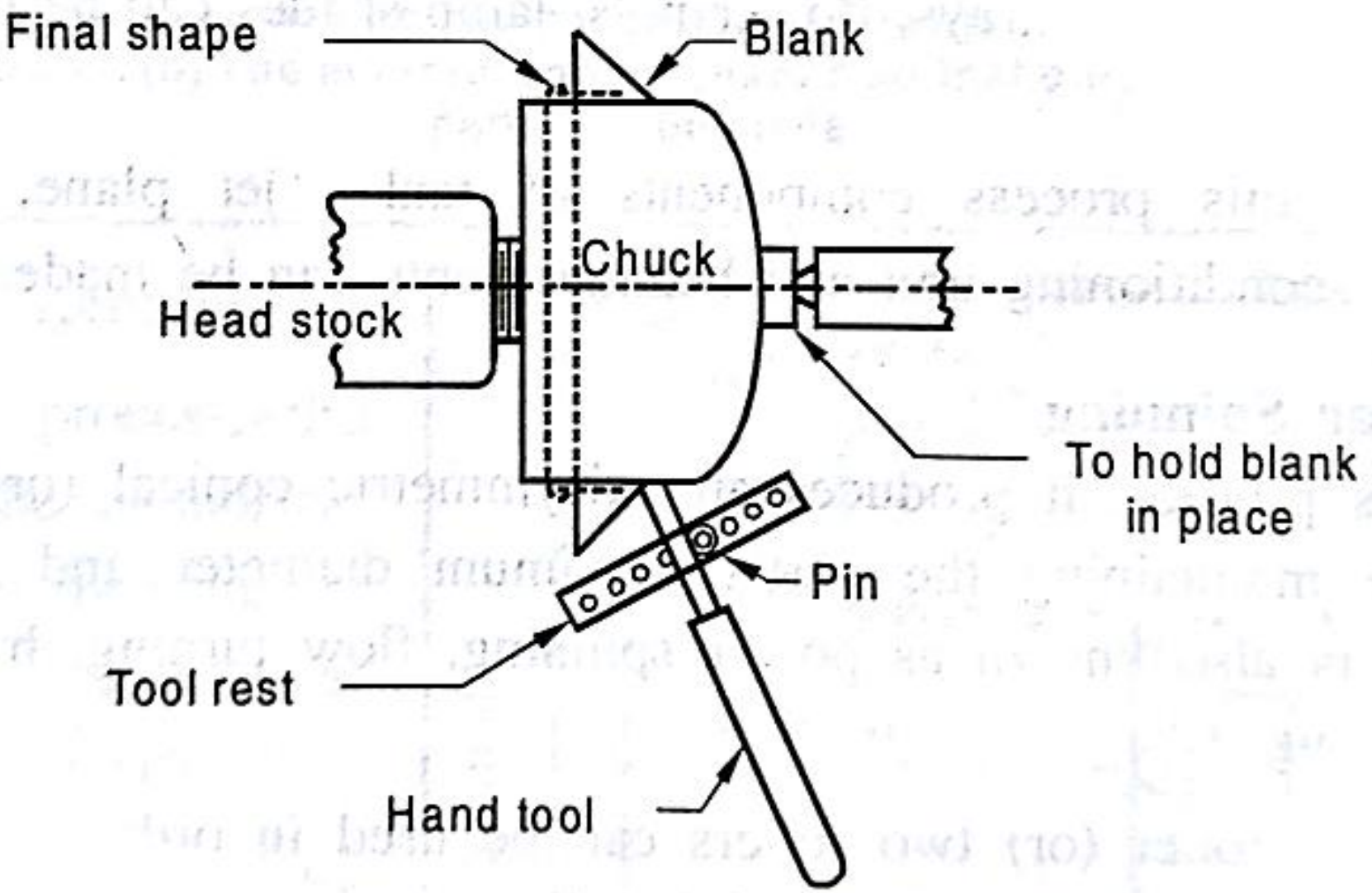
- This step involves the laying down of the material onto the mandrel.
- It is accomplished with short inside to outside moves.
- Material gets easier to form as the part is closer to completion



Step 2 : Trimming Parts having been spun are trimmed at the end to blunt sharp edges and also to bring the component to the desired length.

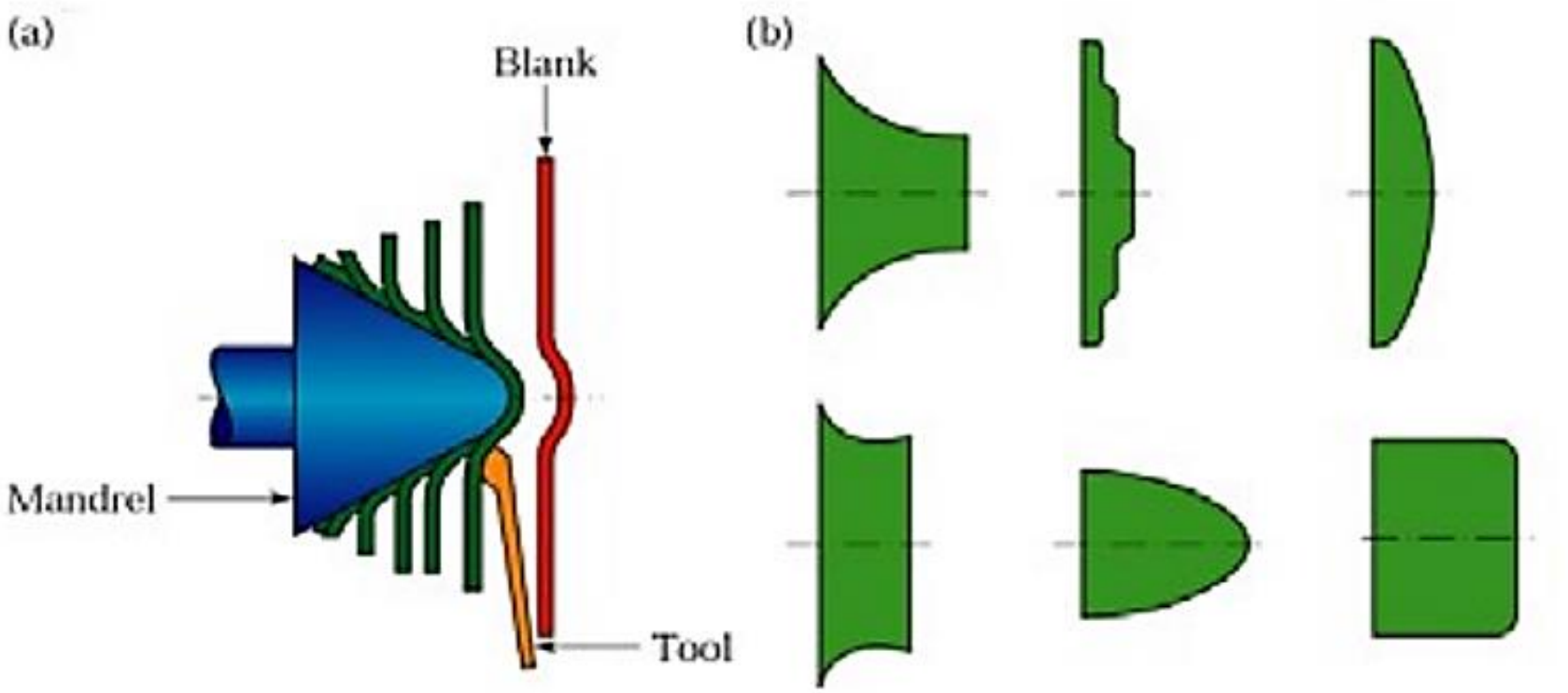
Step 3 : Finishing

- Finishing is done at very high RPMs (1200+) so that a minimum of force need be applied and very smooth strokes can be used.
- The flat side of spinning tool is used for straight surfaces and rounded side for curves and radii.

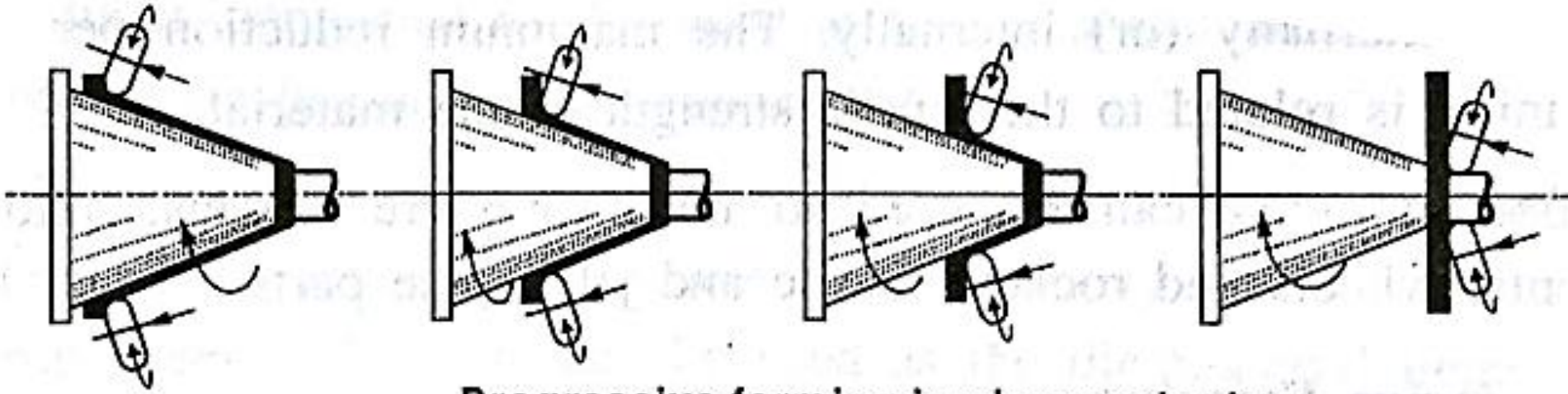


Metal Spinning.

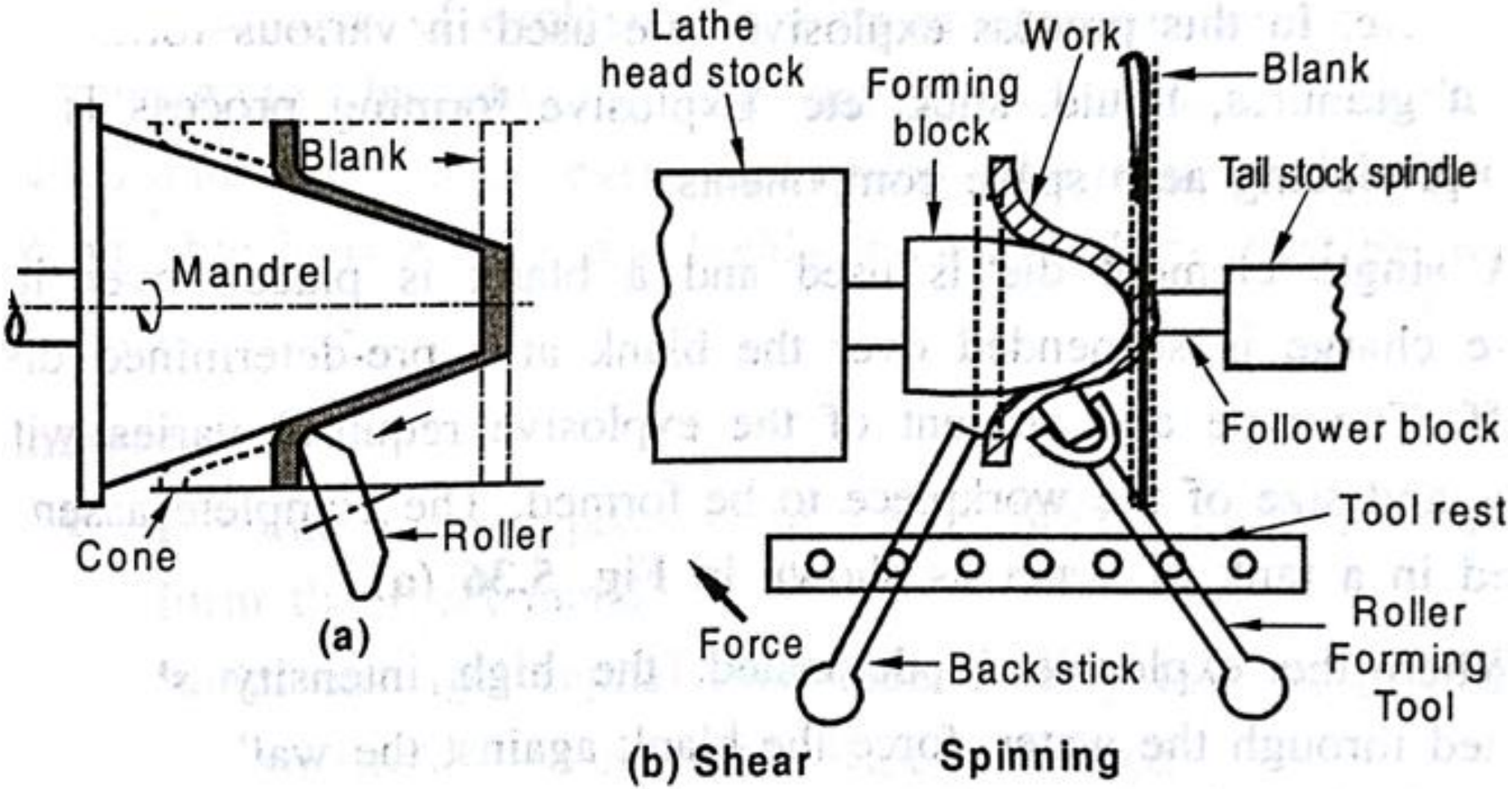
Shear Spinning



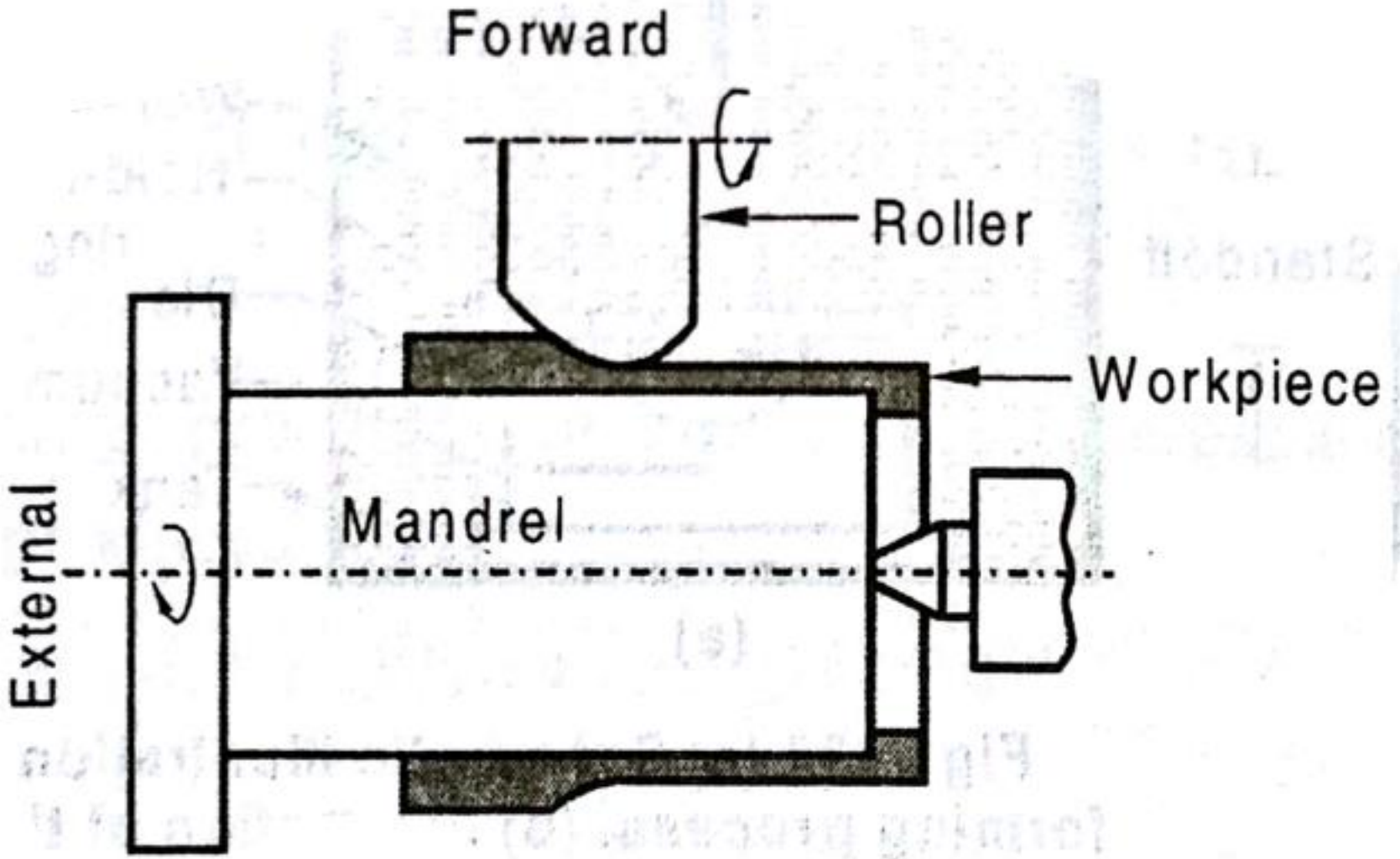
Schematic illustration of the conventional spinning process (b) Types of parts conventionally spun.All parts are antisymmetric



Progressive forming in shear spinning.



Schematic illustration of the shear spinning process for making conical parts. (a) The mandrel conical parts. (b) The mandrel can be shaped so that curvilinear parts can be made



Tube Spinning Process

TUBE SPINNING

- Thickness of cylindrical parts are reduced by spinning them on a cylindrical mandrel rollers
- Parts can be spun in either direction
- Large tensile elongation up to 2000 % are obtained within certain temperature ranges and at low strain rates.

COMPARISON WITH OTHER FORMING PROCESSES

- Low tooling cost compared to other forming techniques.
- Conventional spinning also wastes a considerably smaller amount of material than other methods .
- The standard method of press forming the part requires many steps, as opposed to only three steps for spinning.

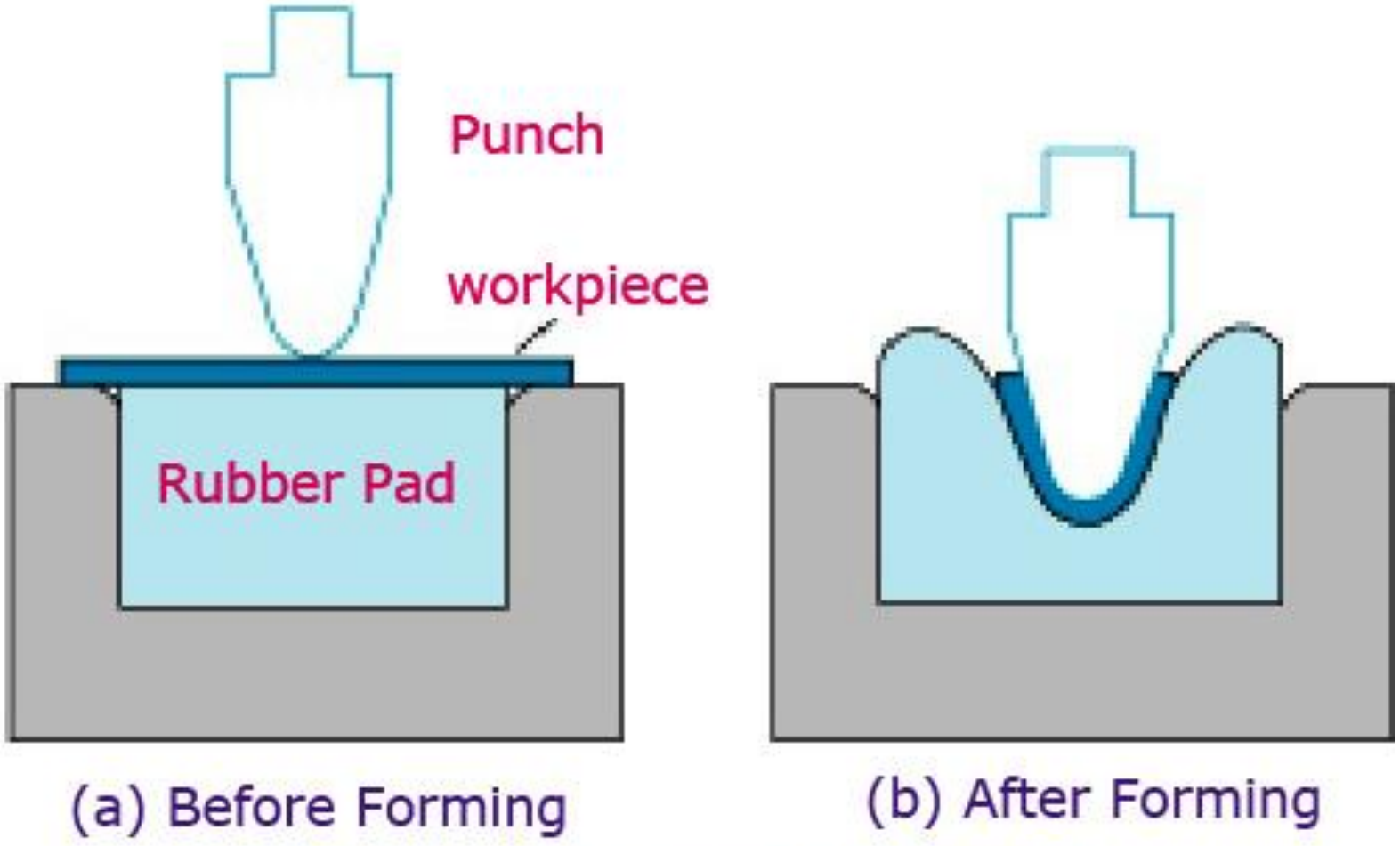
Rubber forming

In bending and embossing of sheet metal, the female die is replaced with rubber pad

- **Rubber pad forming (RPF)** is a metalworking process where sheet metal is pressed between a die and a rubber block, made of polyurethane.

- Under pressure, the rubber and sheet metal are driven into the die and conform to its shape, forming the part.

Rubber pads can have a general purpose shape, like a membrane. Alternatively, they can be machined in the shape of die or punch.



Solid Rubber Pad Forming