FORMING (DEFORMATION) PROCESSES

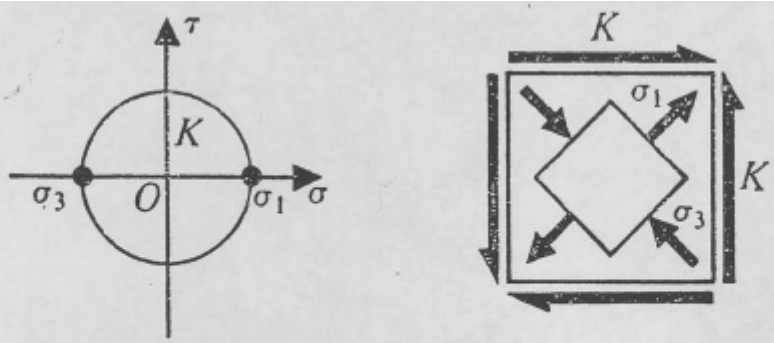


Fig. 3.7 Mohr's circle representation of two-dimensional state of stress.

PLASTISTICITY AND YIELD CRITERIA

FORMING PROCESSES

- Shaping vs forming
- Plastic vs elastic deformation
- Plastic deformation vs liquid flow

FORMING PROCESSES

- Transform a solid material from one shape to another
- The initial shape is simple, the final shape meet desired conditions (geometry, surface topography structure)
- Structure change might be a part of the forming

FORMING PROCESSES (CONT)

- Involve a sequence of shaping operations
- Optimal distribution of shaping between several stages
- Optimal distribution of operations between casting, forming, machining and thermal treatment
- Integration of casting and forming and forming and thermal treatment

FORMING PROCESSES (CONT)

- Extremely high cost of facilities (perhaps the most costly) and maintenance
- The forming contribution to material geometry should be minimized
- Hot, worm and cold forming
- Bulk vs sheet forming

BULK FORMING

- A large fraction of the material is involved in process
- Considerable change of the volume-to-surface area ratio
- Small fraction of elastic deformation (limited spring back)
- E.g. rolling, extrusion, forging

SHEET FORMING

- Limited part of a material undergoes deformation
- A sheet blank is plastically deformed into a complex 3D geometry with no significant (or any) change of the sheet cross section and surface
- Significant spring back
- E.g. shearing, bending, drawing
- Multilayered products

COMPONENTS OF A UNIT PROCESS

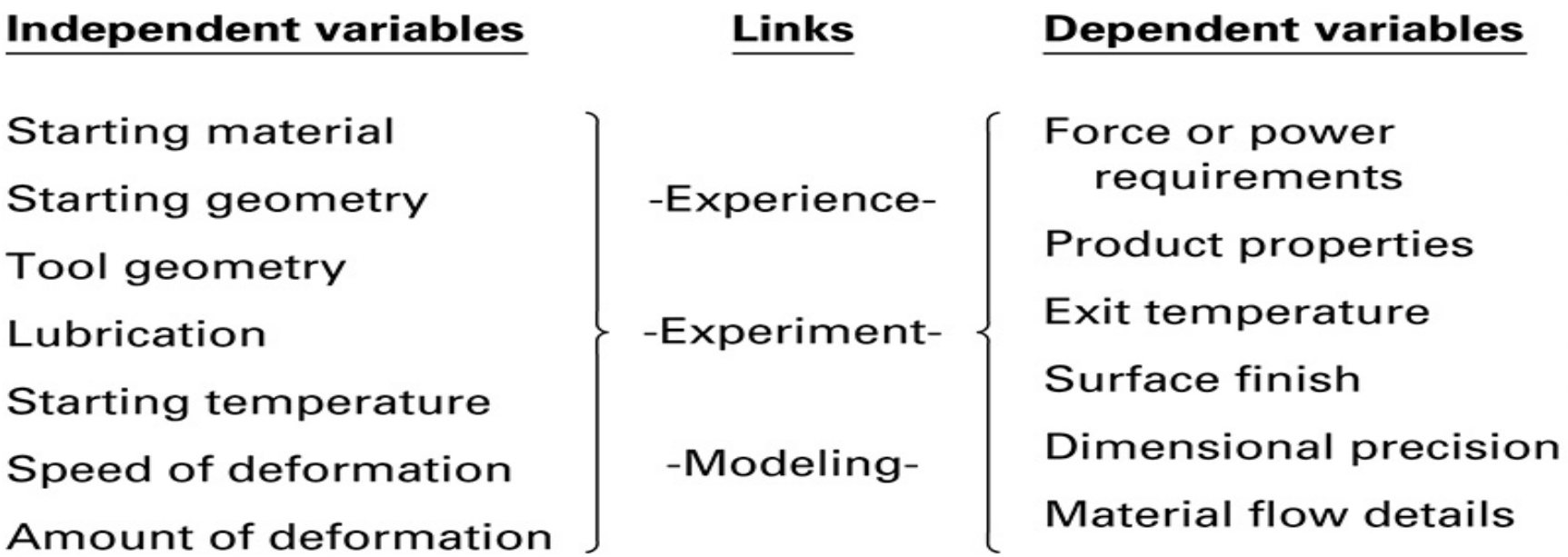
- Material :metals, plastics, green ceramics
- Process output: desired geometry
- Process input : slab, rod, billet, plate, sheet(materials, an unfinished part)
- Off-products: discarded parts, scale, end parts

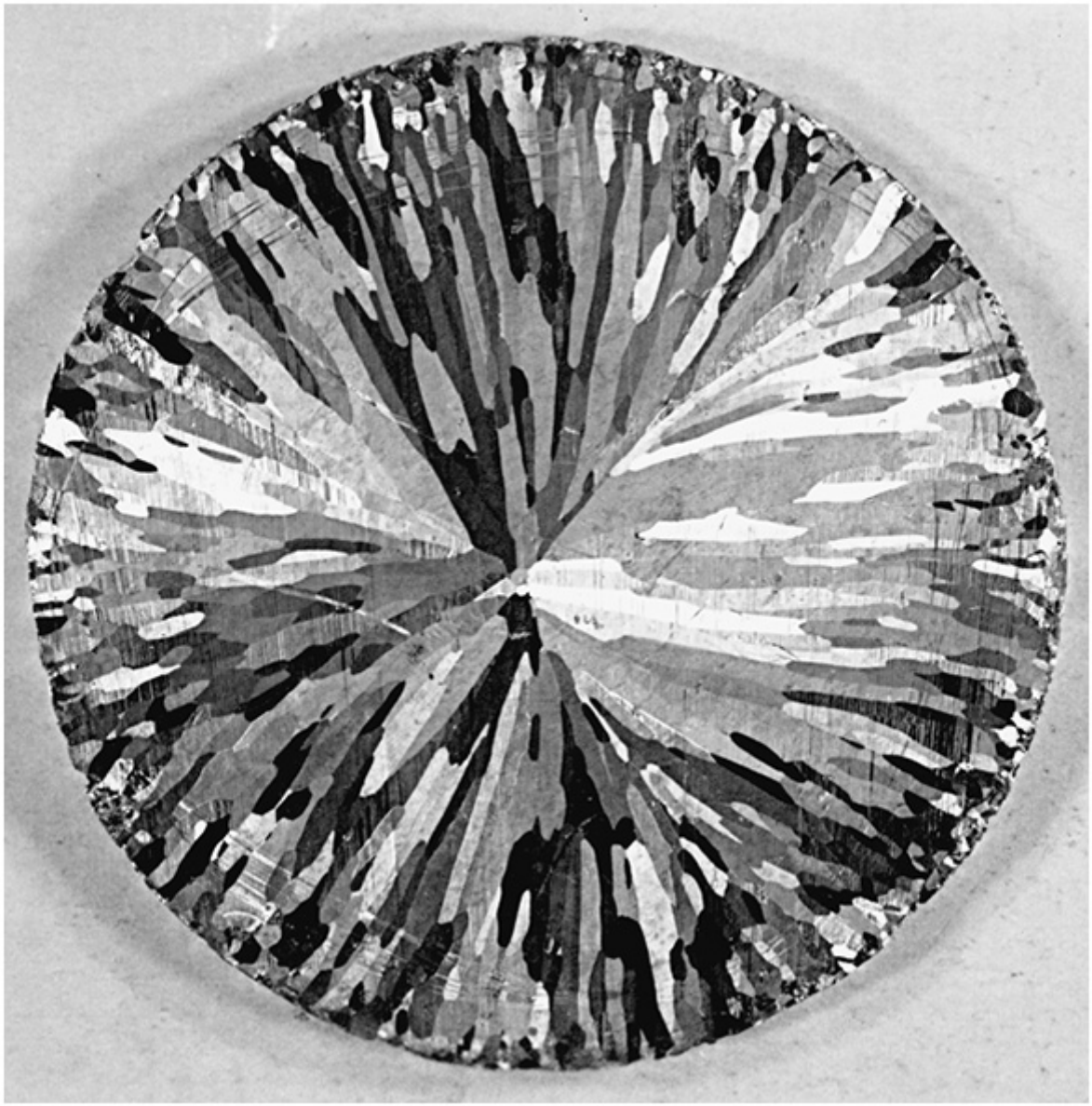
COMPONENTS OF A UNIT PROCESS (cont)

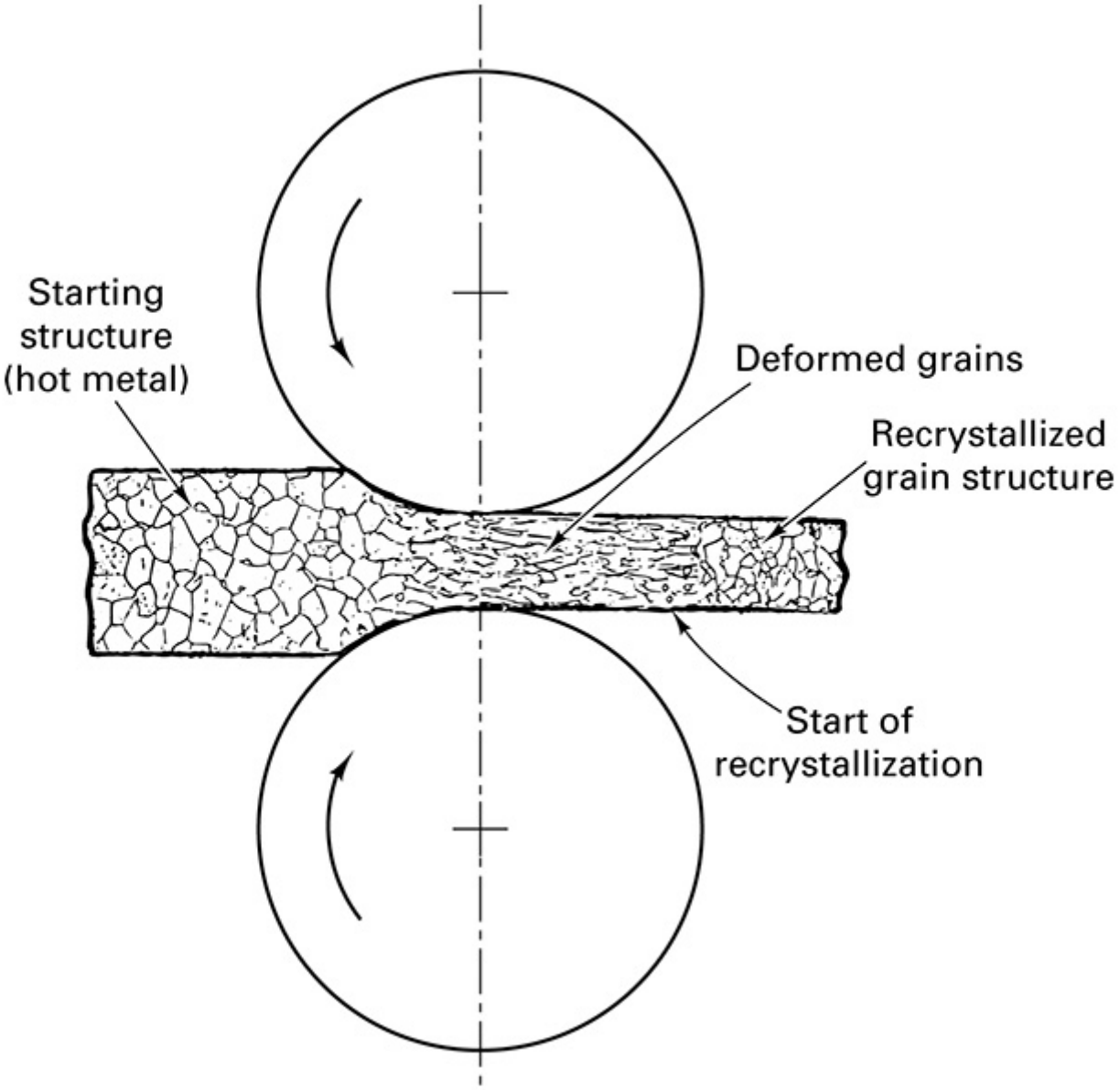
- Set of phenomena changing an object: plastic deformation, recrystallization
- Tool :a forming tool (die, punch, rolls)
- Material fluxes: a workpiece forced into a die; moving tools, workpiece material flow
- Momentum fluxes: impulse of forces applied from a driver to a tool and at the interface to a workpiece
- **Forces** generating fluxes

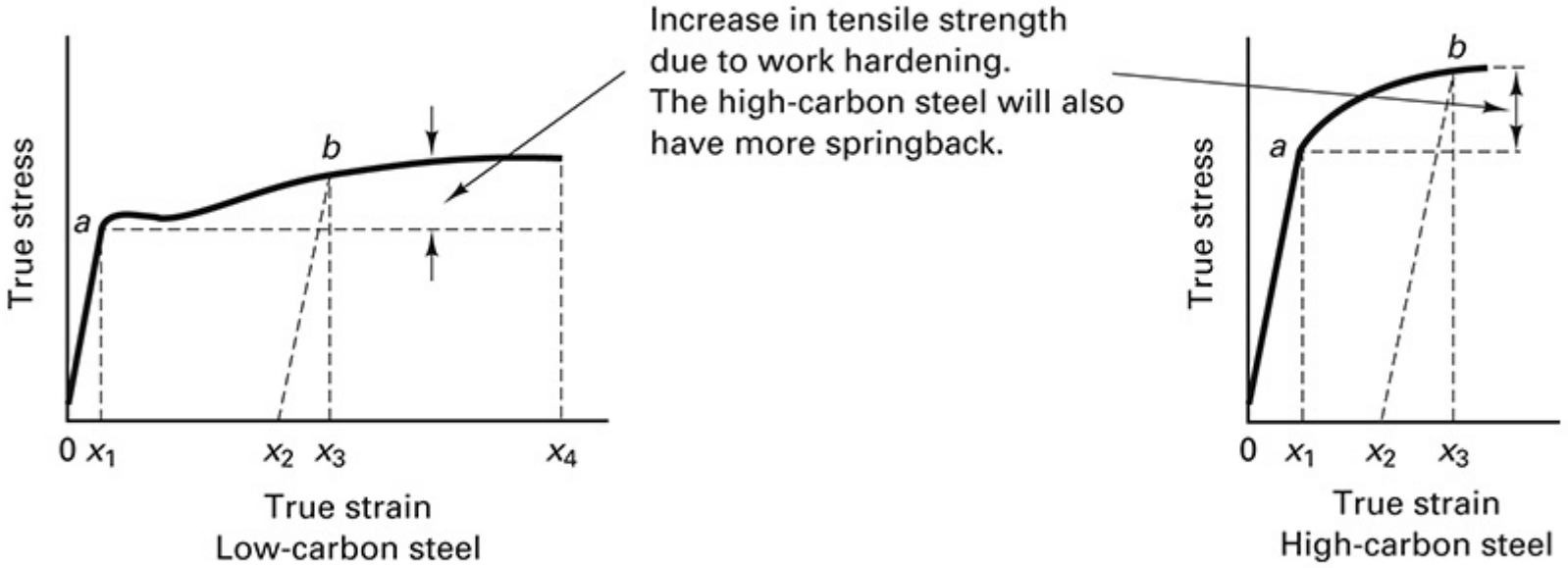
COMPONENTS OF A UNIT PROCESS (cont)

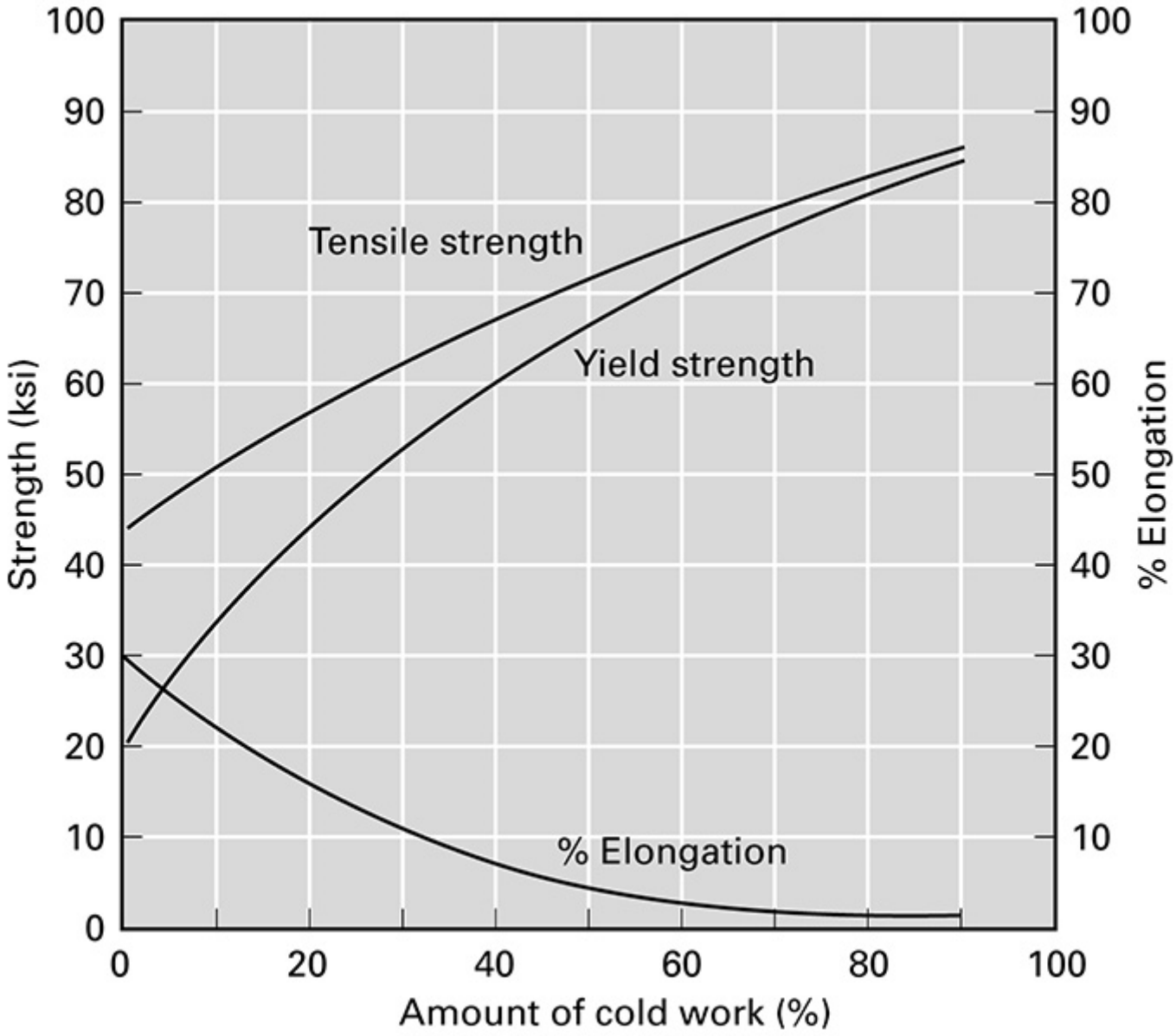
- Energy: electrical energy provided to a driver
- Force exerted by a moving tool on a workpiece
- Workzone: a part of material where defermation occurs
- Tool/material interface: tool-workpiece boundary
- Loading and unloading procedures: batch and continuous processes
- Enclosure: safety conditions
- Environment: no special conditions.

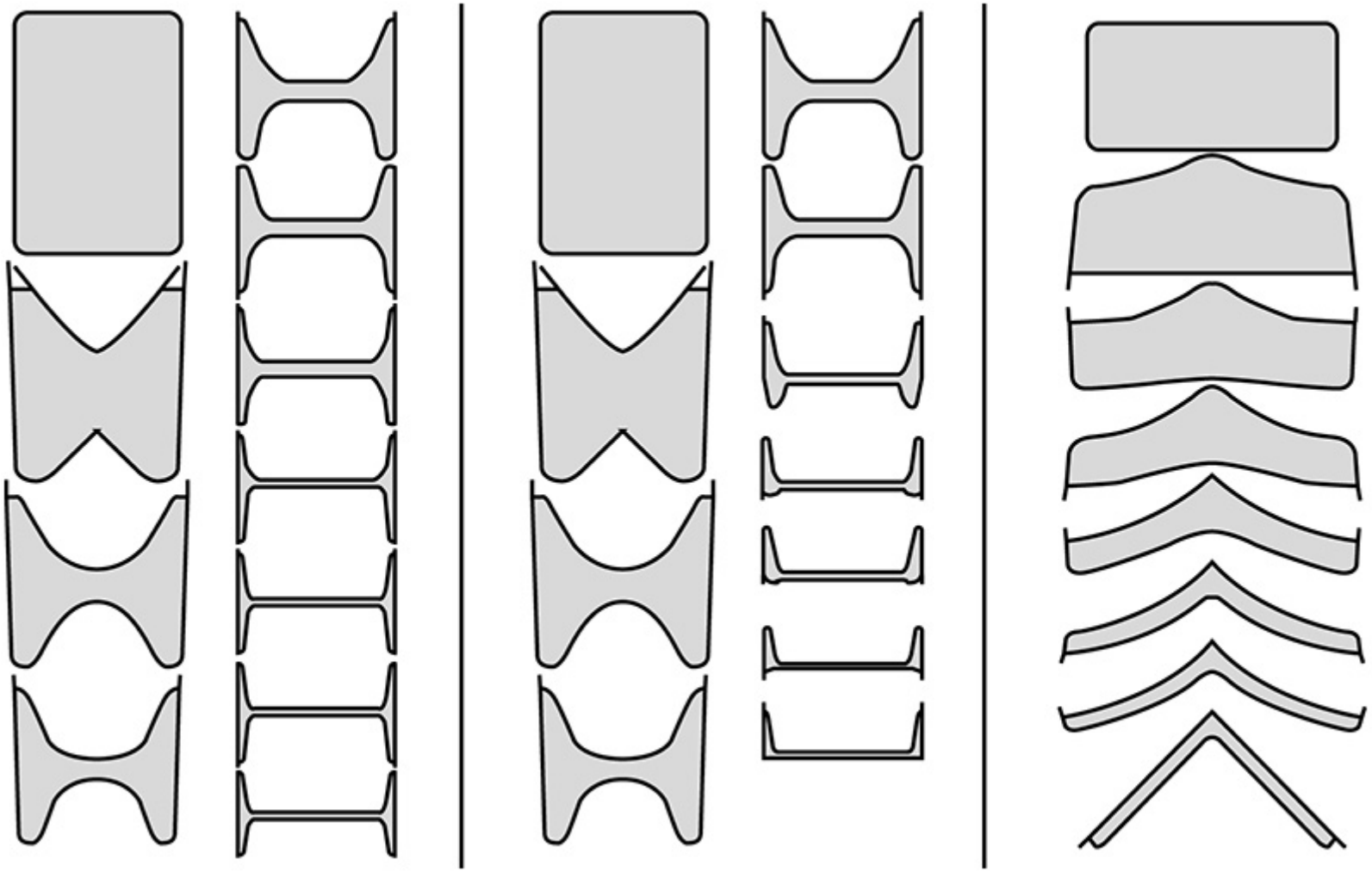

Independent variables
Links
Dependent variables
Starting material
Starting geometry
Tool geometry
Lubrication
Starting temperature
Speed of deformation
Amount of deformation
-Experience-
-Experiment-
-Modeling-
Force or power requirements
Product properties
Exit temperature
Surface finish
Dimensional precision
Material flow details

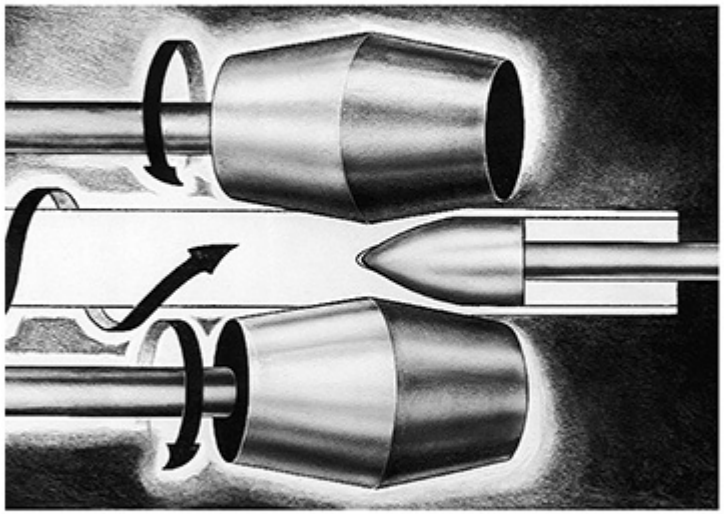


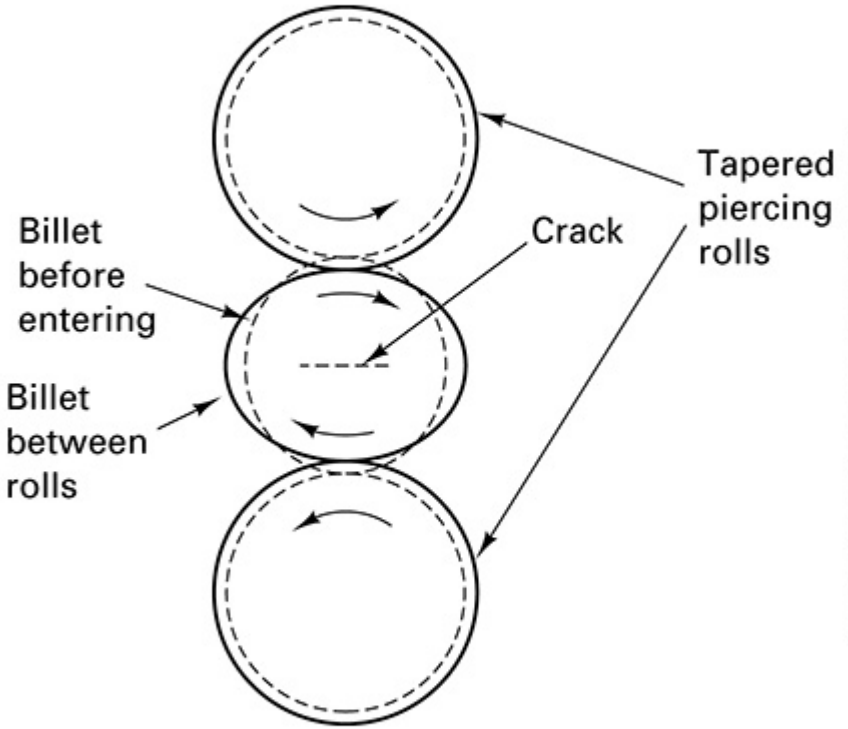

Starting
structure
(hot metal)
Deformed grains
Recrystallized
grain structure
Start of
recrystallization


Increase in tensile strength
due to work hardening.
The high-carbon steel will also
have more springback.
True stress
a
b
0 x_1 x_2 x_3 x_4
True strain
Low-carbon steel
True stress
a
b
0 x_1 x_2 x_3
True strain
High-carbon steel

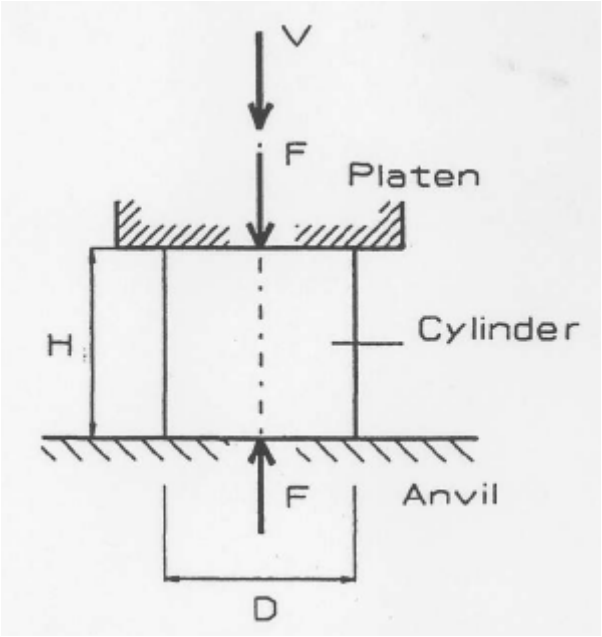

Tensile strength
Yield strength
% Elongation
Strength (ksi)
% Elongation
Amount of cold work (%)
0
10
20
30
40
50
60
70
80
90
100
0
20
40
60
80
100

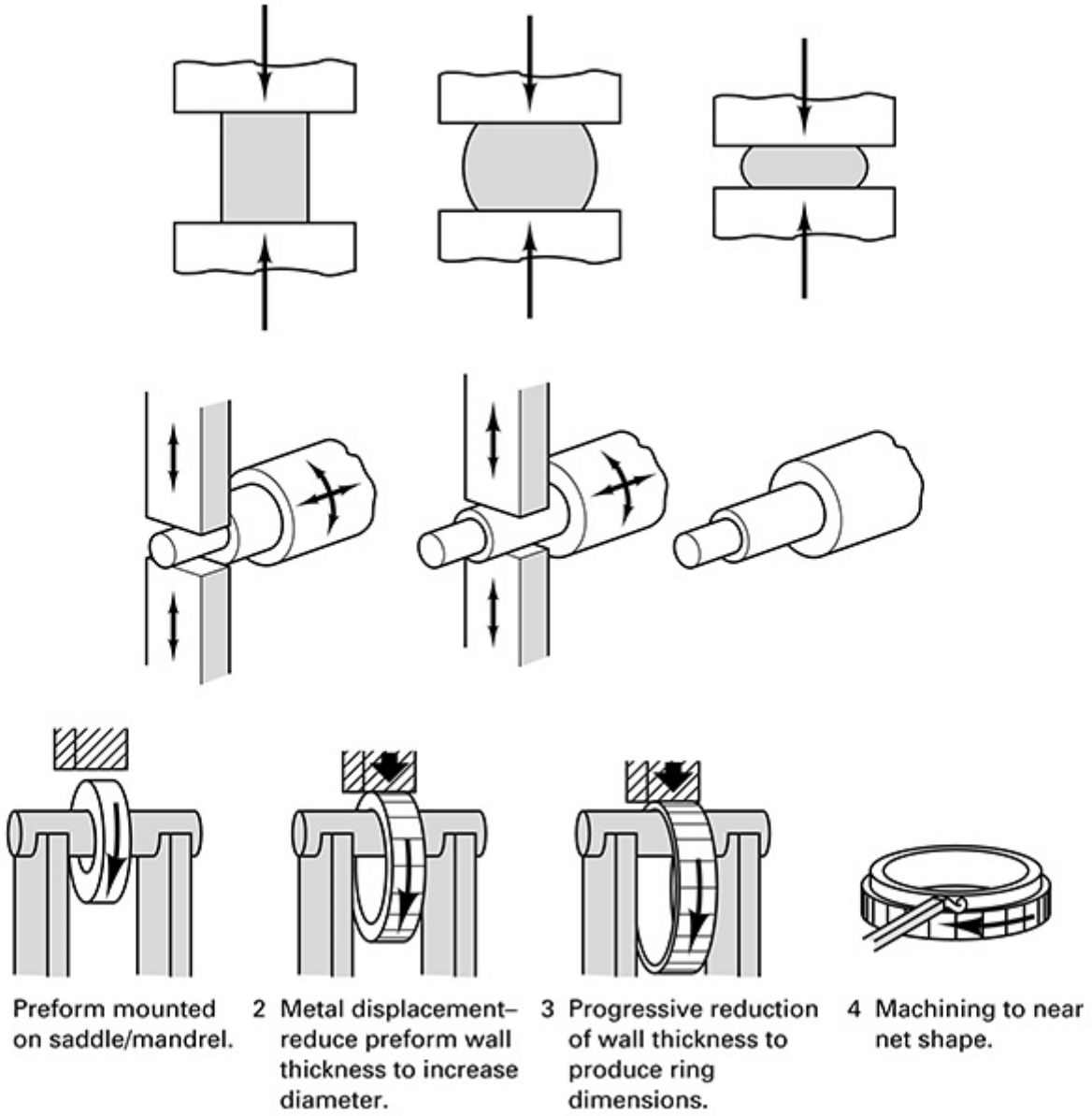





Billet
before
entering
Billet
between
rolls
Crack
Tapered
piercing
rolls

UPSET FORGING





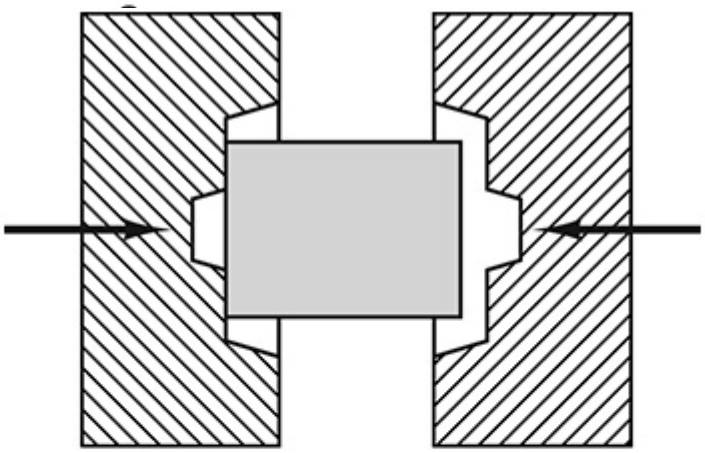
1 Preform mounted on saddle/mandrel.

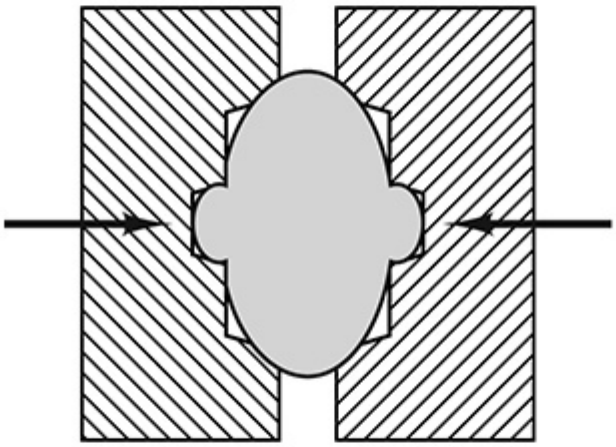
2 Metal displacement– reduce preform wall thickness to increase diameter.

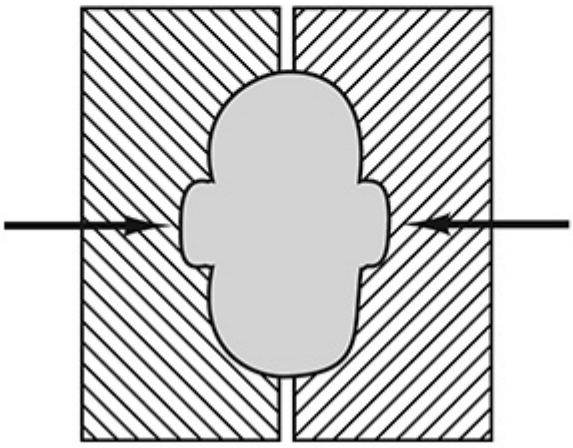
3 Progressive reduction of wall thickness to produce ring dimensions.

4 Machining to near net shape.

True stress







FORGING OPERATION

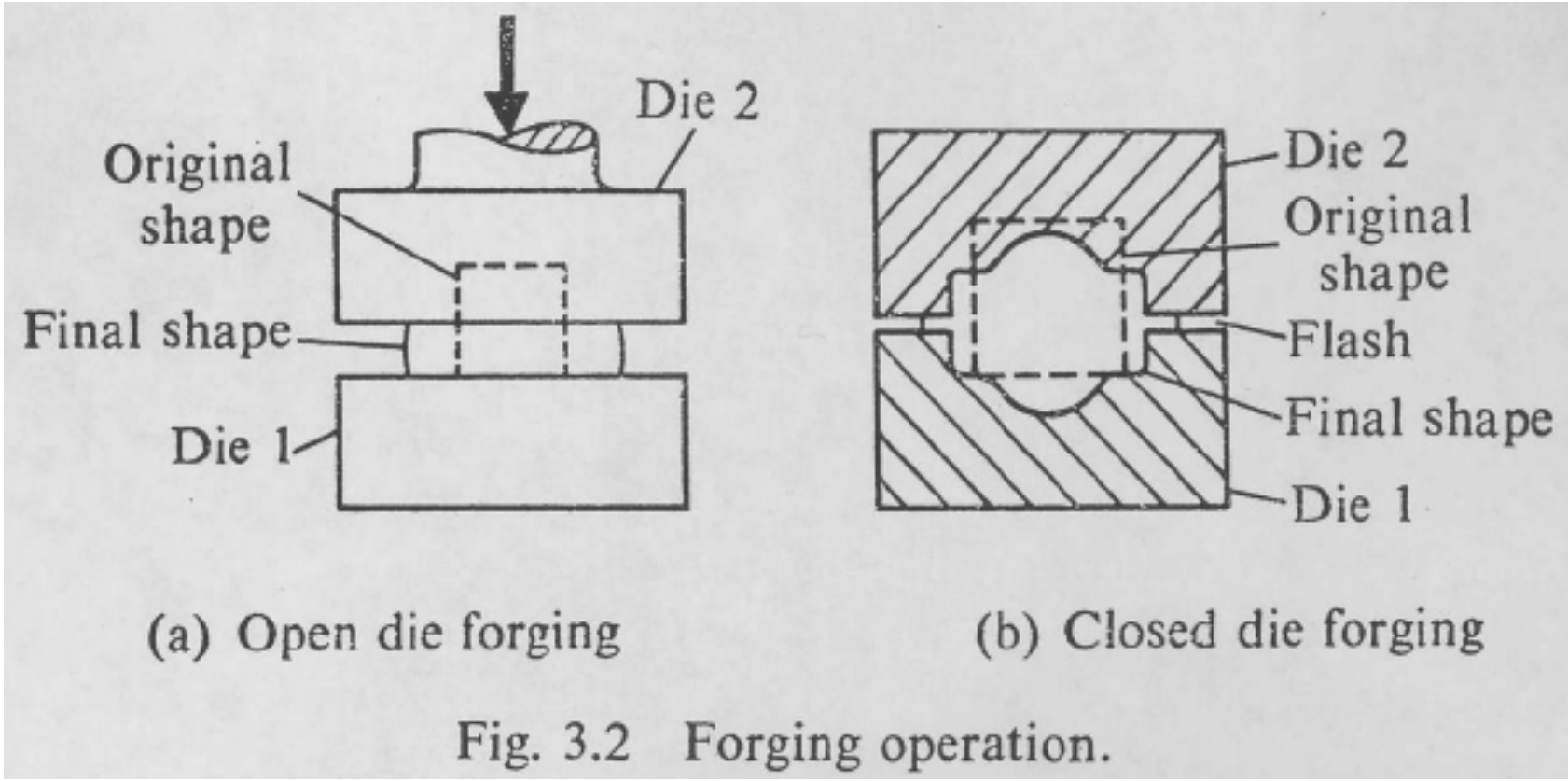


Fig. 3.2 Forging operation.

Extrusion

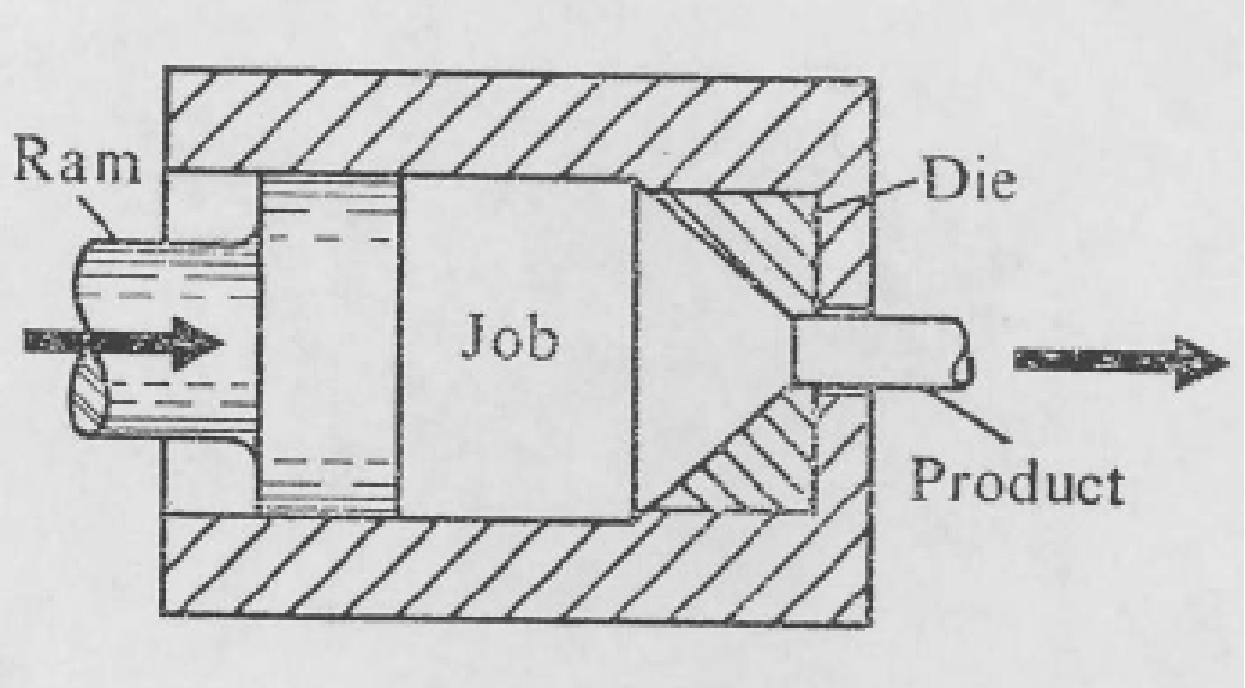
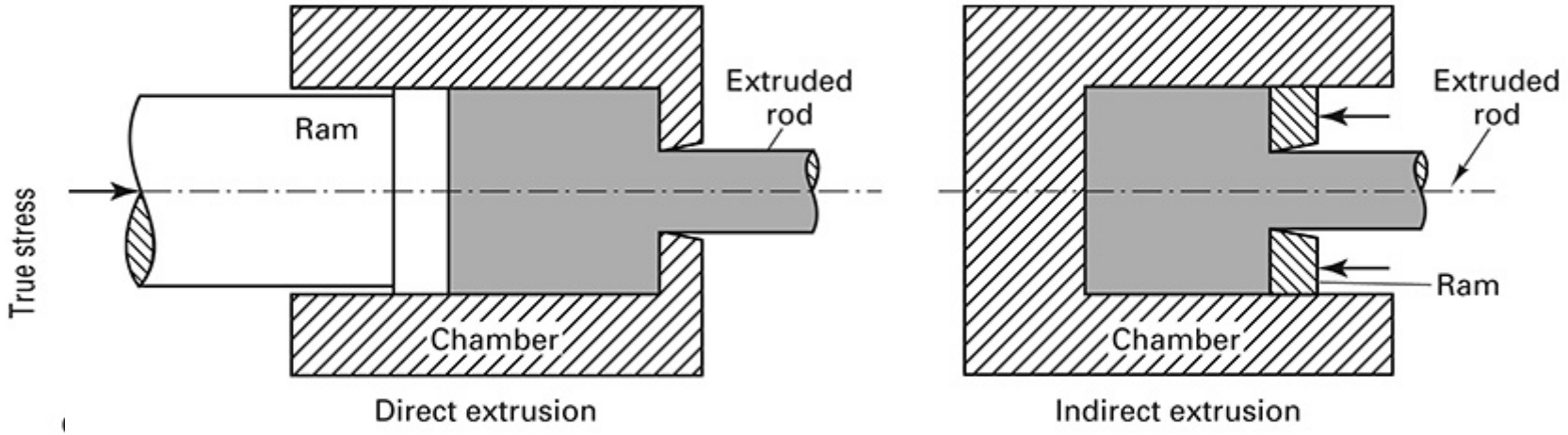


Fig. 3.6 Extrusion


True stress
Ram
Extruded rod
Chamber
Direct extrusion
Extruded rod
Ram
Chamber
Indirect extrusion

Drawing Operation

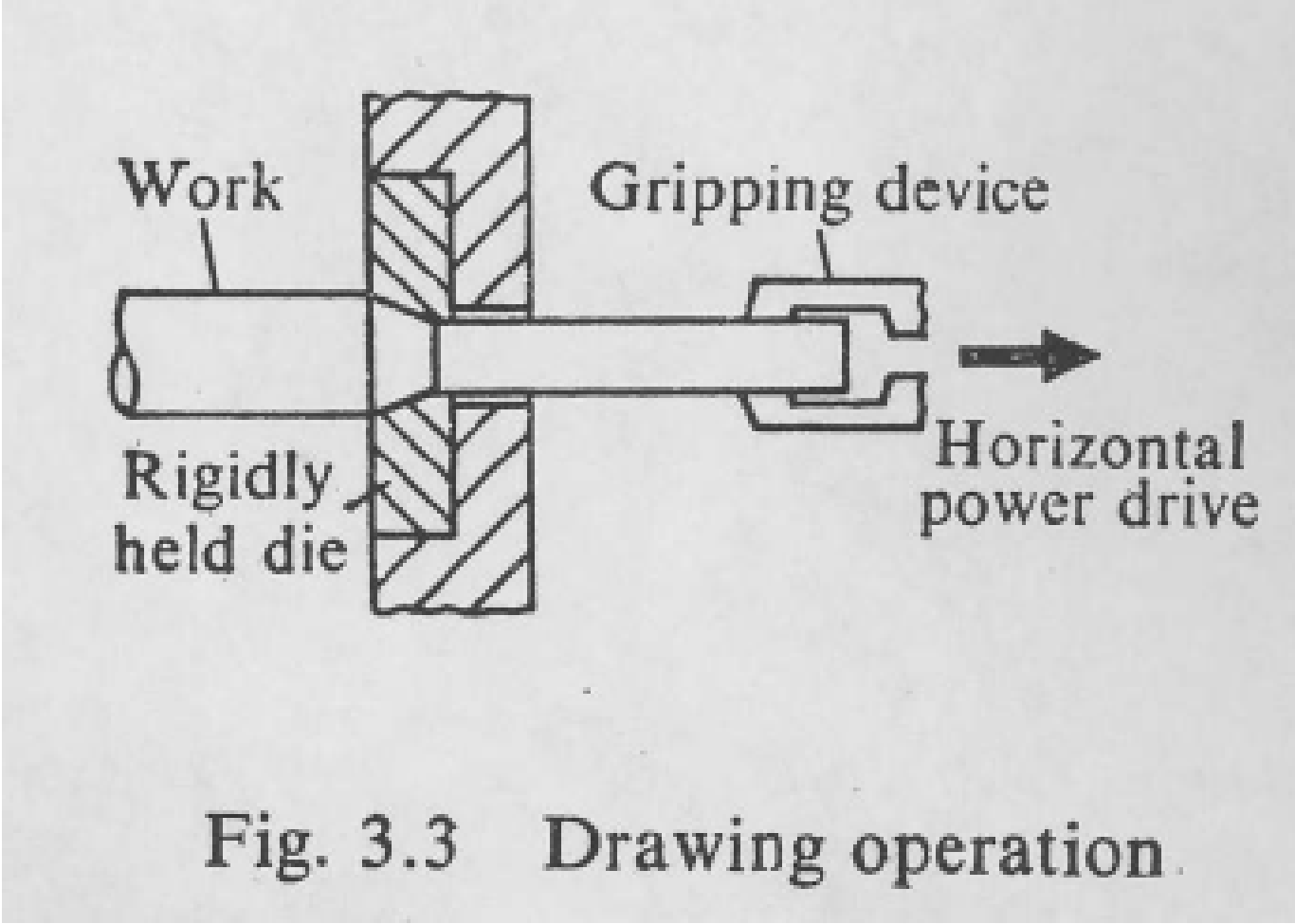
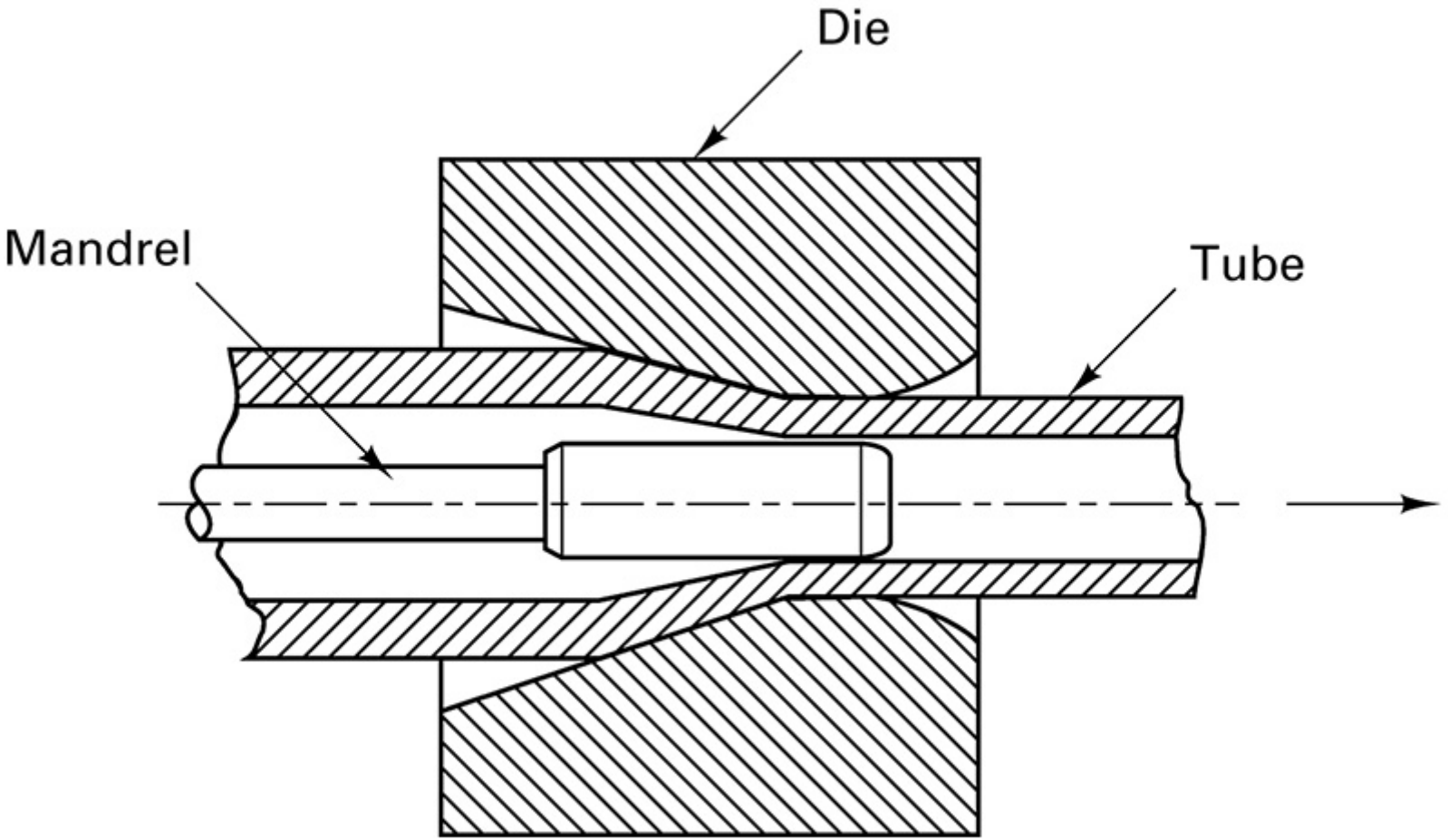


Fig. 3.3 Drawing operation


Die
Mandrel
Tube

Deep Drawing

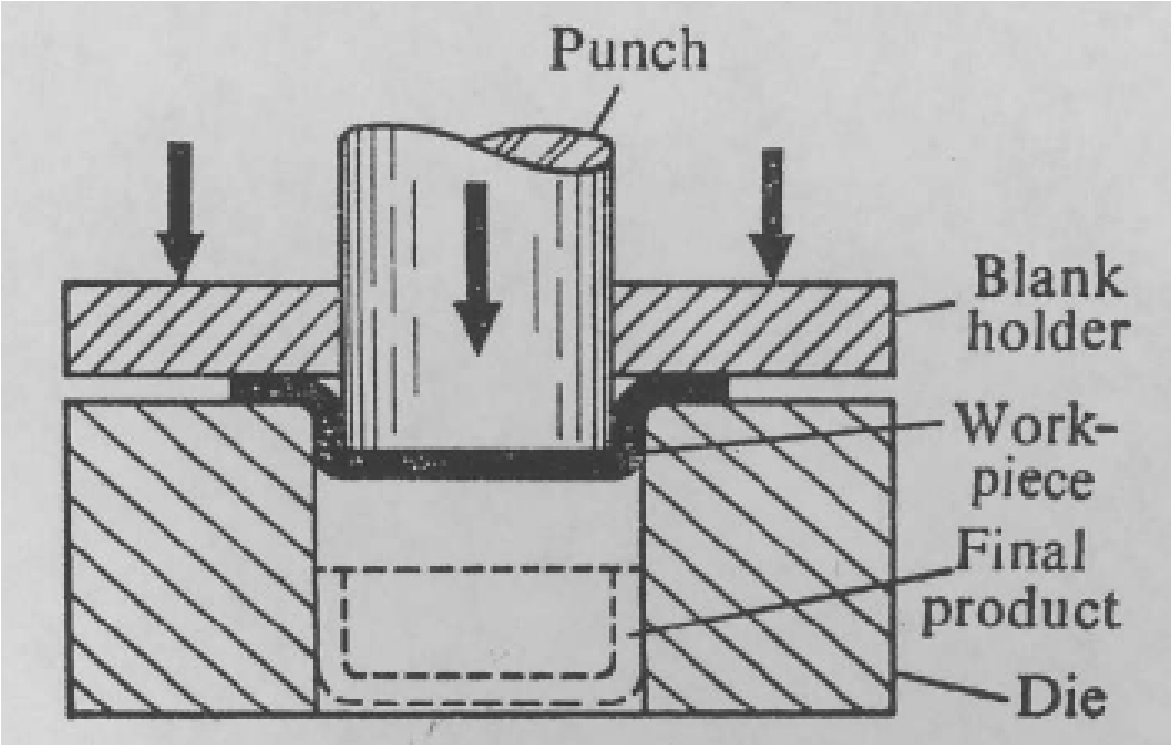
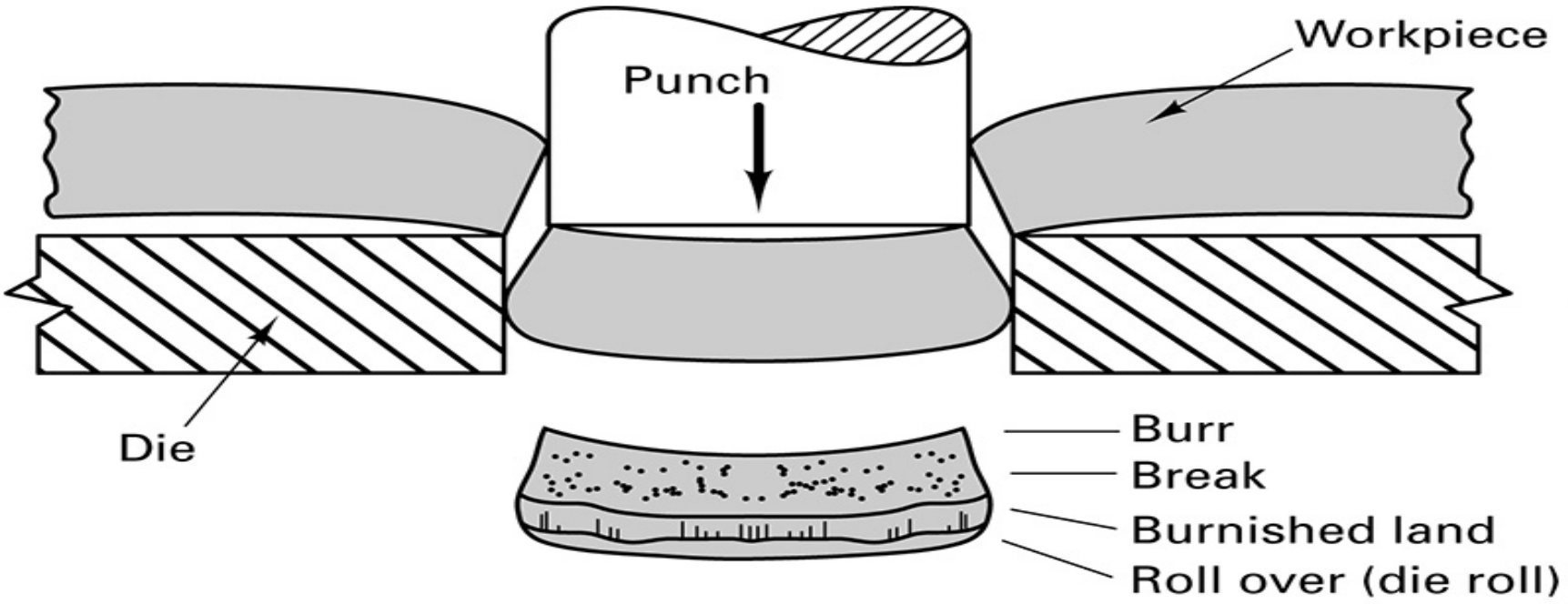
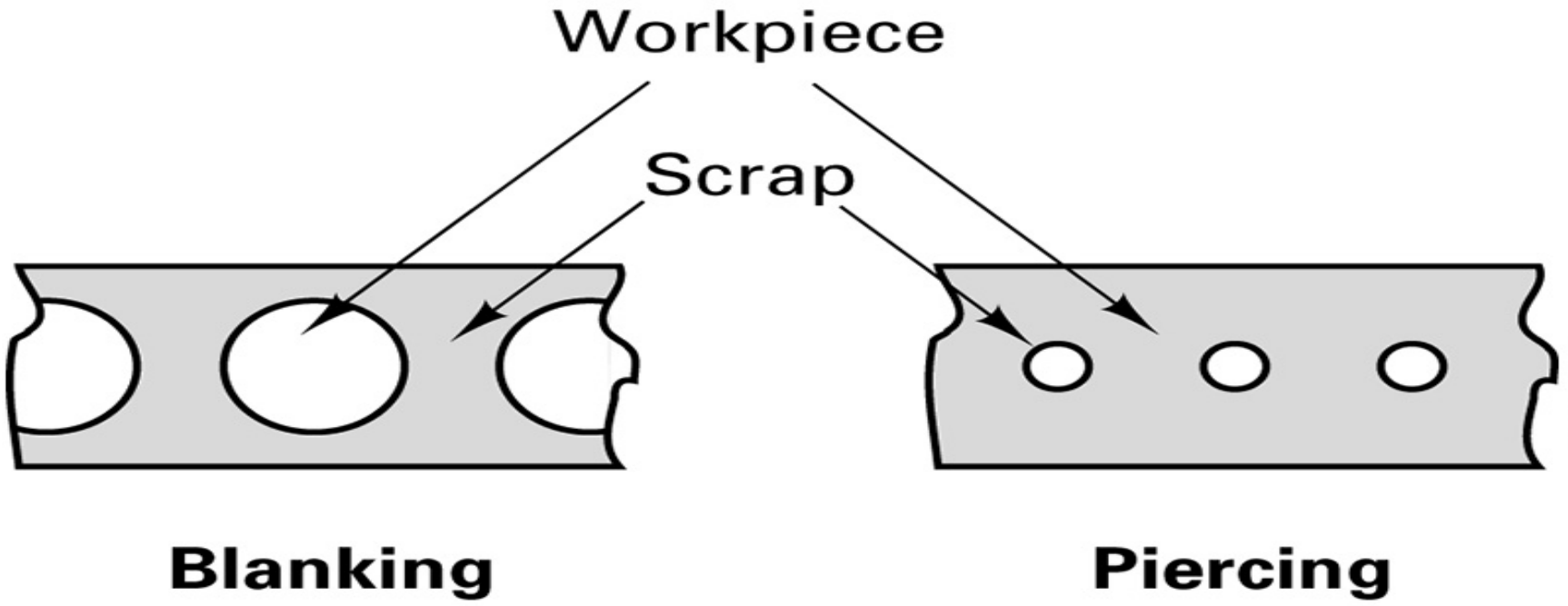


Fig. 3.4 Deep drawing.

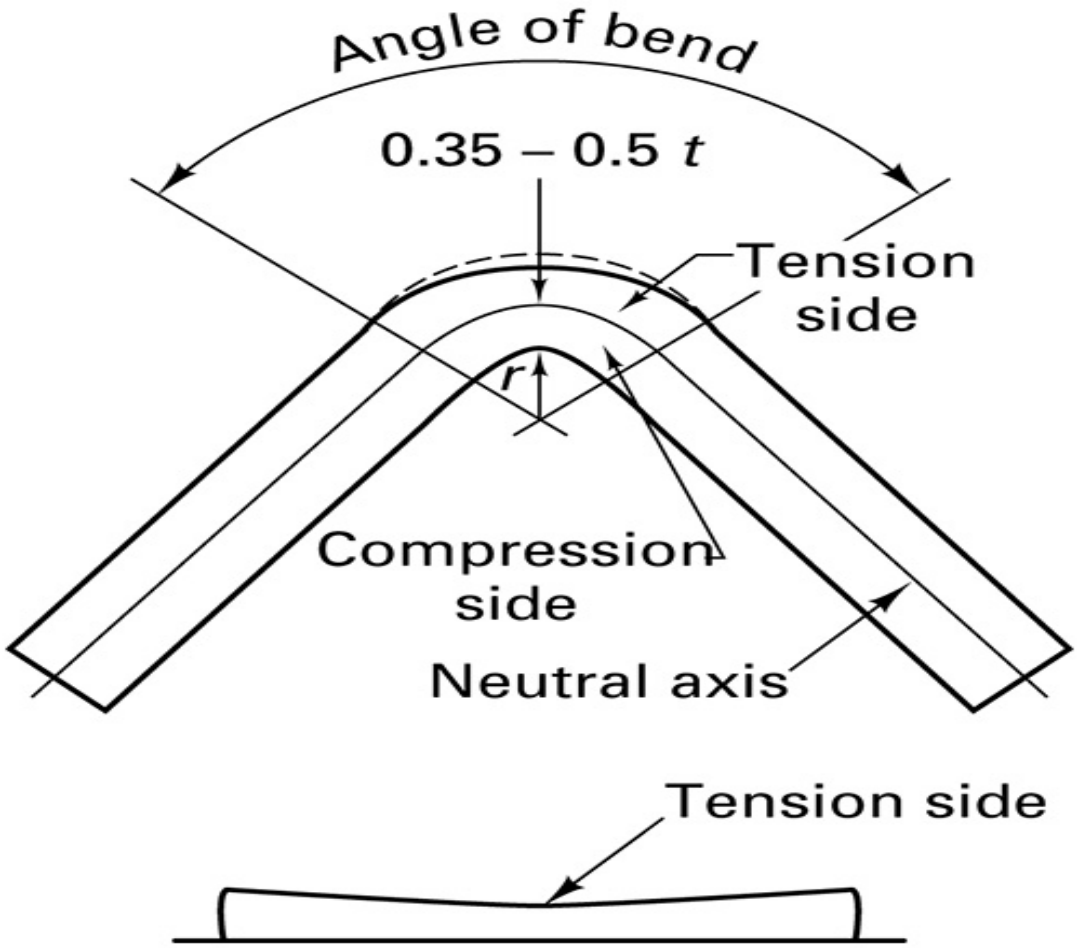
BLANKING


Workpiece
Punch
Die
Burr
Break
Burnished land
Roll over (die roll)

BLANKING VS PIERCING



BENDING


Angle of bend
0.35 – 0.5 t
Tension side
r
Compression side
Neutral axis
Tension side

BENDING

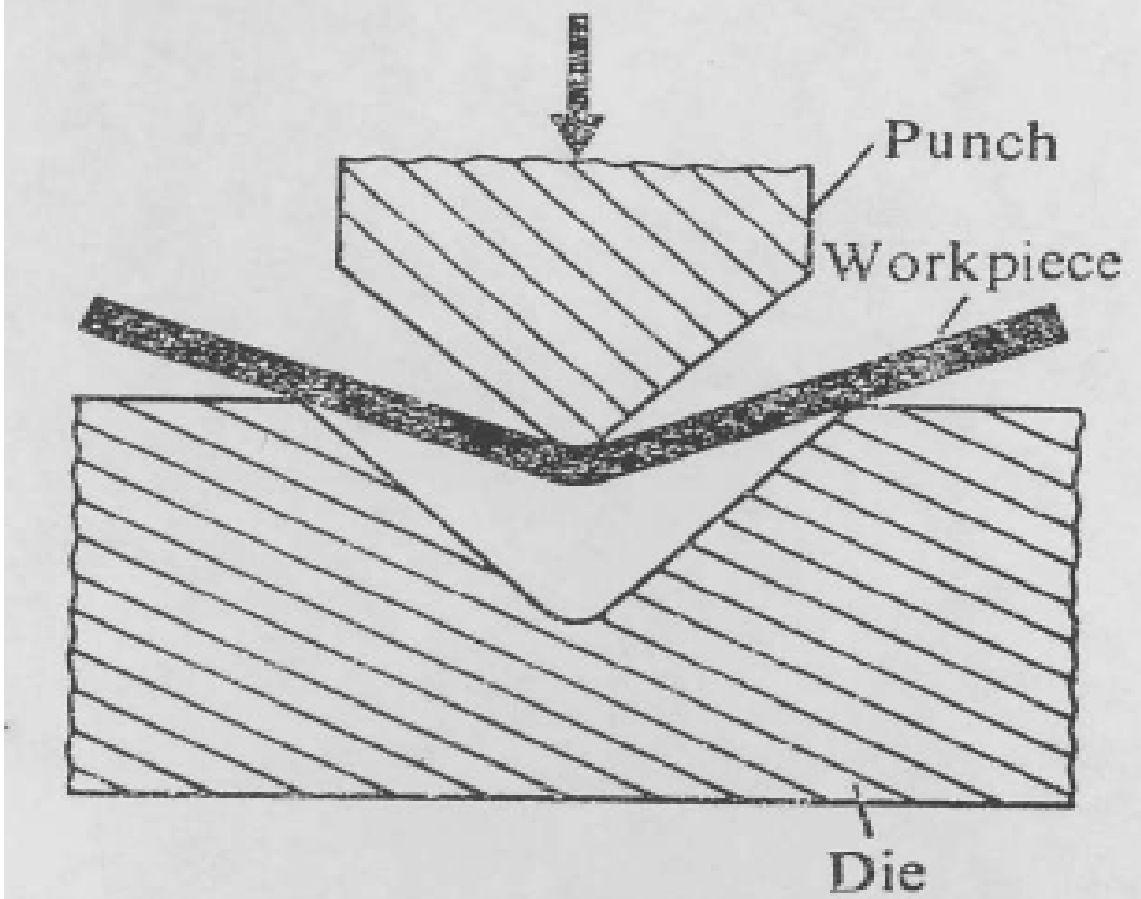
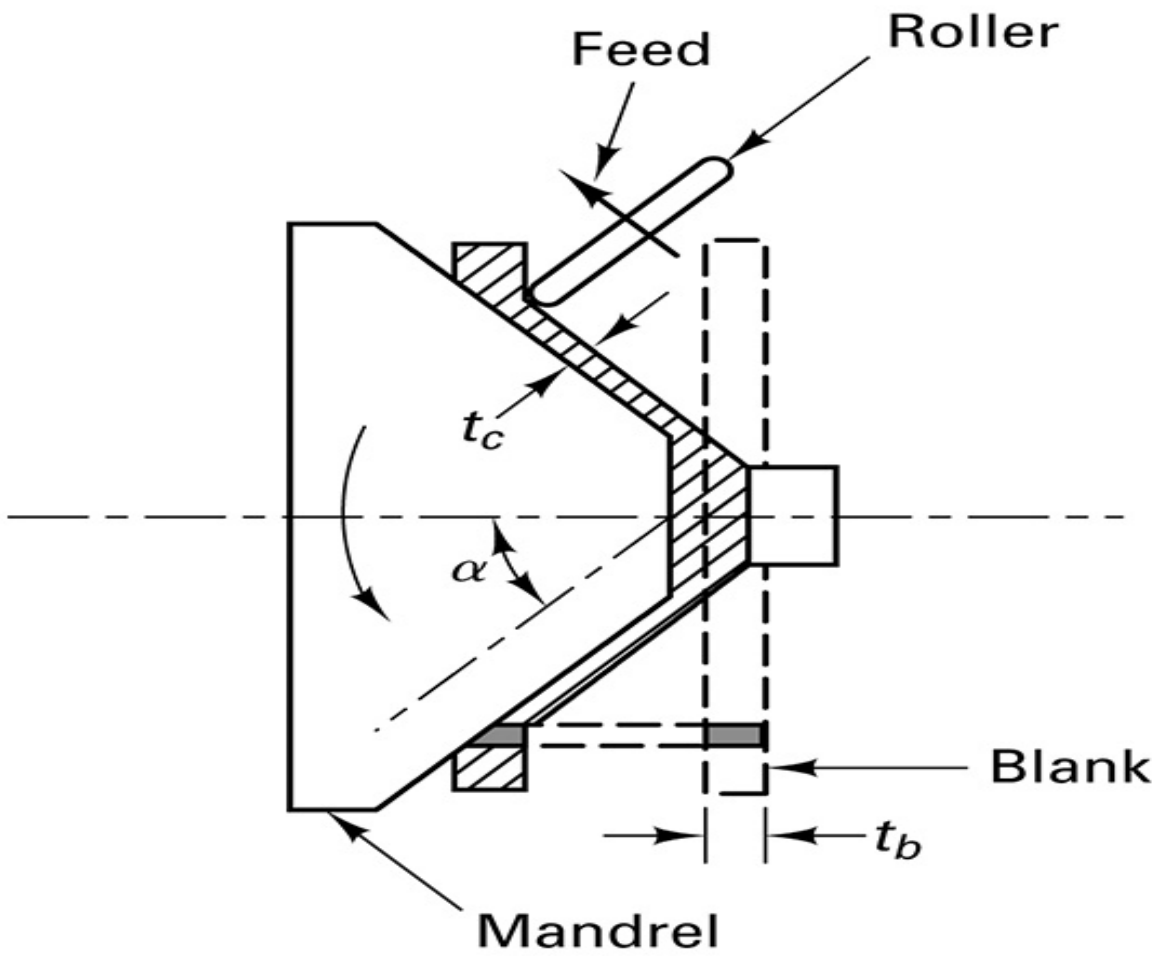
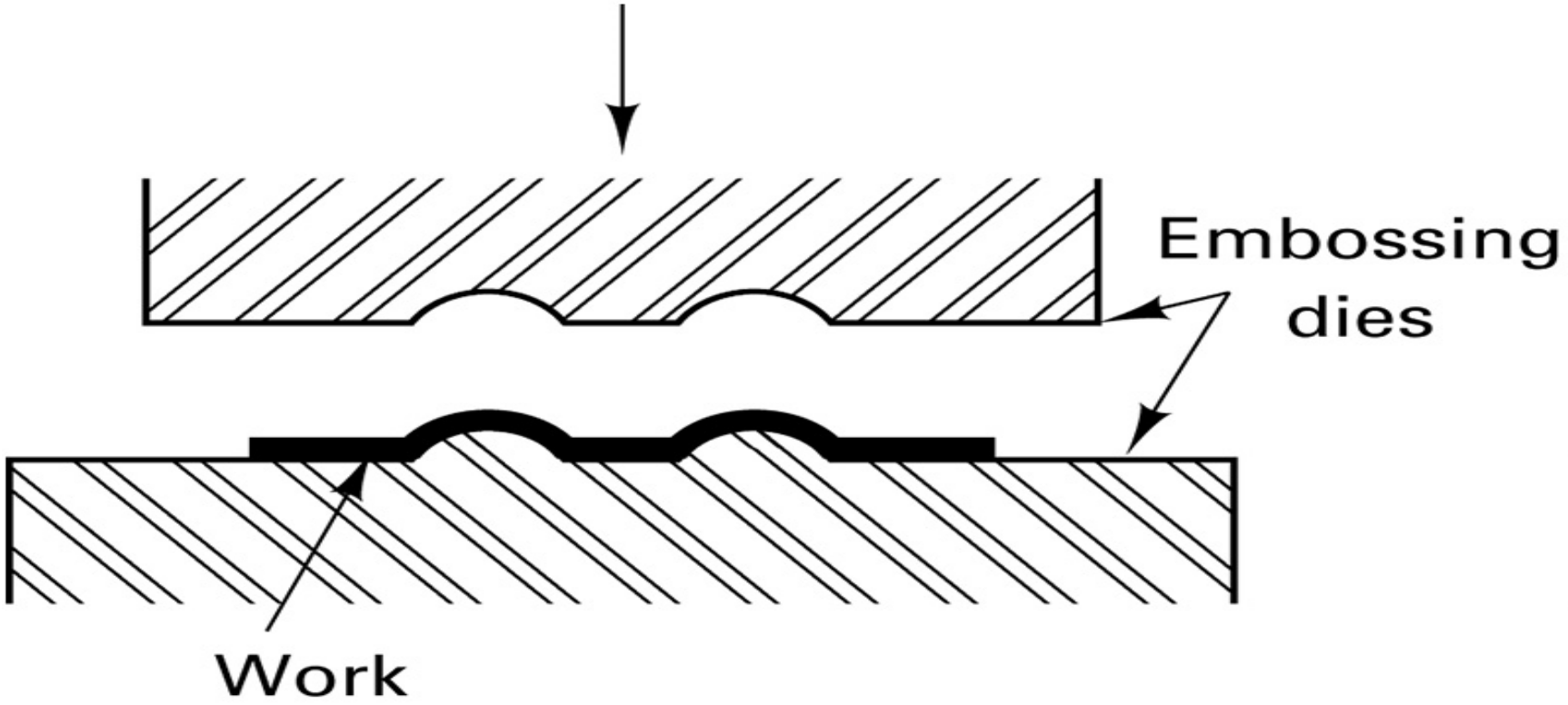


Fig. 3.5 Bending.

SHEAR FORMING



EMBOSSING



DRAWING: FREE BODY DIAGRAM

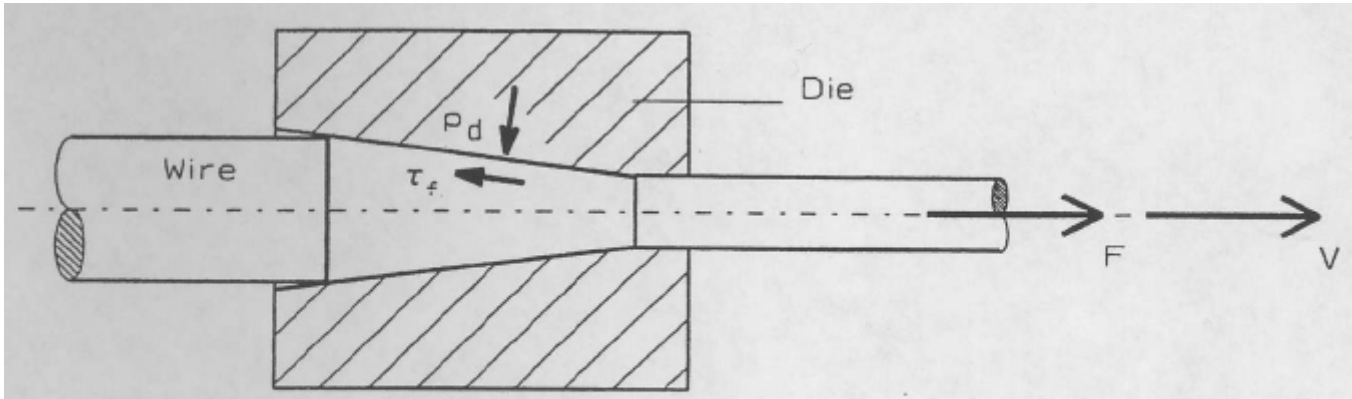


Fig. 1.2.2 Operation diagram of wire drawing

ROLLING

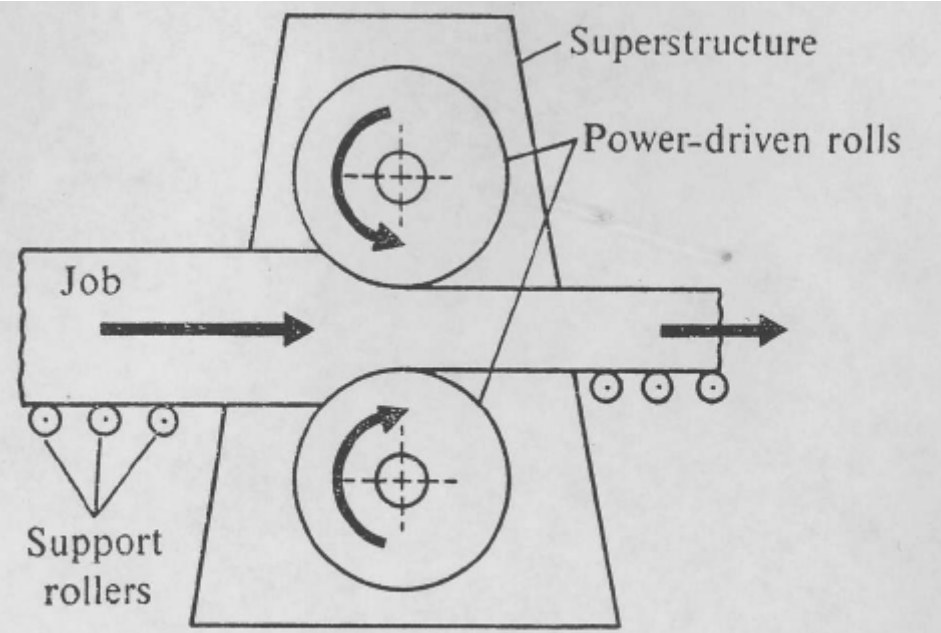
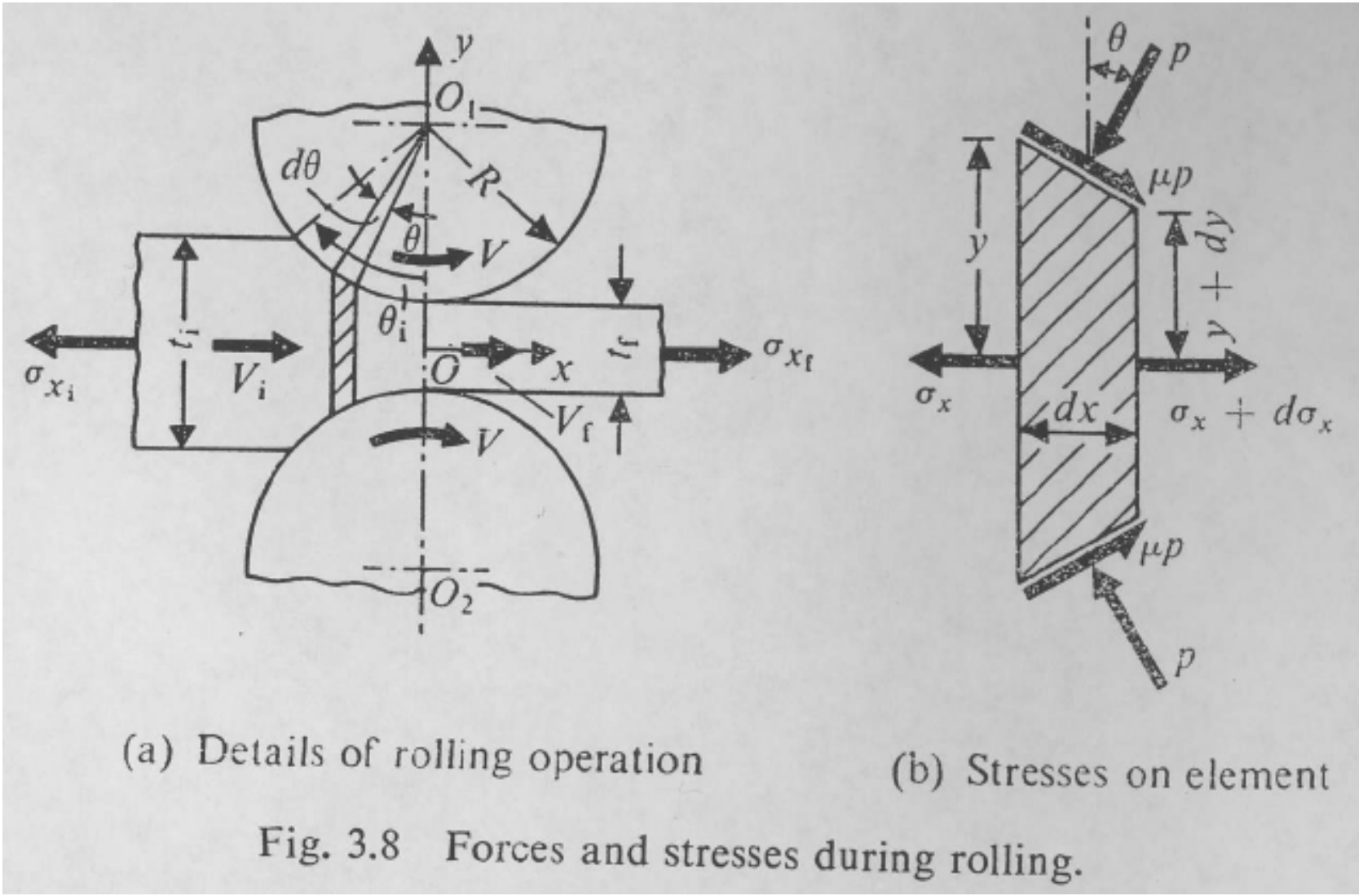


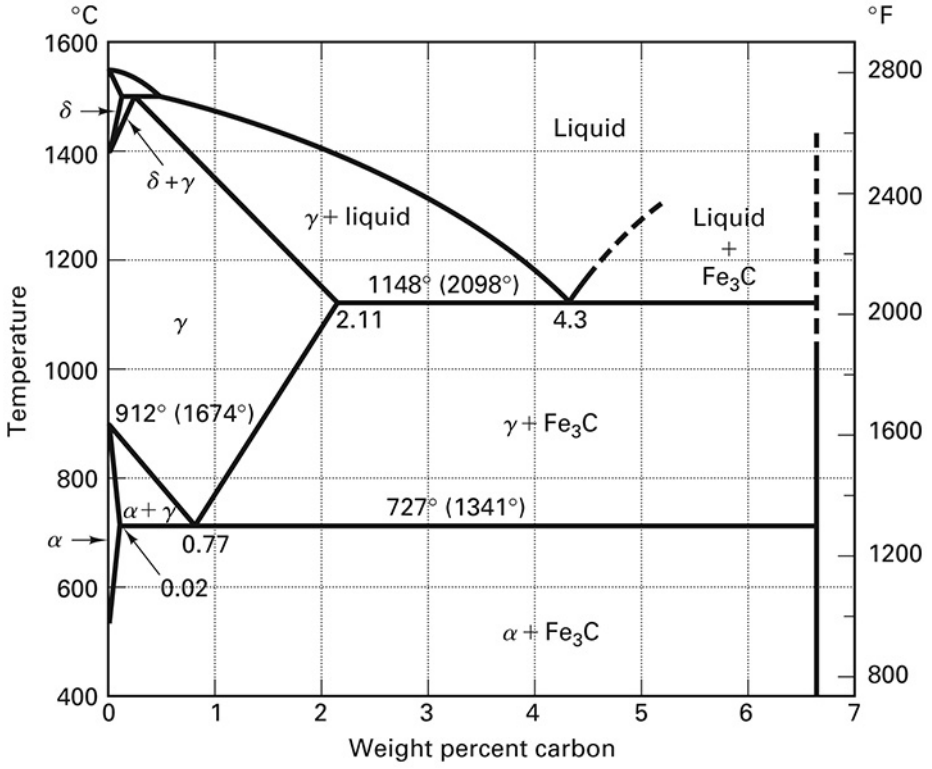
Fig. 3.1 Rolling operation.



(a) Details of rolling operation

(b) Stresses on element

Fig. 3.8 Forces and stresses during rolling.


°C
°F
1600
1400
1200
1000
800
600
400
2800
2400
2000
1600
1200
800
δ
δ + γ
Liquid
γ + liquid
Liquid
+
Fe3C
1148° (2098°)
2.11
4.3
γ
912° (1674°)
γ + Fe3C
α + γ
727° (1341°)
0.77
α
0.02
α + Fe3C
Temperature
0
1
2
3
4
5
6
7
Weight percent carbon