EDPT 601

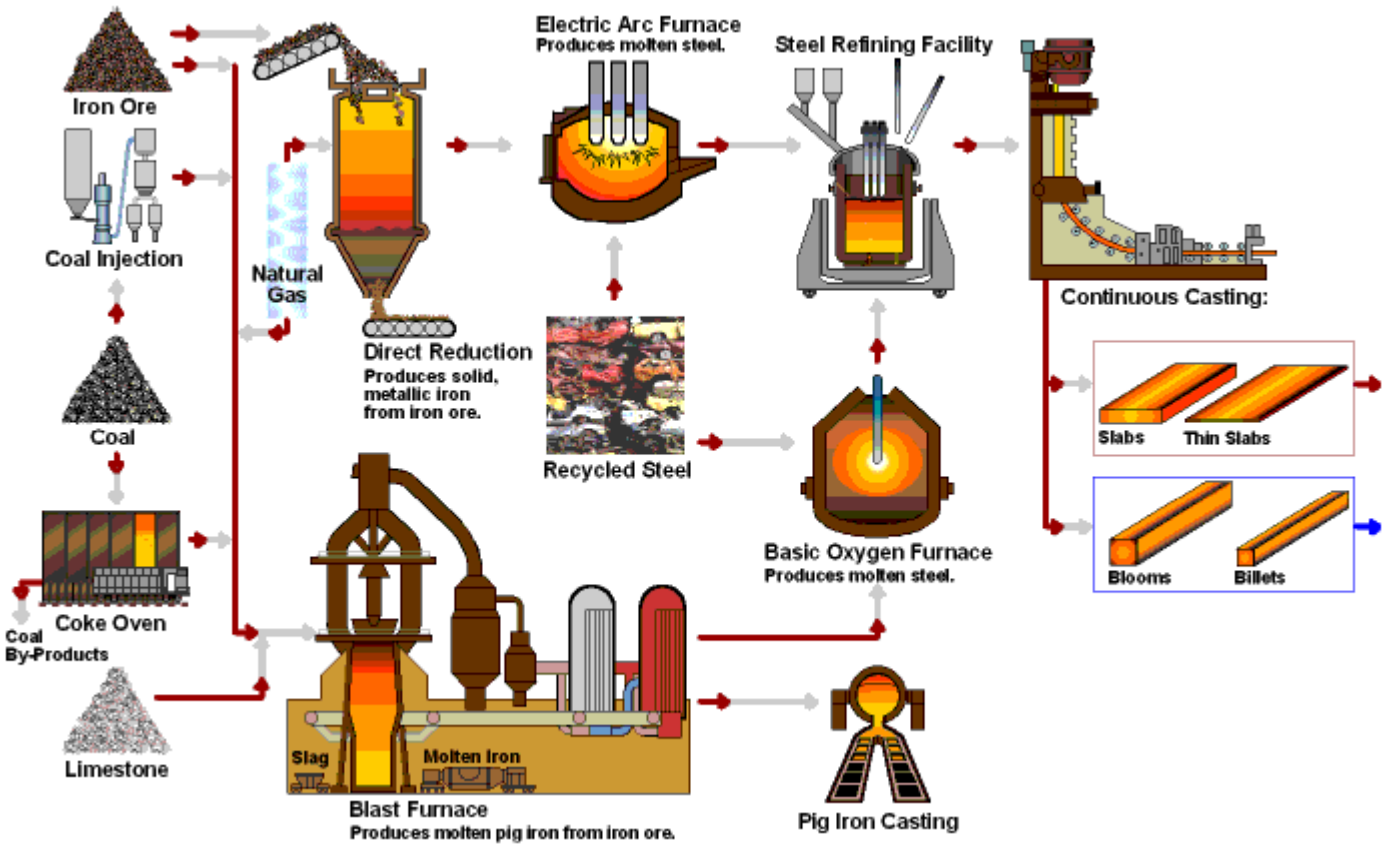
MATERIALS MANUFACTURING TECHNOLOGY

Metal Forming Processes:

Fundamentals and hot working processes

Refs: Ch 17 and 18 DeGarmo

Where does metal forming starts?



FUNDAMENTALS OF METAL FORMING

- Deformation are processes in manufacturing that induce shape changes on the work-piece by plastic deformation under forces applied by various tools and dies

Classification of forming processes

Forming or working Operations can be classified as:

1- Primary working operations:

A solid piece from cast ingots is broken down into slabs, plates.. by rolling, forging, extrusion

2- Secondary working operations:

Are further processes in order to obtain a final or semi final product e.g. bolts, nuts, wires..

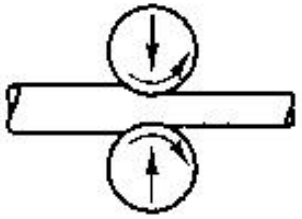
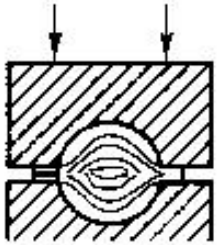
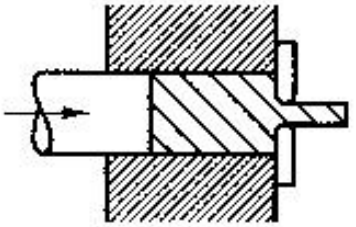
Classification of forming processes

Another Classification – based on temperature is:

- **hot working (T more than 0.6Tm)**
- **cold working (T less than 0.3 Tm)**
- **warm working**

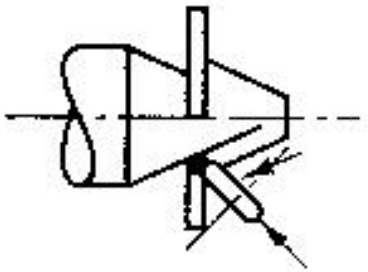
Main forming operations or processes

Hot working operations

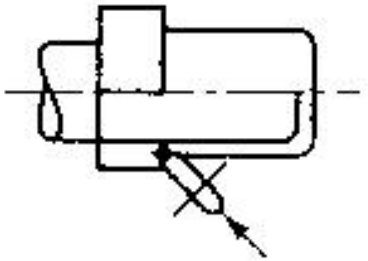
Process	Schematic Diagram
Rolling	
Forging	
Extrusion	

Cold working operations

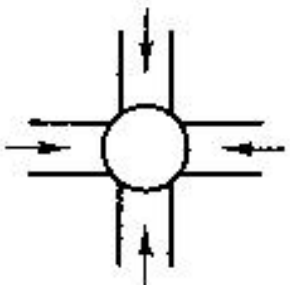
Shear spinning



Tube spinning

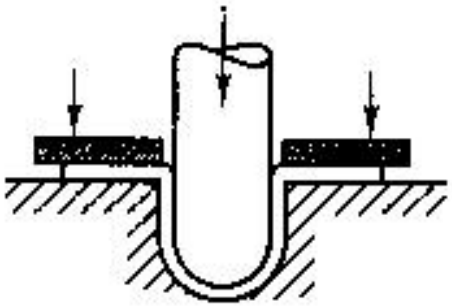


Swaging or kneading

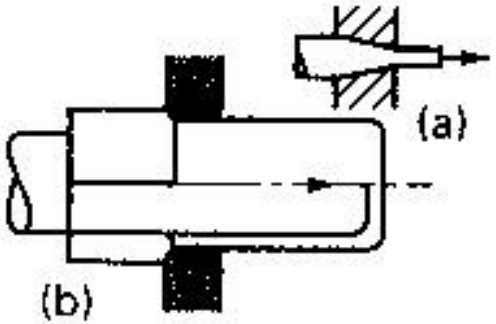


Cold working operations

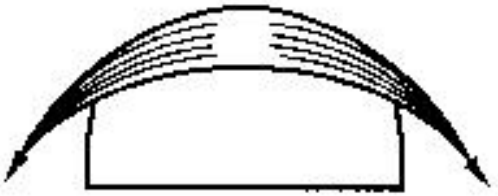
Deep drawing



Wire and tube drawing



Stretching



Straight bending

General parameters that assess the suitability of a material for a given deformation process:

Characteristics of the material being deformed are:

- strength or resistance to deformation (flow stress) at the forming temperature, speed of deformation and amount of prior deformation
- ductility - formability limits
- reaction of the material with various environments or lubricants

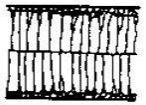
Effect of lubrication on forming process- mainly cold working :

- reduction of forces
- reduction of tool wear
- acting as coolant
- retardation of corrosion

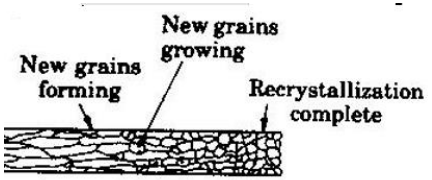
Hot working (T more than 0.6Tm)

- Is the plastic deformation above recrystallization temperature
- Minimum temperature is the recrystallization temperature
- Maximum temperature is determined by the excess oxidation, grain growth or undesirable phase transformation

Advantages and Disadvantages of Hot Working



Ingot with nonuniform grains



Wrought product with small, uniform grains

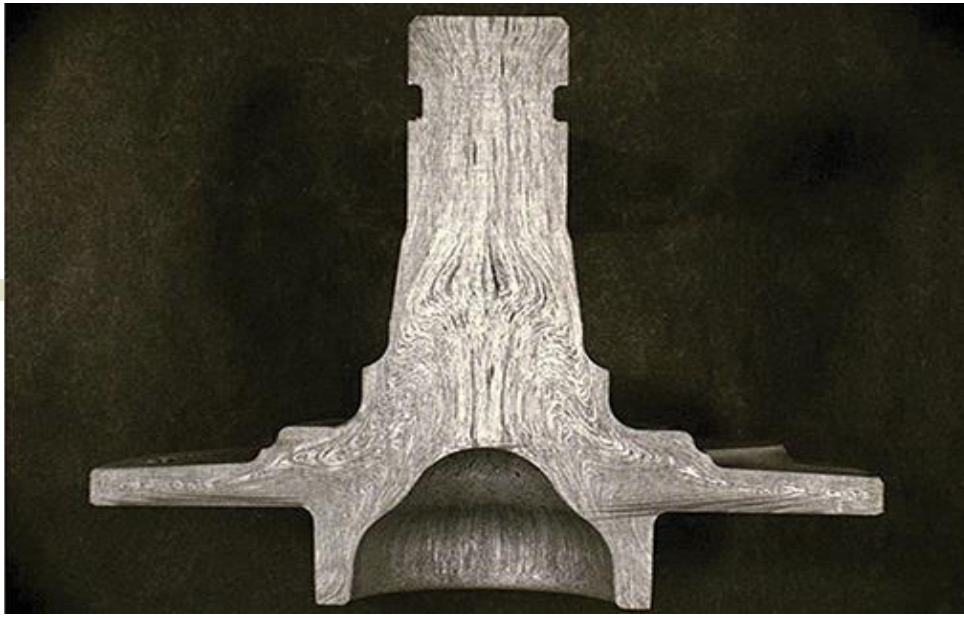
Advantages

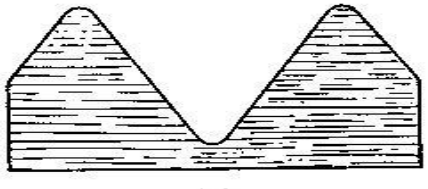
1. breaking down the undesirable cast structure
2. closing down gas porosity and shrinkage porosity
3. breaking down inclusions
4. forming recrystallized grains
5. may produce a "flow structure"
6. lower forces and power

Disadvantages:

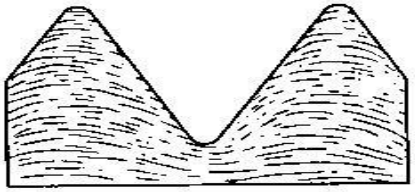
1. Heavy scale
2. Poor dimensional tolerances and surface finish
3. Need of heating equipment
4. Expensive tooling

Grain Flow results in better mechanical properties





(a)



(b)

FIGURE 17-5 Schematic comparison of the grain flow in a machined thread (a) and a rolled thread (b). The rolling operation further deforms the axial structure produced by the previous wire- or rod-forming operations, while machining simply cuts through it.

Cold working: (T less than 0.3 Tm)

Advantages

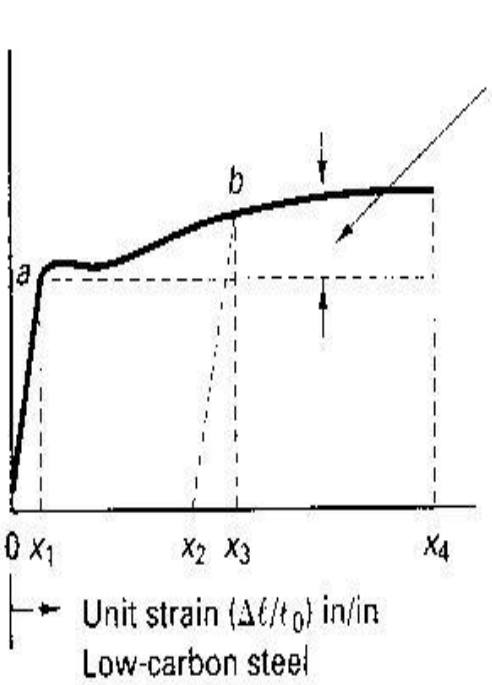
- no heating required
- good surface finish
- closer tolerances
- strength, fatigue and wear properties are improved through strain hardening
- directional properties
- minimizing contamination problems

Disadvantages

- higher forces
- more powerful equipment and stronger tooling
- less ductility is available
- metal surface must be clean and scale-free
- intermediate anneals may be needed
- residual stresses may be produced
- elastic spring back

Stress – Strain Diagram

Note:
Yield strength
Strain hardening
Ductility
Spring back
%reduction
in area



Increase in tensile strength due to work hardening produced by the motion and multiplication of dislocations. The high carbon steel will also have more springback.

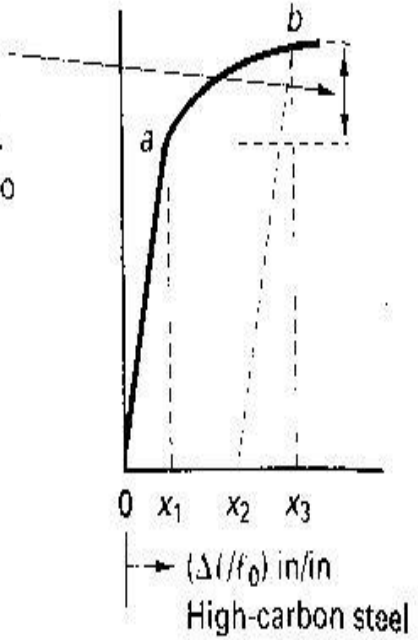


FIGURE 17-6 Use of true stress–true strain diagrams to assess the suitability of two metals for cold working.

Warm Forming (0.3 to 0.6 Tm)

Advantages compared to cold forming

- reduced loads on tooling and equipment
- higher ductility
- reducing number of anneals
- reducing amount of strain hardening compared to hot forming
- less scaling and decarburization
- better dimensional accuracy and smoother surfaces
- less energy
- longer tool life

For steel between 550 C and 800 C

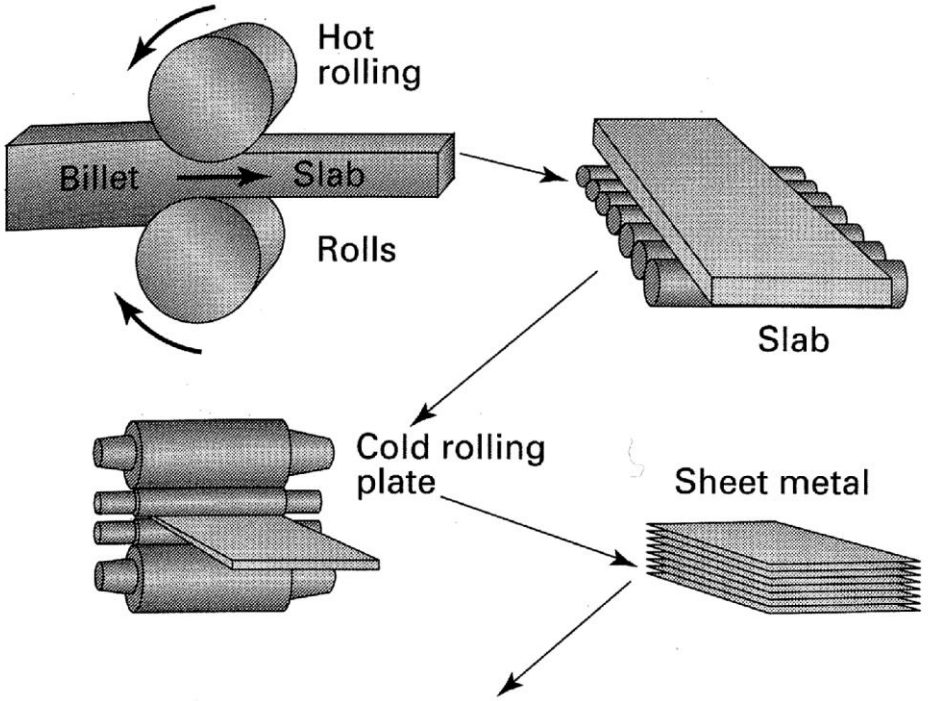
Classification of Hot Working Processes

Are classified as:

- Rolling
- Forging
- Extrusion
- Hot Drawing
- Piercing

Rolling

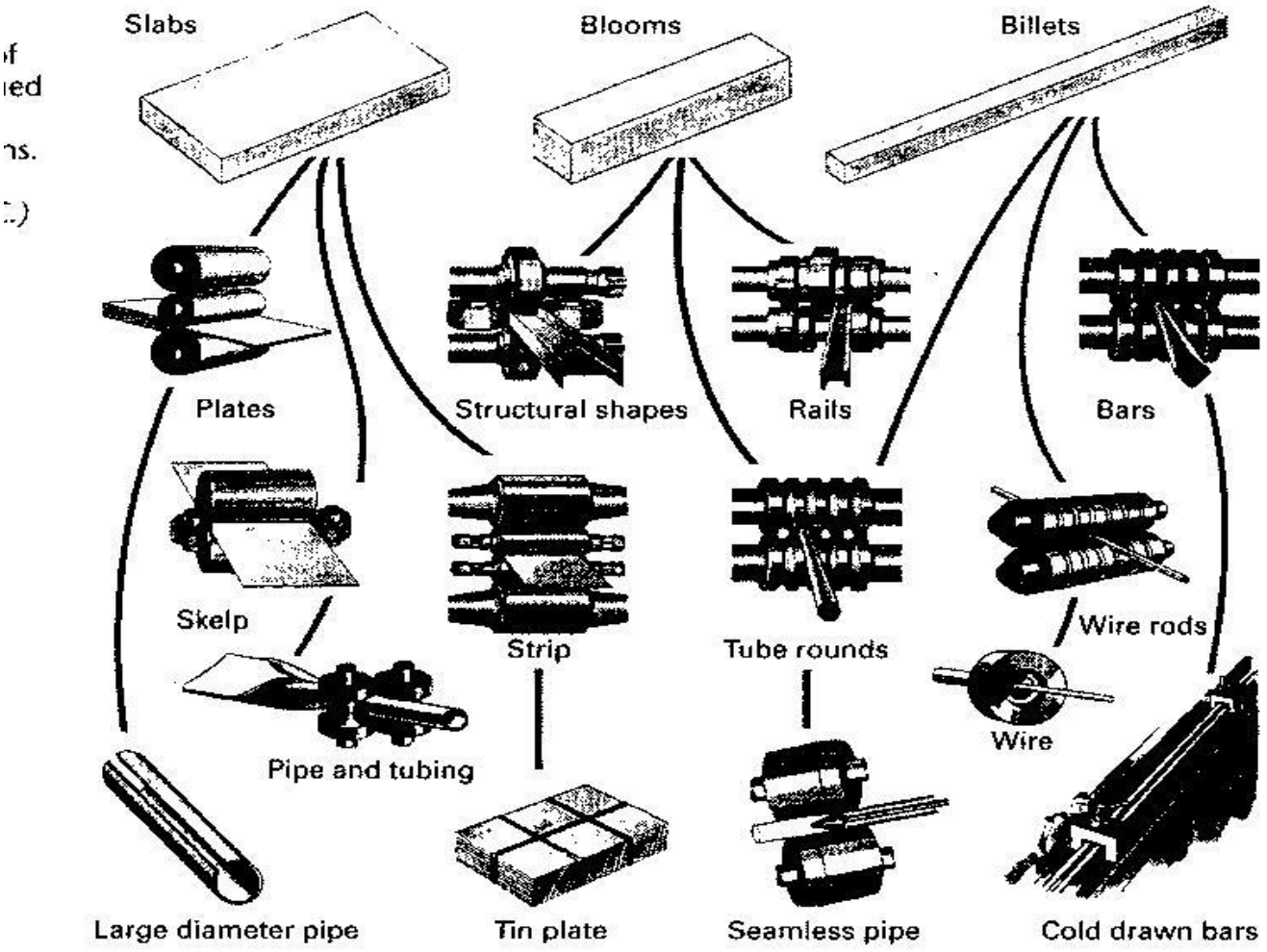
- Accounts for about 90% of all metals produced by metal working processes
- Most deformation takes place in thickness which increases length + some increase in width
- A_1V_1 (entry) = A_2V_2 (final)



Cast billets of metal are passed through successive rollers to produce sheets of steel rolled stock.


FLY

Production of various finished and semi finished steel shapes by rolling



Raw Materials for hot rolling: definitions

Blooms:

- Min 6" X 6"

Billets

- Min 1.5"X 1.5"

Slabs

- Min 1" X 10“

Finished Products of flat rolling: definitions

Plates

- Thickness ≥ 6mm
- Used in ship hulls, boilers, bridges, machine structures, battle ships and tanks

Sheets

- ≤ 6mm thick
- Used for automobile body, appliances, containers for food and beverage, kitchen and office equipment, aircraft, beverage cans (0.15mm thick) , Al foils (0.008mm) to wrap candy and cigarettes
- Sheets are also provided as strips in coils

Effect of Rolling on Grain Structure

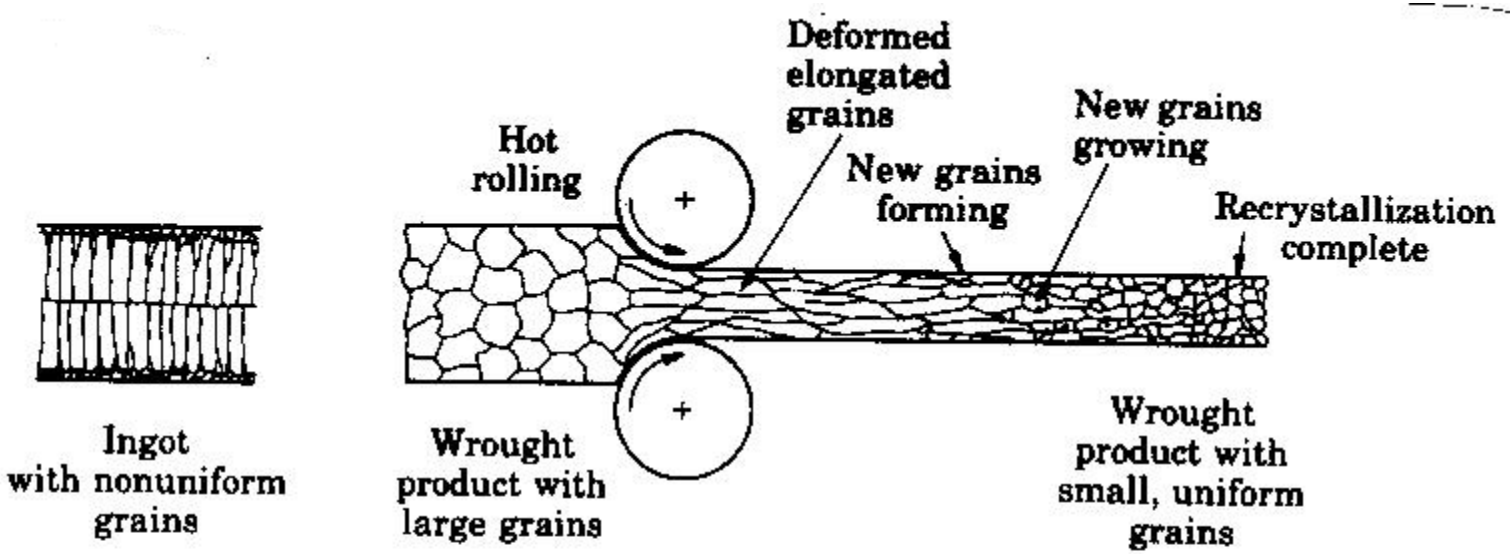


FIGURE 6.32 Changes in the grain structure of cast or large-grain wrought metals during hot rolling. Hot rolling is an effective way to reduce grain size in metals for improved strength and ductility. Cast structures of ingots or continuous castings are converted to a wrought structure by hot working.

Importance of temperatures on product quality

- **Heating and soaking**: soaking time must ensure that the temperature on the surface and inside the material are equal in order to obtain uniform deformation

- **Finishing temperature** (50ºC to 100ºC above recrystallization temperature)- ensures uniform grain size and prevents unwanted strain hardening

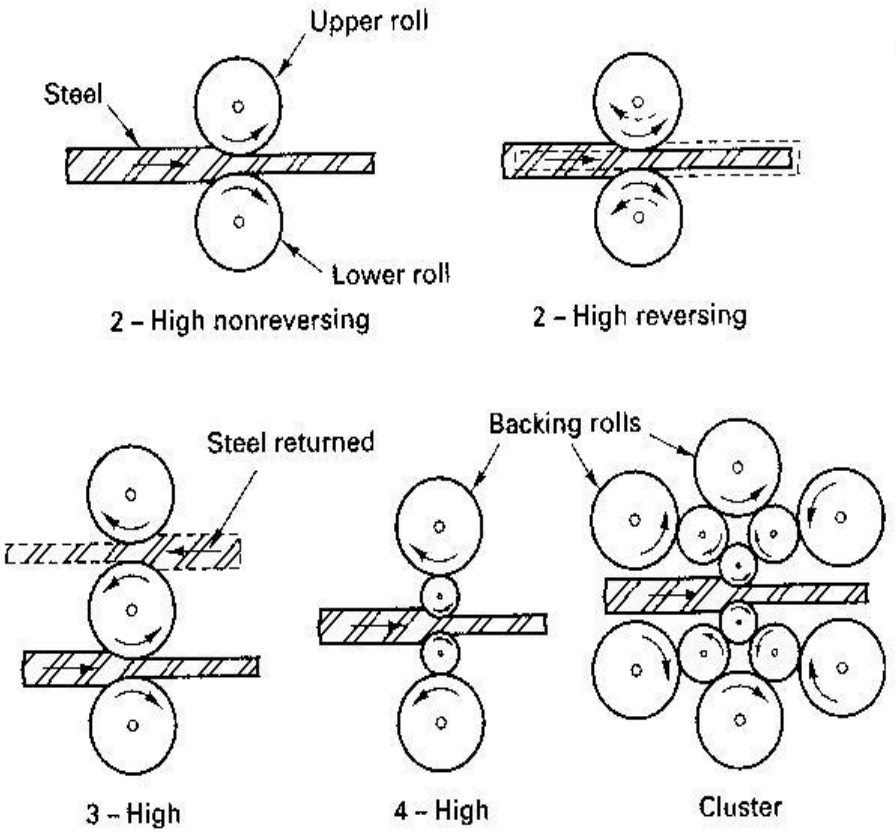
Metal Forming Processes:

Hot working processes

Refs: Ch 17 and 18 DeGarmo

Rolling mill configurations

FIGURE 18-3 Various roll configurations used in rolling operations.



Schematic showing the effect of roll diameter on length of contact for a given reduction

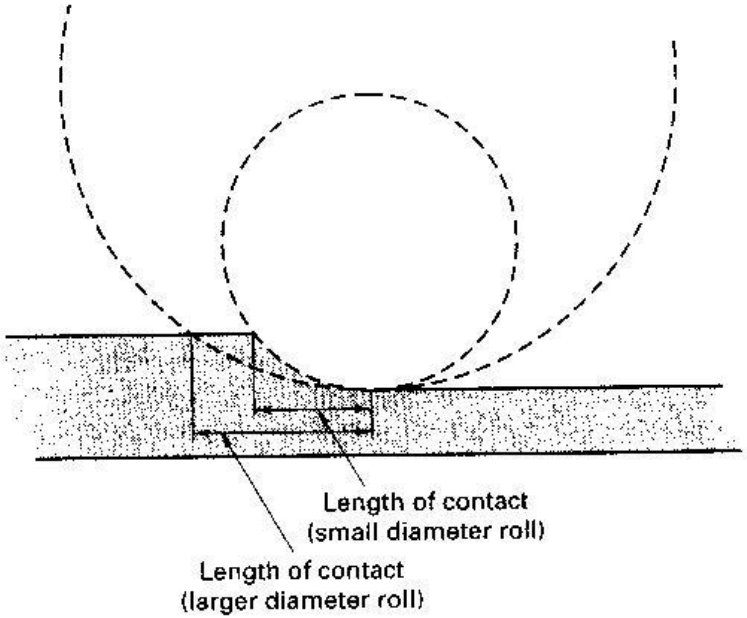


FIGURE 18-4 Schematic showing the effect of roll diameter on length of contact for a given reduction.

- Rolling force is proportional to the area of contact between the rolls and the rolled material

Shape Rolling: to produce different sections

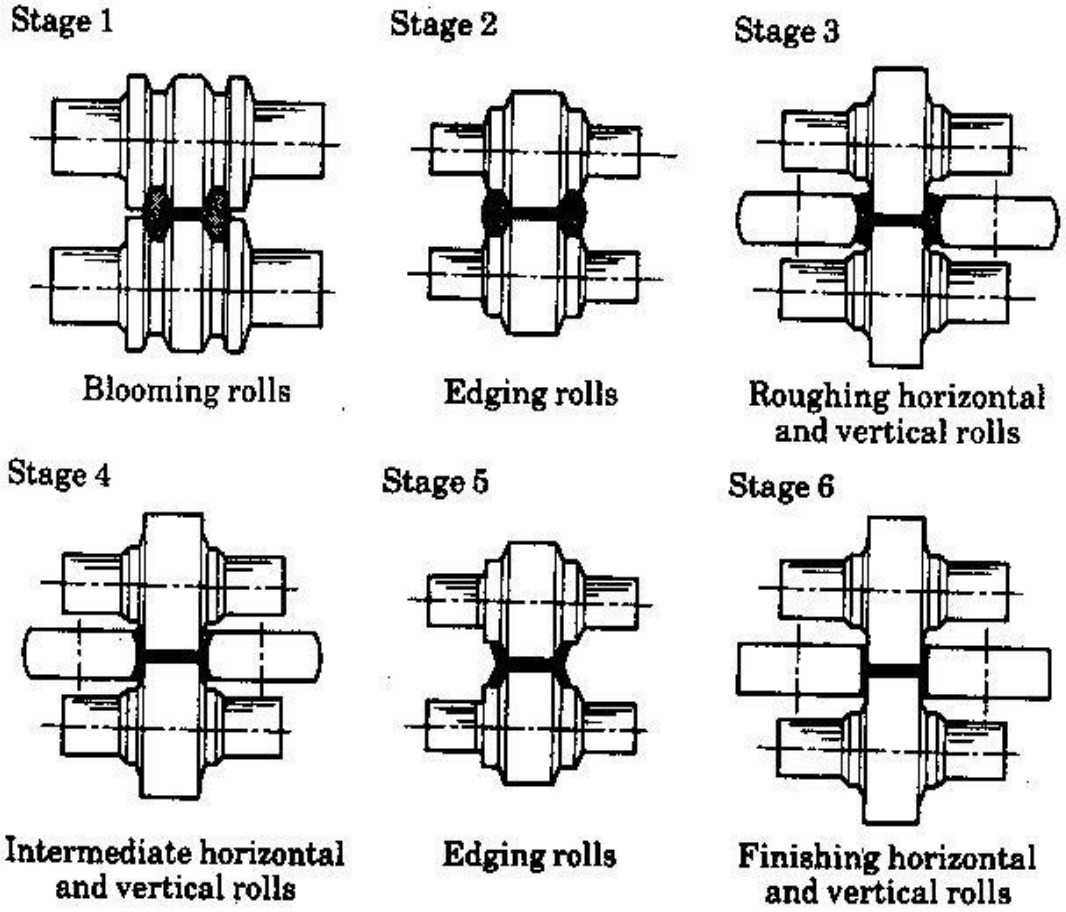
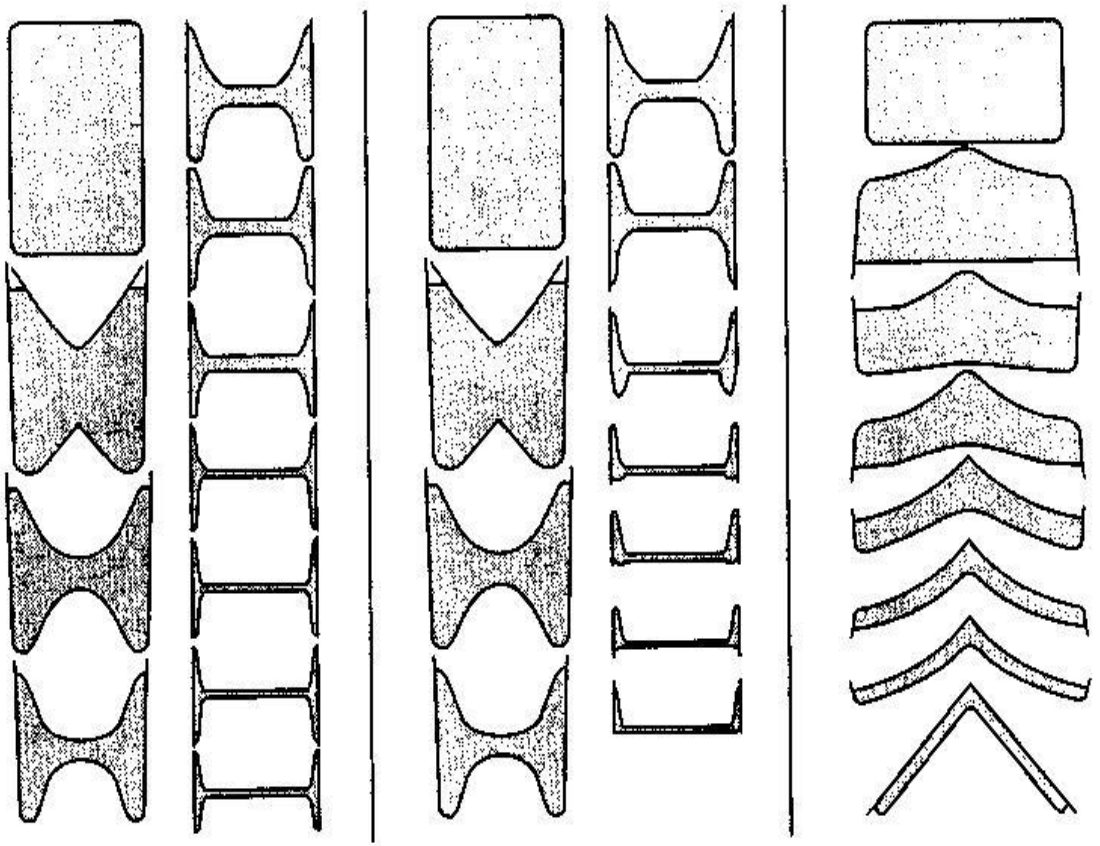


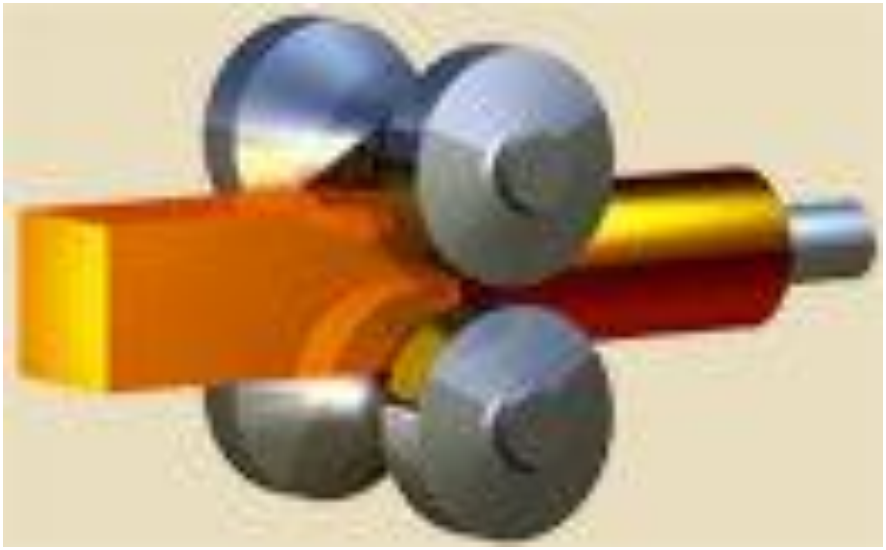
FIGURE 6.46 Stages in shape rolling of an H-section part. Various other structural sections, such as channels and I-beams are also rolled by this process.

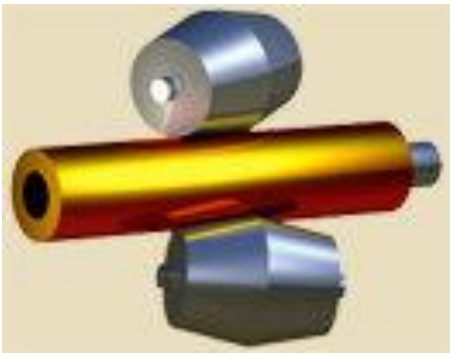
Typical roll-pass sequences used in producing various structural shapes

FIGURE 18-5 Typical roll-pass sequences used in producing various structural shapes.



Shape rolling of tubes





Continuous Rolling Mills

- Several rolling stands are working simultaneously and the change in section is produced in sequence

Rolling Defects

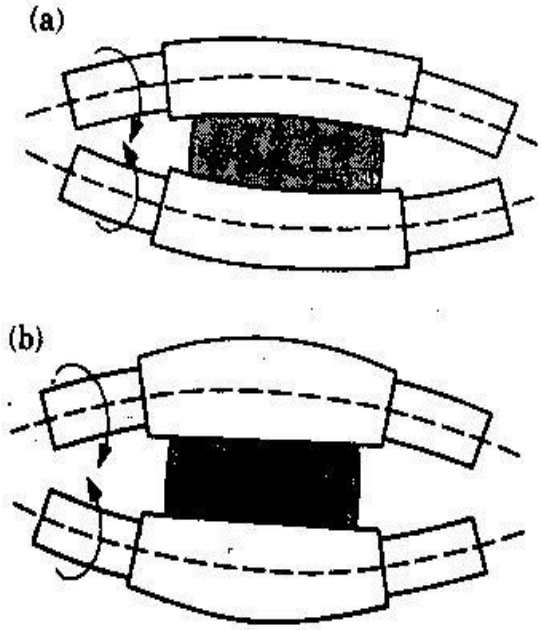


FIGURE 6.39 (a) Bending of straight cylindrical rolls because of the roll-separating force. (b) Bending of rolls, ground with camber, that produce a sheet of uniform thickness during rolling.

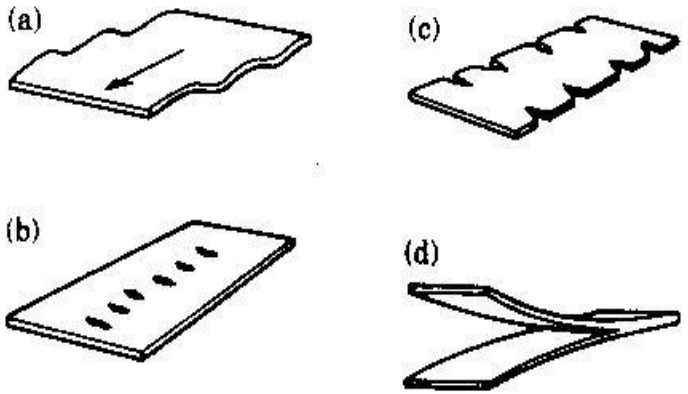


FIGURE 6.41 Schematic illustration of typical defects in flat rolling: (a) wavy edges; (b) zipper cracks in center of strip; (c) edge cracks; (d) alligatoring.

Ring Rolling

Seamless rings are produced with a circumferential grain orientation

Applications: rockets, turbines, airplanes, pipelines, pressure vessels

Diameters: can be as large as 8m with face heights as great as 2m

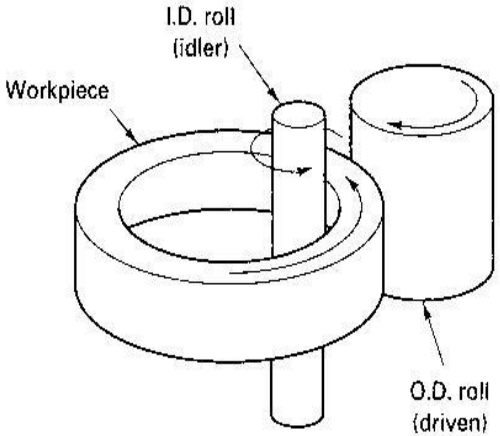


FIGURE 18-6 Schematic of a horizontal ring rolling operation. As the thickness of the ring is reduced, its diameter will increase.