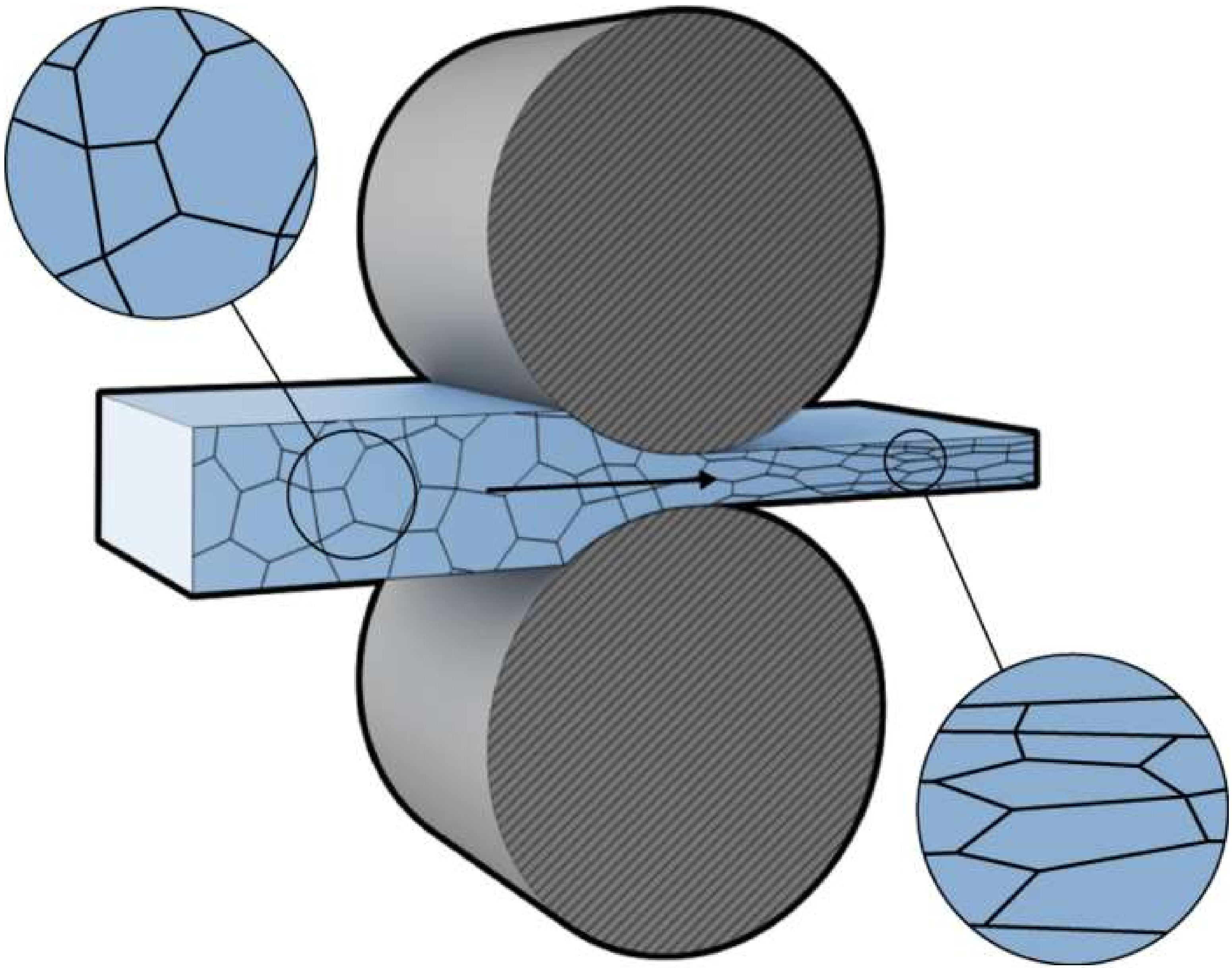
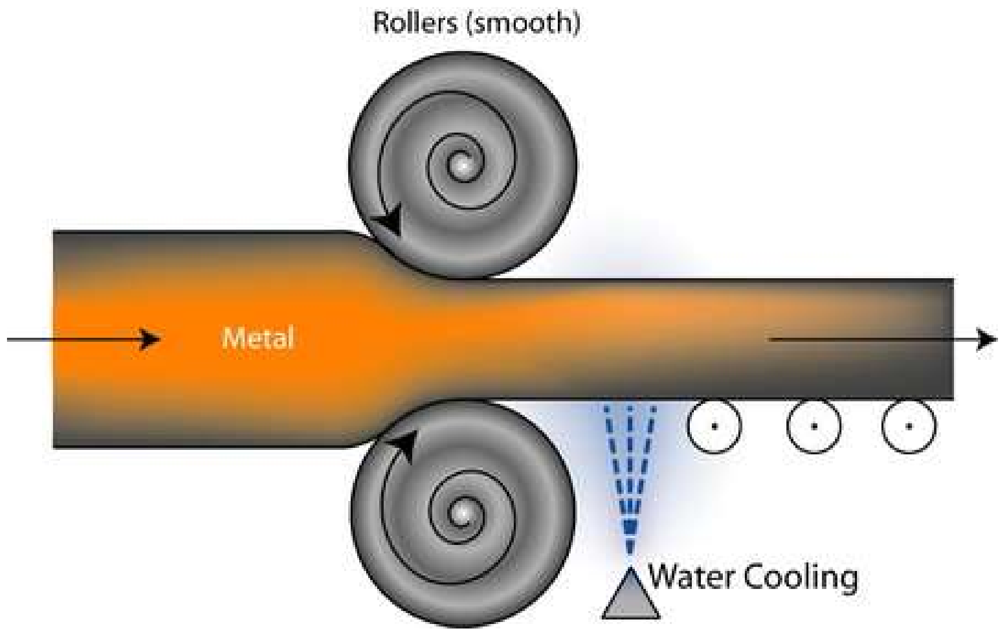
Rolling Processes



MANUFACTURINGGUIDE

Rolling Processes

Working Principle



Rolling works on same as any other metal forming process. When a compressive force applied by a set of rolls on ingot or any other product like blooms or billets, plastic deformation takes place which decrease its cross section area and convert it into required shape.
These rolls are designed according to the final product requirement.
They are cylindrical in shape and fitted with the die of the required shape which to be rolled on blooms or billets. Rolling can be done in both hot and cold way.

Rolling Processes

The process of plastically deforming metal by passing it between rolls is known as Rolling.

In deforming metal between rolls, the work is subjected to high compressive stress from the squeezing action of the rolls and to surface shear stresses as a result of the friction between rolls and metals.
The frictional forces are also responsible for drawing the metal into the rolls

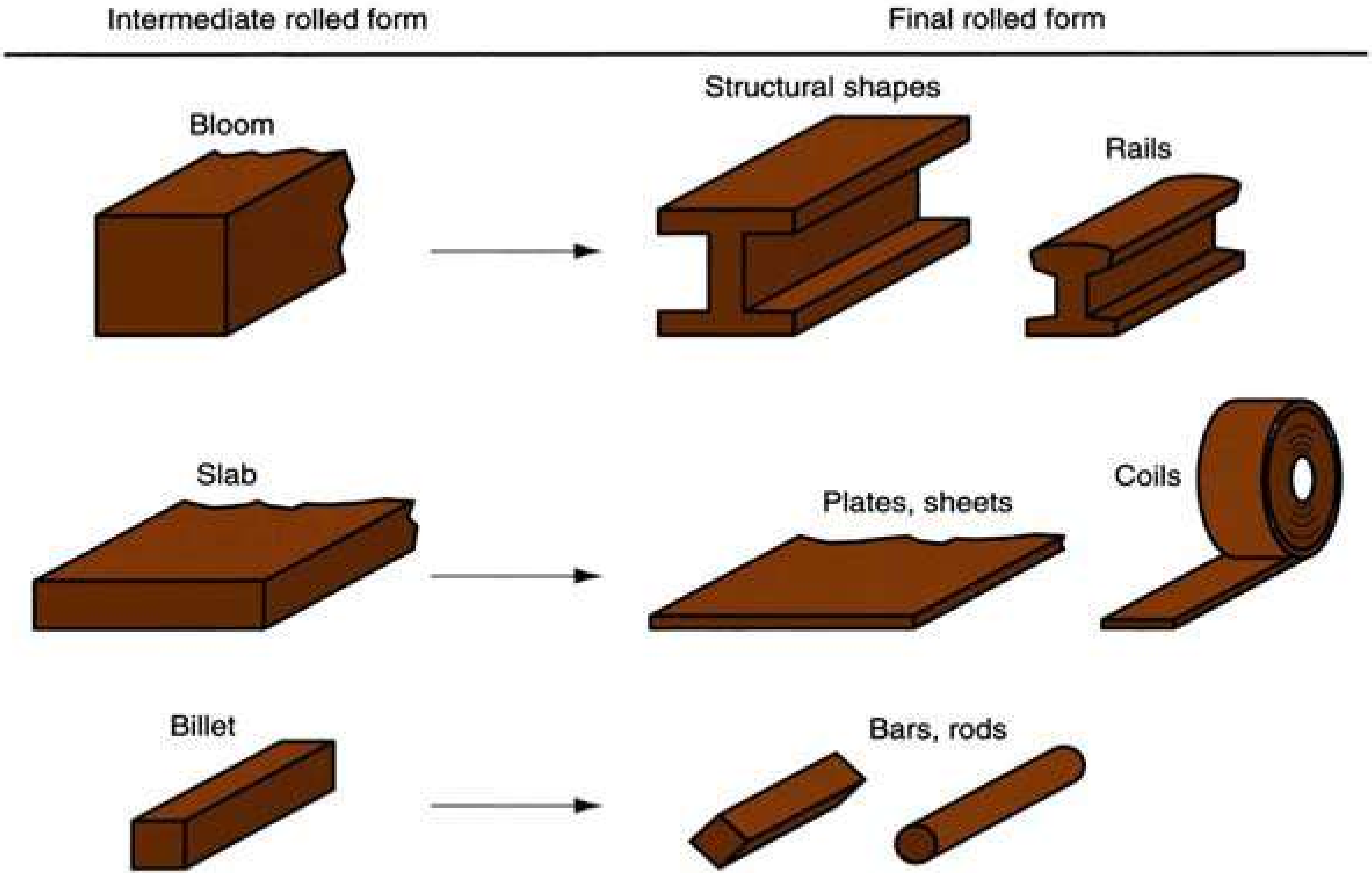
TERMINOLOGY

INGOT

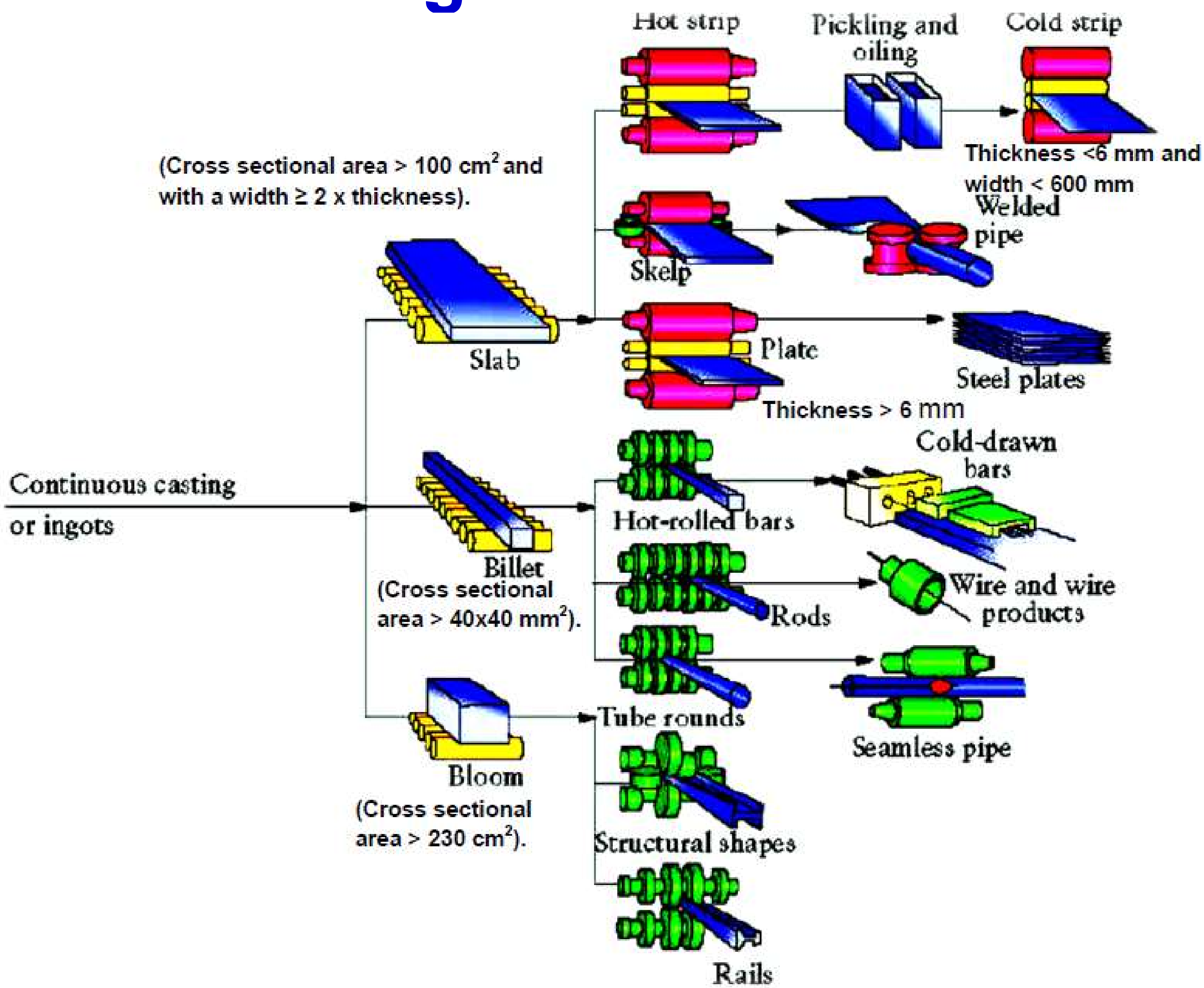
Bloom, Billet & Slab are Semi finished products

- **BLOOM** [150 x150 mm] or [250x300 mm]
  Width is equal to thickness & Cross section is more than 230 cm2
- **BILLET** : Minimum Cross Section is 40x40
  [50 x 50] or [125 x 125]
- **SLAB** : Cross sectional area is more than 100 cm2
  Width is twice of thickness
- **PLATE** [$t > 6.35$ mm]
- **SHEET** [$t < 6.35$]
- **STRIP** [$t = 6.35$ & $b = 600$ mm]
- **FOIL** [$t < 1.5$ mm & $b= 300$mm]

Rolling Processes



Rolling Processes



TERMINOLOGY

Angle of contact or Angle of bite – The Angle subtended at the centre of the roll by arc AB (Metal in contact with the roll)

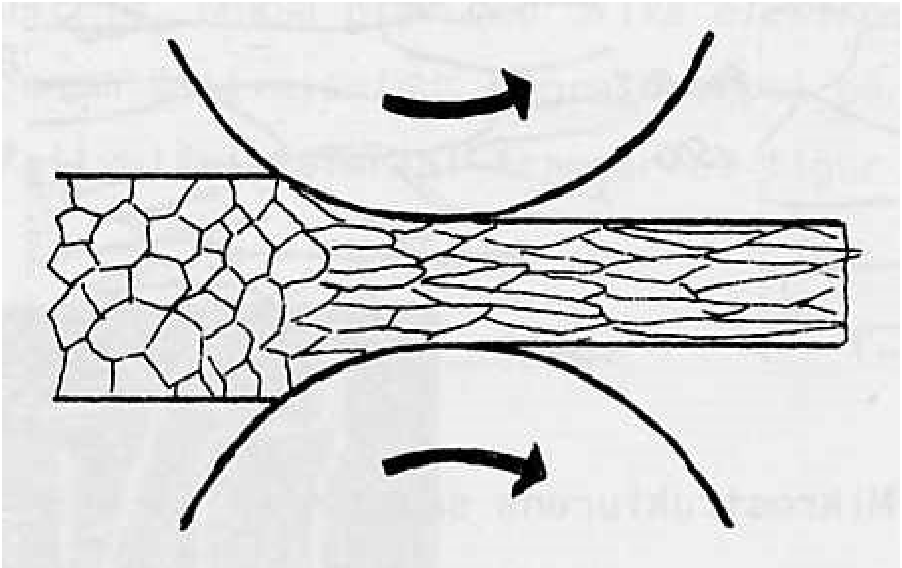
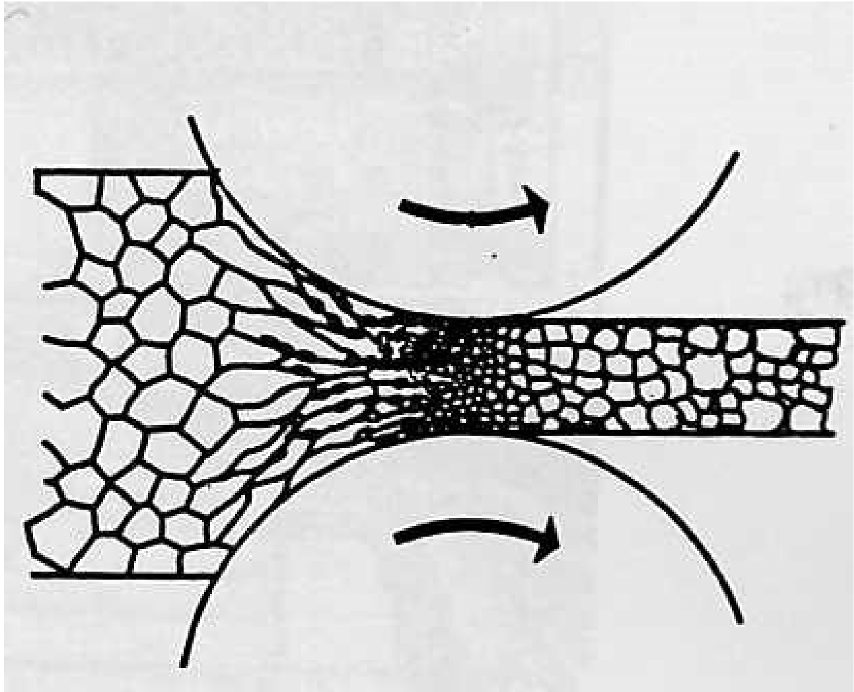
Rolling Pass – The feeding of material between the rolls once

Rolling mill – Consists of rolls , bearings & Housings and Drive for applying power to rolls

Classification of Rolling Process

- Based on work piece geometry :
  - Flat rolling - used to reduce thickness of a rectangular cross section
  - Shape rolling - square cross section is formed into a shape such as an I-beam
- Based on work temperature :
  - Hot Rolling – most common due to the large amount of deformation required
  - Cold rolling – produces finished sheet and plate stock

Rolling Processes

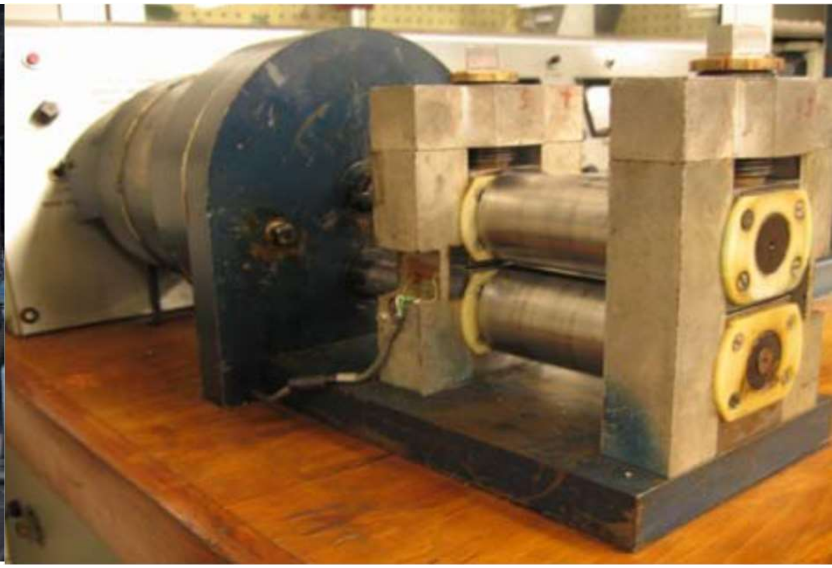
Cold Rolling	Hot Rolling
	

Rolling Mills

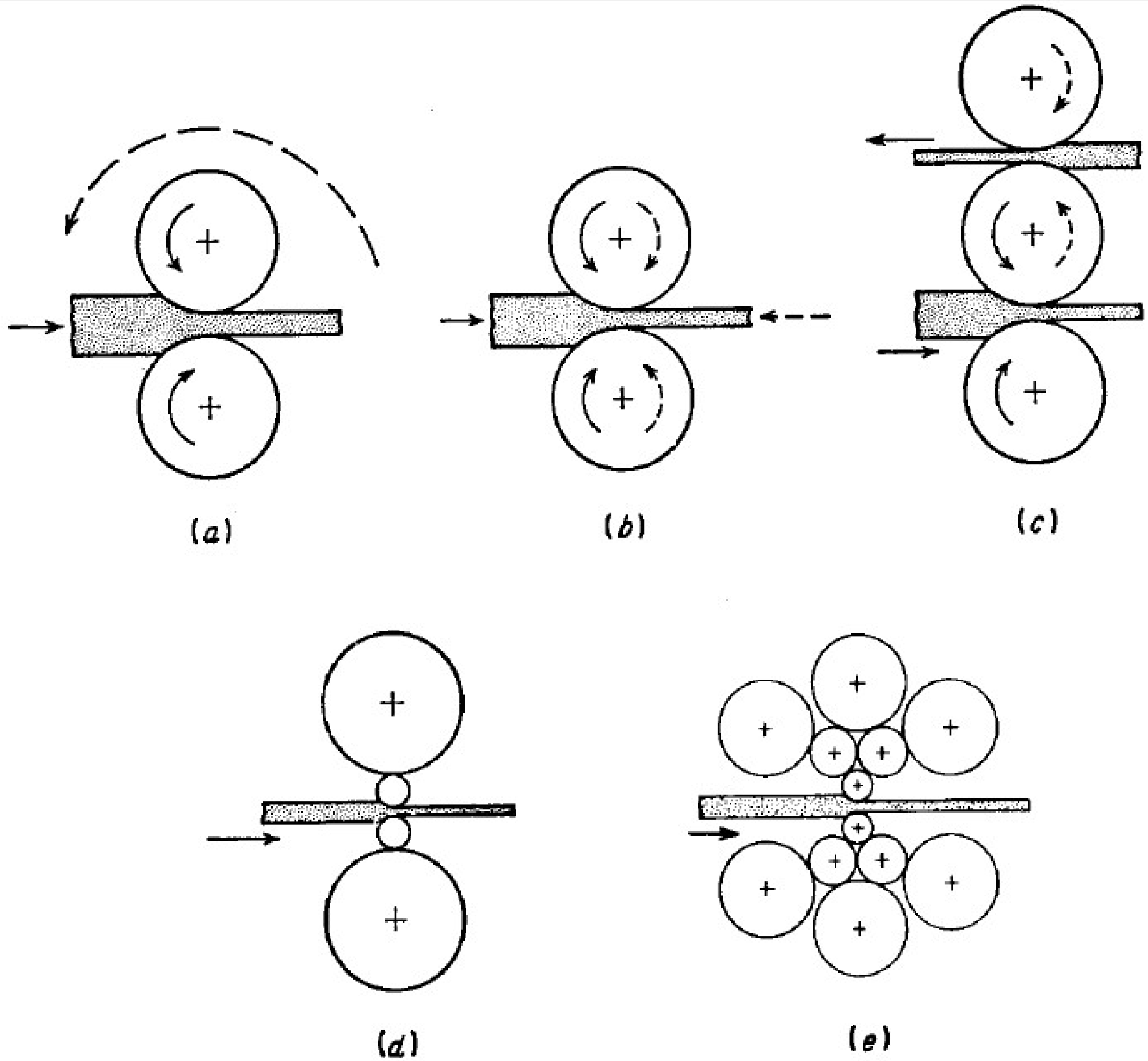
A rolling mill consist of basically of rolls, bearings, a housing for containing these parts and a drive for applying power to the rolls and controlling their speed.

The force involved during rolling are in MN range.

Very rigid construction is needed and very large motors are required to provide necessary powers.



Rolling Mills

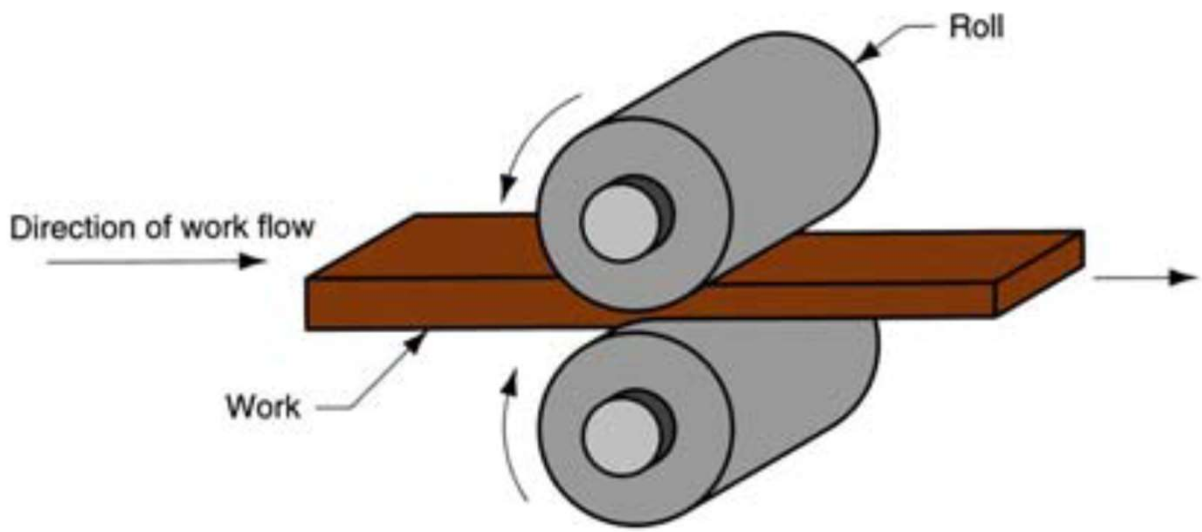


(a) two-high Pullover; (b) Two-high Reversing; (c) Three high; (d) Four high & (e) Cluster

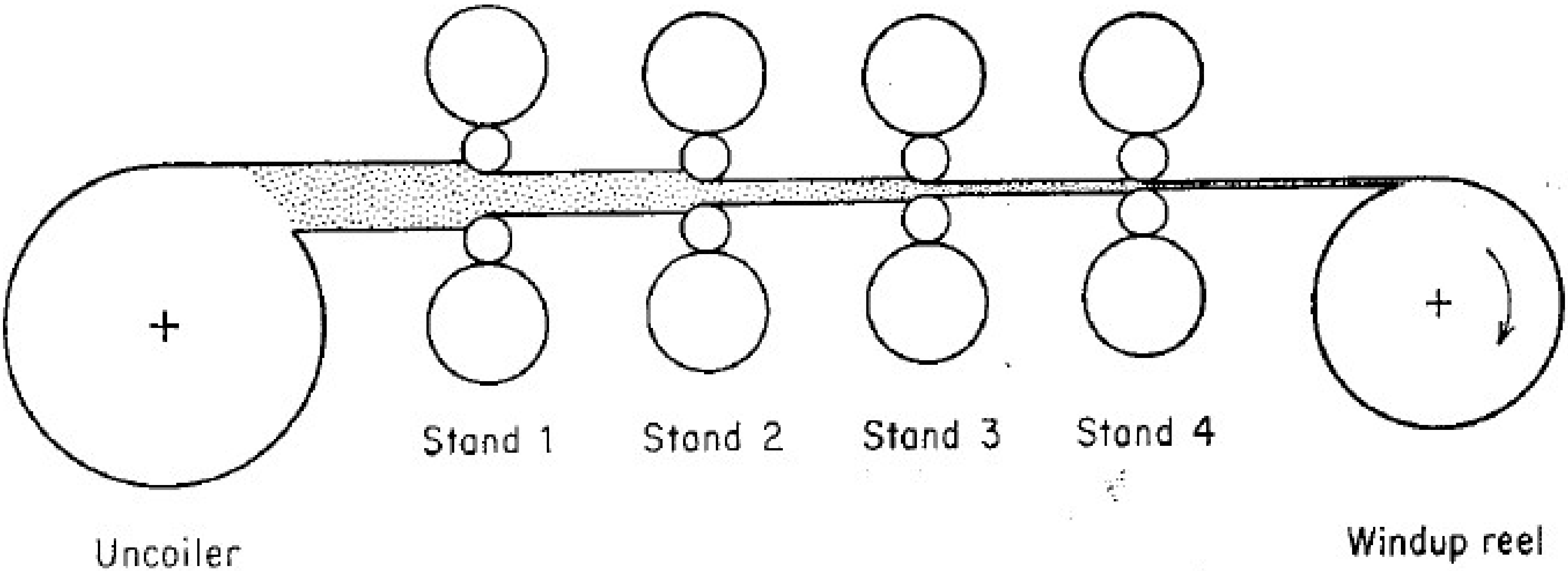
Rolling Mills

A machine used for rolling metal is called rolling mill.

A typical rolling mill consists of a pair of rolls driven by an electric motor transmitting a torque through a gear and pair of cardans. The rolls are equipped with bearings and mounted in a stand with a screw-down mechanism

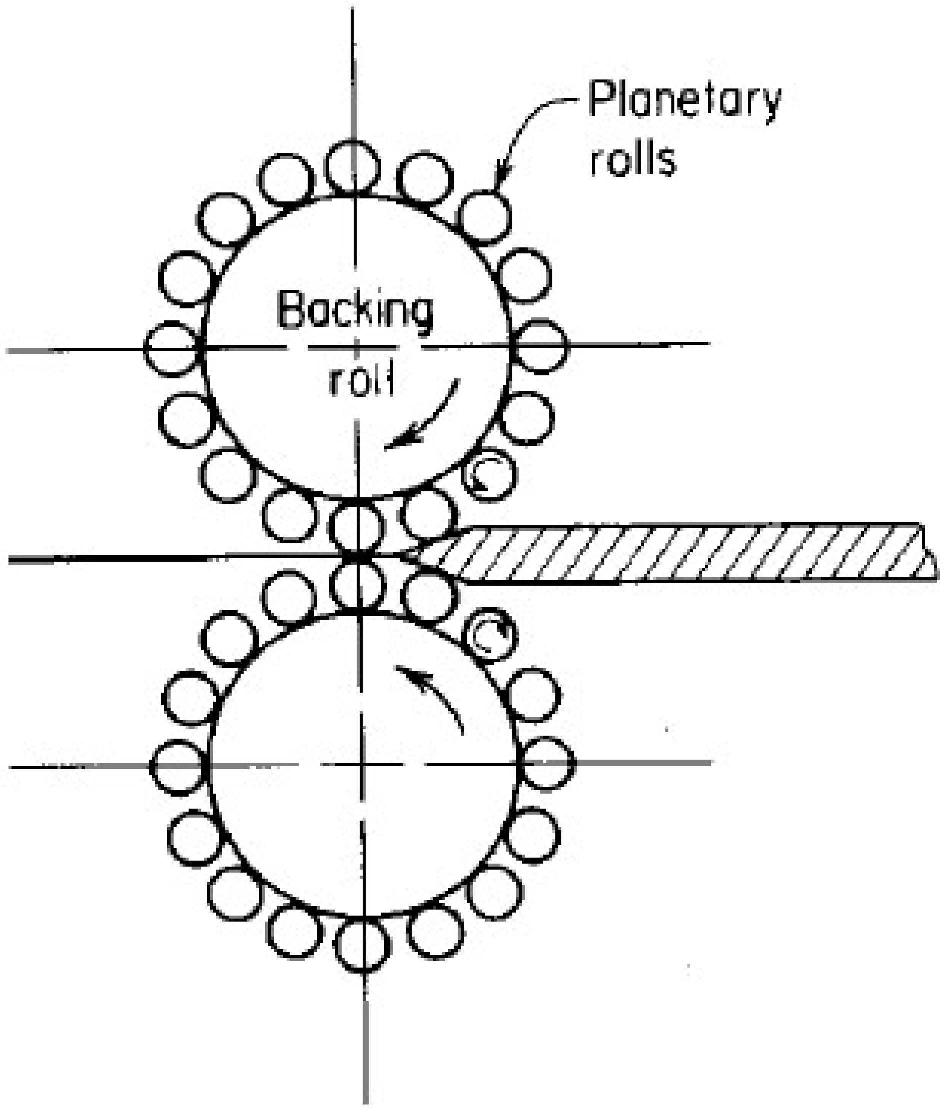


Rolling Mills



Schematic drawing of strip rolling on a four-stand continuous mill

Rolling Mills



Arrangements of rolls in Planetary mills

Rolling of Shapes

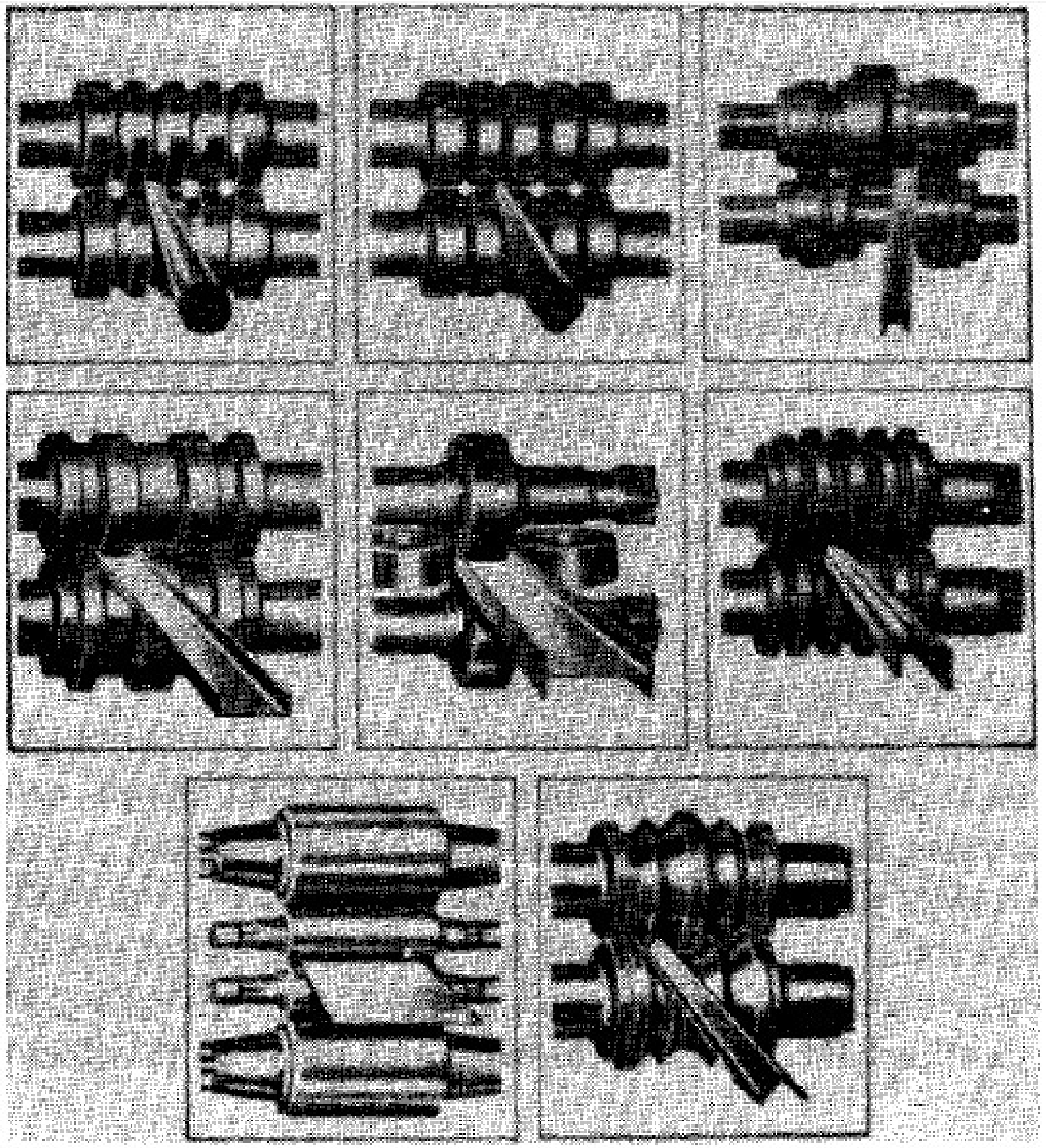
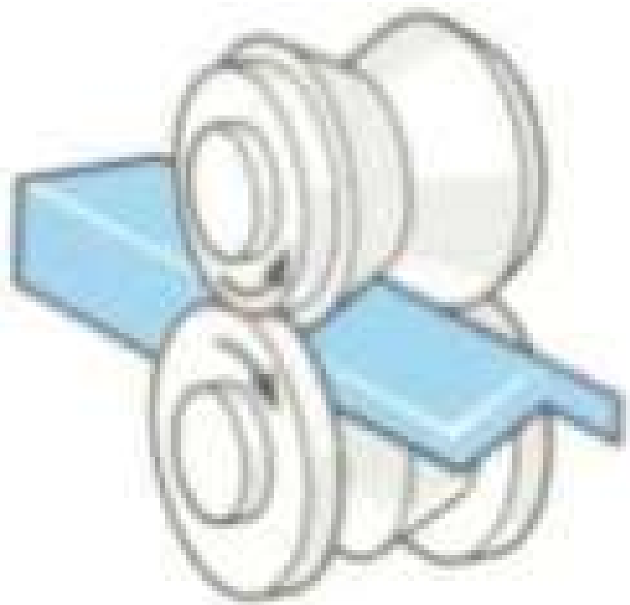
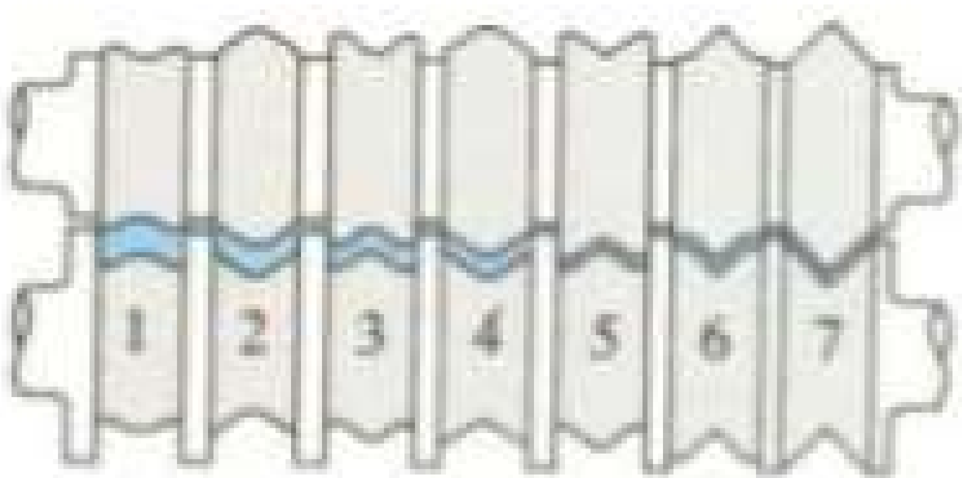


Figure 17-4 Rolling of bars and structural shapes. *(American Iron and Steel Institute.)*

Rolling of Shapes

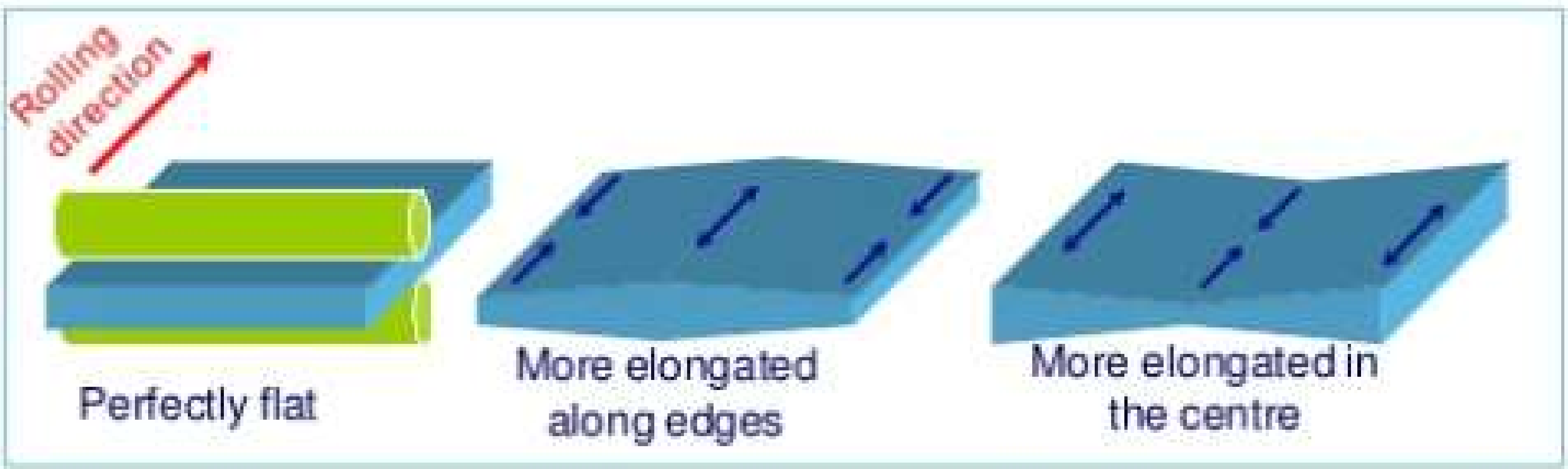




Rolling Defects

•The *roll gap* must be perfectly parallel to produce sheets/plates with equal thickness at both ends.

•The rolling speed is very sensitive to *flatness*. A difference in elongation of one part in 10,000 between different locations in the sheet can cause waviness.



Rolling Defects

Defects in rolling may be either surface or structural defects:
Surface defects include scale and roll marks.

Structural defects include:
Wavy edges: bending of the rolls causes the sheet to be thinner at the edges, which tend to elongate more. Since the edges are restricted by the material at the center, they tend to wrinkle and form wavy edges.

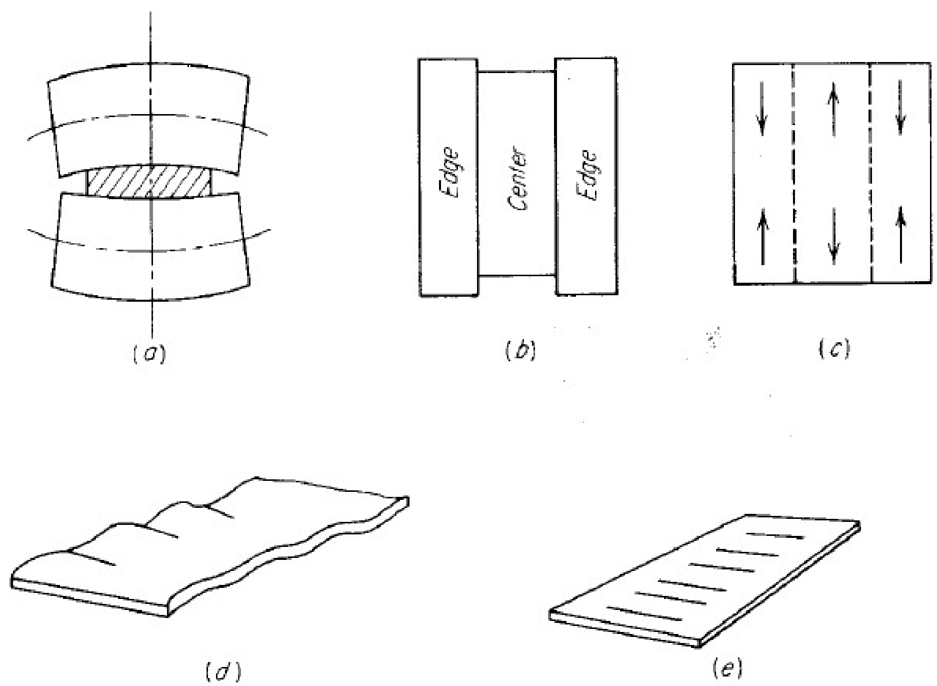


Figure 17-9 Consequences of roll bending to produce long edge.

Rolling Defects

Center and edge cracks: caused by low material ductility and barreling of the edges.

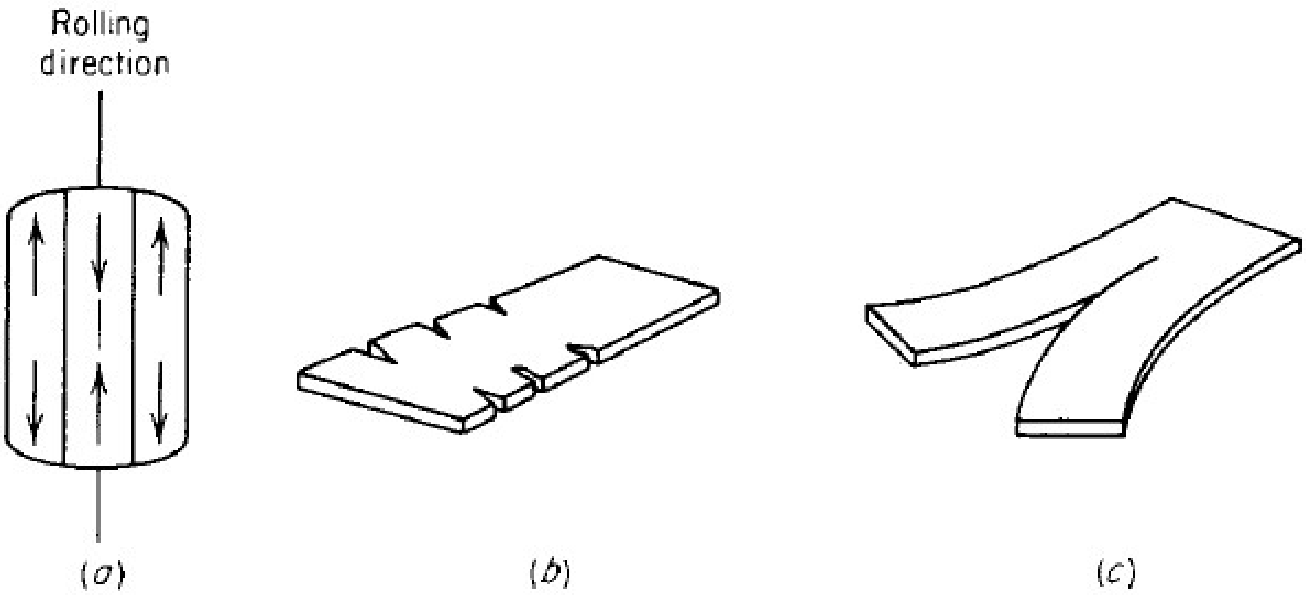


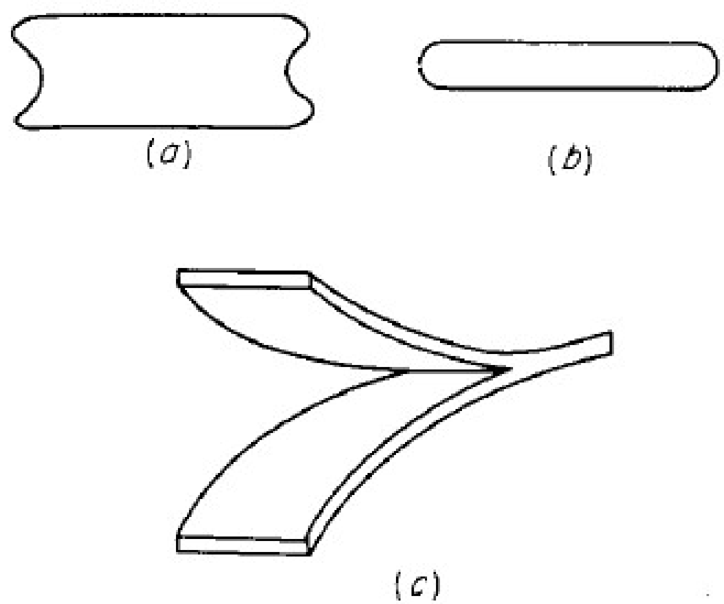
Figure 17-10 Defects resulting from lateral spread.

Rolling Defects

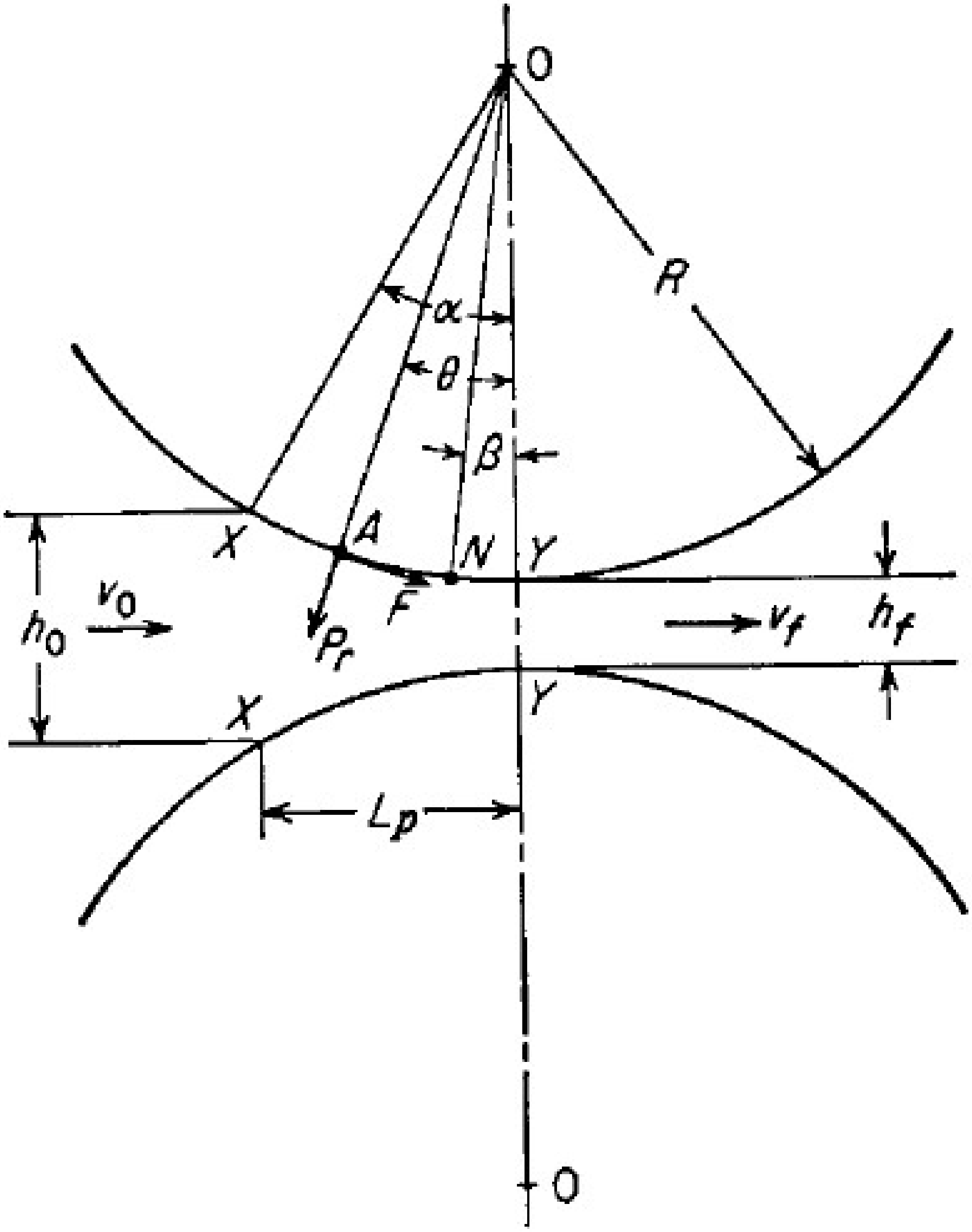
Alligatoring: results from inhomogeneous deformation or defects in the original cast ingots.

This defect always occurs when the ratio of slab thickness to the length of contact fall within the range of 1.4 to 1.65

Other defects may includes residual stresses



Analysis of Rolling



P_r → Radial Force

P → vertical component of P_r is called Rolling Load also called separating force (from force exerted by metals)

F → Tangential Frictional Force

H_o → Initial Thickness

H_f → Final thickness

V_o → Entrance Velocity

V_f → Exit Velocity

L_p → projected length

R → Radius of Roll

α → Contact Angle

N → Neutral point / No Slip Point

Analysis of Rolling

Specific Rolling Pressure (p)

Rolling load divided by the contact area

The contact area between the metal and rolls is equal to the product of the width of the sheet and the Projected length of the arc of the contact L_p

$$L_p = \left[R(h_0 - h_f) - \frac{(h_0 - h_f)^2}{4} \right]^{1/2} \approx \left[R(h_0 - h_f) \right]^{1/2}$$

Therefore, the specific roll pressure is given by

$$p = \frac{P}{bL_p}$$

Analysis of Rolling

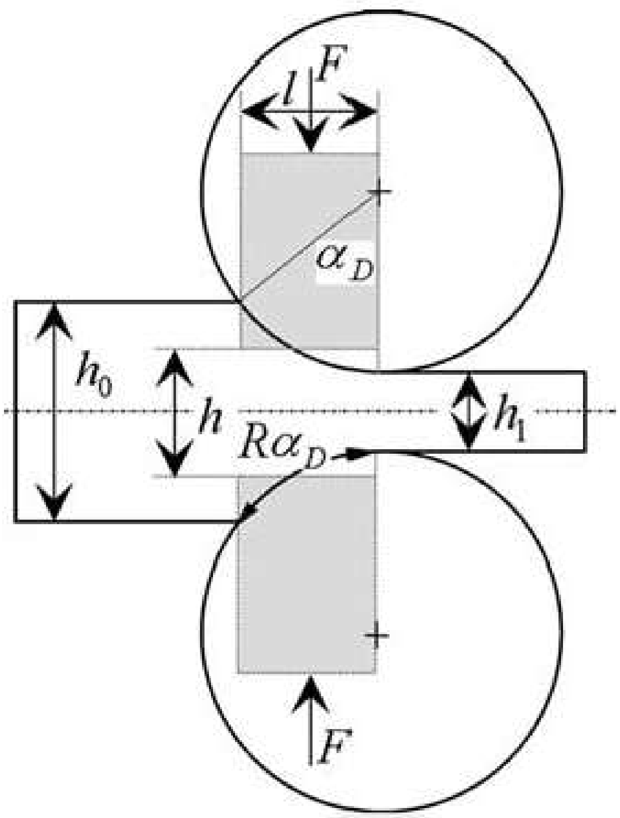


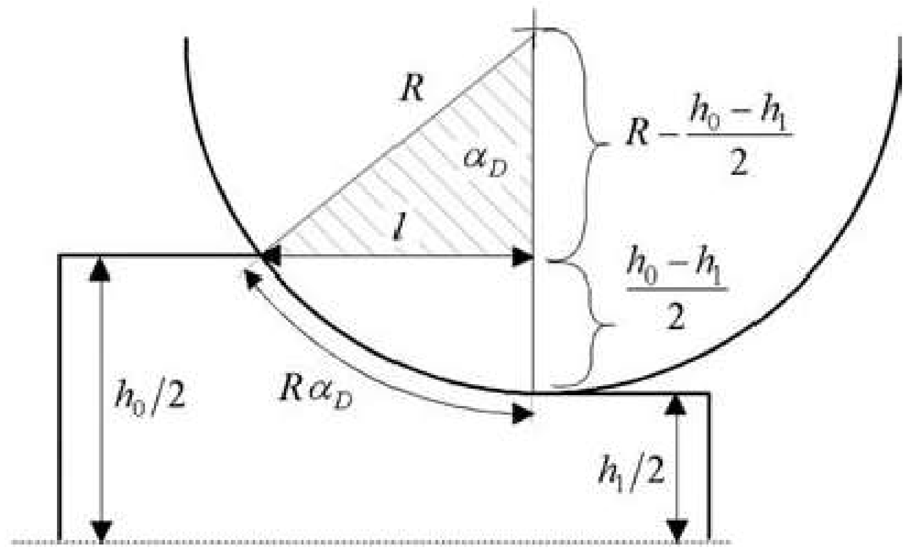
Figure 20.2. Rolling considered as equivalent to plane strain compression to deduce a rolling load formula.

Analysis of Rolling

20.4 Length of the Projected Arc of Contact

The formula for the rolling load, eq. 20-5, which was developed earlier in this chapter, shows that the rolling load depends strongly on the projected length of the arc of contact. In the literature,[1] it is sometimes recommended to replace this length l with the real length of the arc of contact, $R\alpha_D$, which has a somewhat higher value than l, and therefore provides a higher estimate of the rolling load; see eq. 20-6.

Figure 20.6. Geometrical relationship in rolling.

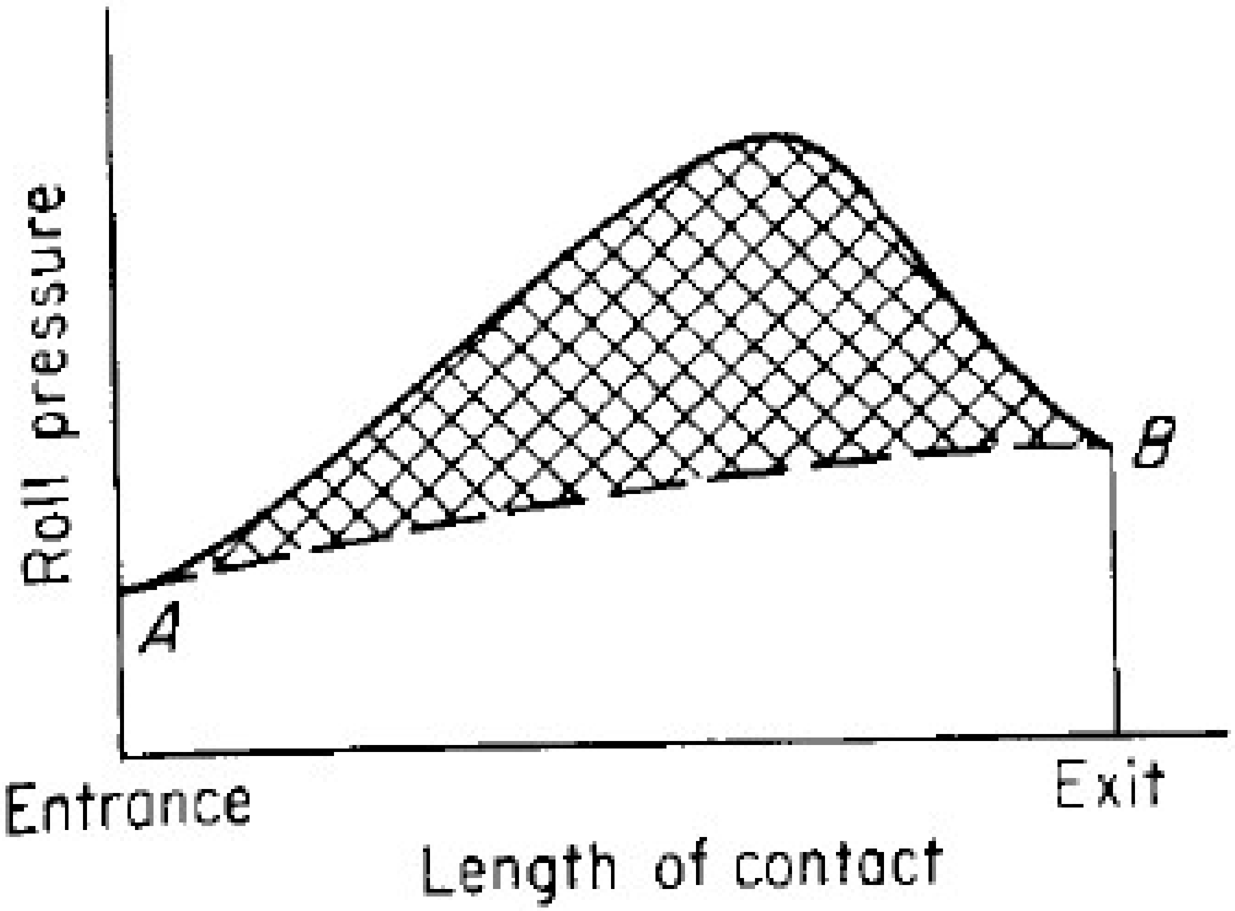


of contact, the following approximate formula can be used (see Example 20.2):

$$l \approx \sqrt{R(h_0 - h_1)} = \sqrt{R\,\Delta h} \qquad (20\text{-}16)$$

1. Altan, T., Oh, S.-I., and Gegel, H. L.: "Metal Forming, Fundamentals and Applications," ASM Int., Metals Park, Ohio, 1983, pp. 253–254.

Analysis of Rolling



Distribution of Specific Rolling Pressure (*p)* along the arc of contact

Analysis of Rolling

Example Determine the maximum possible reduction for cold-rolling a 300 mm-thick slab when $\mu = 0.08$ and the roll diameter is 600 mm. What is the maximum reduction on the same mill for hot rolling when $\mu = 0.5$?

Analysis of Rolling

Example Determine the maximum possible reduction for cold-rolling a 300 mm-thick slab when $\mu = 0.08$ and the roll diameter is 600 mm. What is the maximum reduction on the same mill for hot rolling when $\mu = 0.5$?

$$\tan \theta_{\max} = \mu \qquad \alpha = \theta_{\max} = \tan^{-1}(0.08) = 4.6^\circ$$

From Fig. 17-5 $\sin \alpha = L_p/R = \sqrt{R\Delta h}/R$, $\Delta h = 1.91$ mm. Note that the same result would be obtained from Eq. (17-5).

$$(\Delta h)_{\max} = \mu^2 R = (0.08)^2(300) = 1.92 \text{ mm}$$

For hot rolling

$$(\Delta h)_{\max} = (0.5)^2(300) = 75 \text{ mm}$$