Unit Two: Principles Rolling Processes

1.1.Hot Rolling

Rolling is the most rapid method of forming metal into desired shapes by plastic deformation through compressive stresses using two or more than two rolls. It is one of the most widely used of all the metal working processes. *The main objective of rolling is to convert larger sections such as ingots into smaller sections*. The coarse structure of cast ingot is convened into a fine-grained structure using rolling process as shown in Fig. 3.1. Hot rolling process is being widely used in the production of large number of useful products such as rails, sheets, structural sections, plates etc.

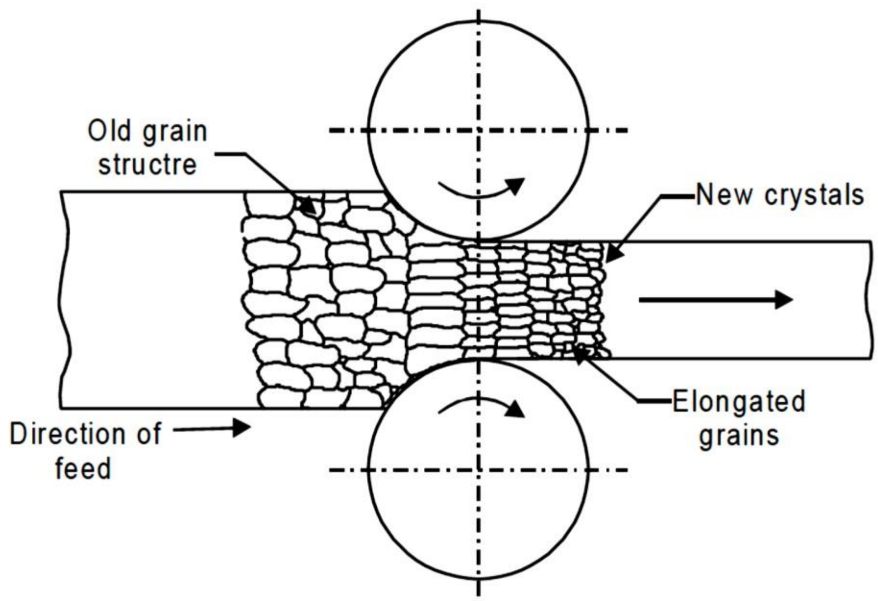


Fig. 3.1 Grain refinement in hot rolling process

1.2.Hot Rolling Mills Types

1. **Two-High Rolling Mill:** A two-high rolling mill has two horizontal rolls revolving at the same speed but in opposite direction. The rolls are supported on bearings housed in sturdy upright side frames called stands. The space between the rolls can be adjusted by raising or 1owering the upper roll.
2. **Three-High Rolling Mills:** It consists of three parallel rolls, arranged one above the other. The directions of rotation of the upper and lower rolls are the same but the intermediate roll rotates in a direction opposite to both of these.

3. **Four-High Rolling Mill:** It is essentially a two-high rolling mill, but with small sized rolls. Practically, it consists of four horizontal rolls, the two middle rolls are smaller in size than the top and bottom rolls.
4. **Cluster Mill:** It is a special type of four-high rolling mill in which each of the two smaller working rolls are backed up by two or more of the larger back-up rolls for rolling hard thin materials

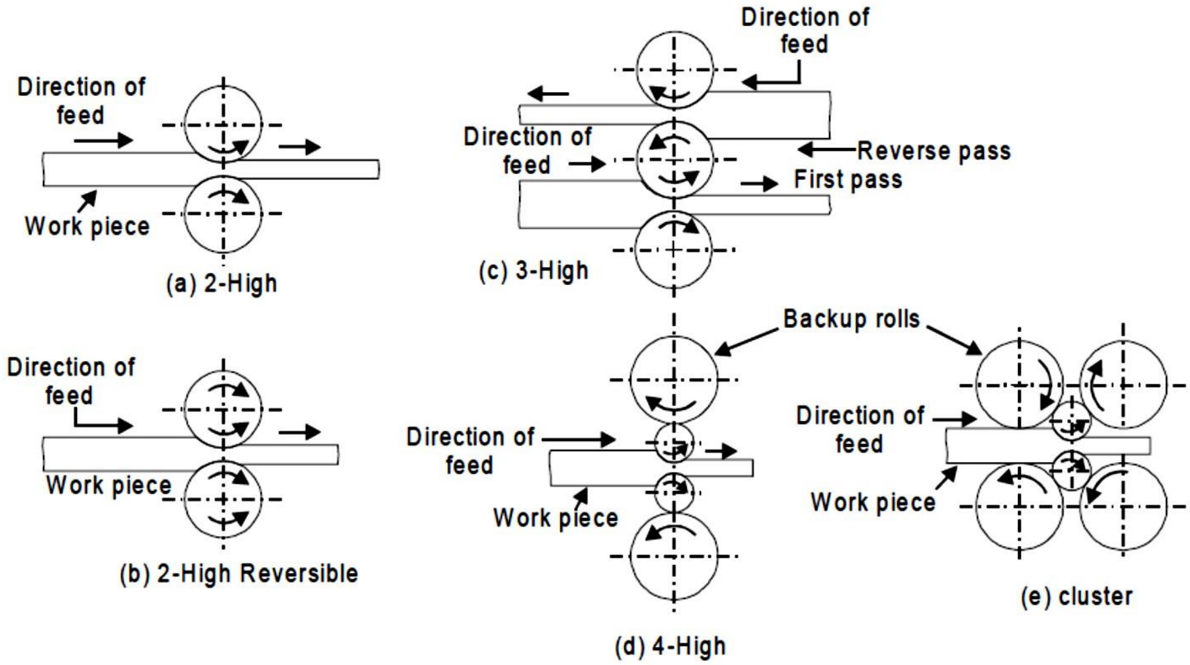
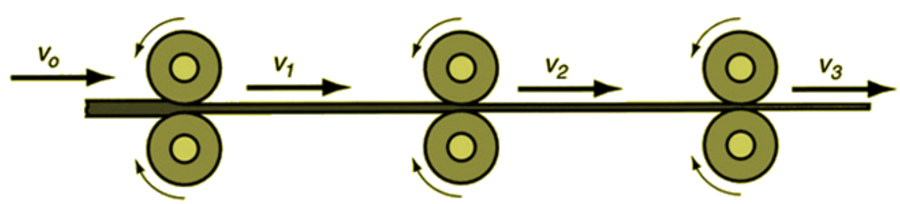


Fig. 3.2 Hot rolling stand arrangements

5. **Continuous (Tandem) Rolling Mill:** It consists of a number of non-reversing two-high rolling mills arranged one after the other, so that the material can be passed through all of them in sequence. It is suitable for mass production work only, because for smaller quantities quick changes of set-up will be required and they will consume lot of time and labor.



Tandem Rolling Mill

1.3.Shape Rolling

Shape rolling of steels is a process which requires a lot of heat and a lot of force. Reheating is carried out to around 1200°C and then the metal is continuously fed through rollers to draw the desired dimensions. Popular shapes have good application in the construction business as I, H, and U shaped beams or girders can be produced for structural integrity.

Steel is a strong material that is highly resistant to shaping at normal temperatures, but this resistance lessens considerably at higher tempertures. For that reason, the billets, blooms and slabs from the steelmaking process are shaped into basic products at carefully controlled elevated temperatures.

The method that is most used for shaping is to heat the steel to around 1,200°C in a reheat furnace and roll the steel, squeezing it between sets of cylinders or rolls. Rolls are arranged in pairs and housed in a 'stand'.

For long products, a series of specially shaped and angled rolls (referred to as stands) are used to transform the section to the required shape. The figure shows the stand used to create open sections.

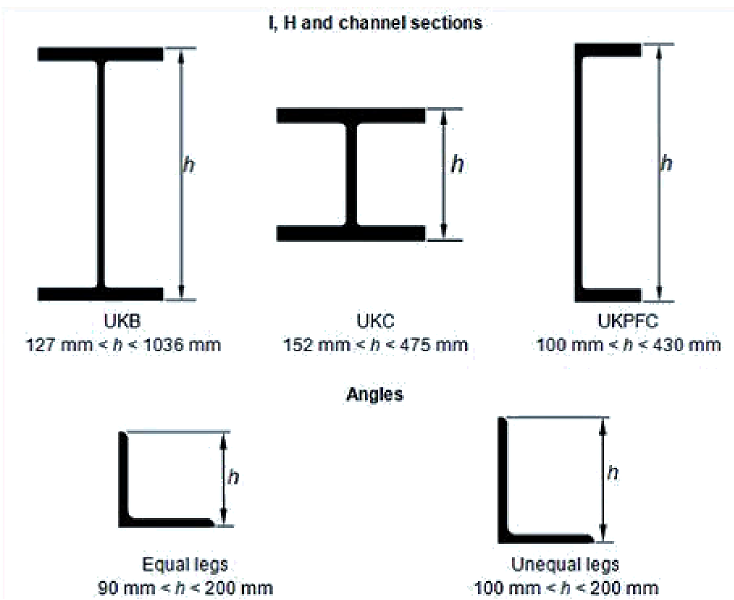


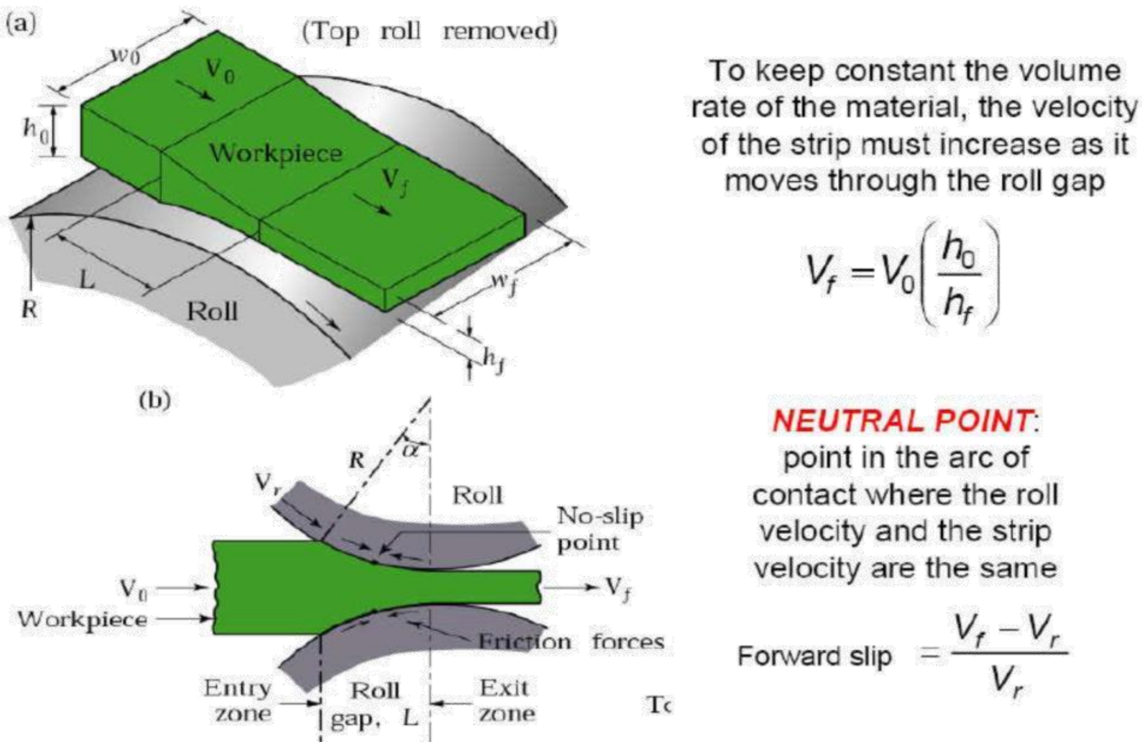
Figure 1: Standard open sections

1.4.Flat Rolling Analysis:

the volume of metal exiting the rolls equals the volume entering.

$$h_\circ w_\circ L_\circ = h_f w_f L_f$$

w_o and w_f are the *width* before and after work, mm



Draft thickness (d)

$$d = h_\circ - h_f = 2R\,(1-\cos\alpha)$$

h_o= starting thickness, mm (in); and
h_f= final thickness, mm (in).
R = roll radius in mm
(α) = bite angle in degree.

The maximum draft (dmax)

$$d_{max} = \mu^2 R$$

coefficient of friction, μ

Reduction (r)

$$r = \frac{d}{h_\circ}$$

Contact length (L)

$$L = \sqrt[2]{R(h_\circ - h_f)}$$

True strain (ε)

$$\varepsilon = \ln \frac{h_\circ}{h_f}$$

Average flow stress (Yf)

$$\overline{Y_f} = \frac{K\varepsilon^n}{1+n}$$

K and n: (strength and strain hardening)

Roll force in flat rolling:

$$F = \overline{Y_f}\ w\ L$$

The torque in rolling

$$T = 0.5FL$$

The power

$$\text{Power (in Kw)} = \frac{2\pi FLN}{60000}$$

F is in newtons,

L is in meters, and

N is the revolutions per minute (rpm)

Ex: A 300-mm-wide strip 25-mm thick is fed through a rolling mill with two powered rolls each of radius = 250 mm. The work thickness is to be reduced to 22 mm in one pass at a roll speed of 50 rev/min. The work material has a flow curve defined by K = 275 MPa and n = 0.15, and the coefficient of friction between the rolls and the work is assumed to be 0.12. Determine if the friction is sufficient to permit the rolling operation to be accomplished. If so, calculate the roll force, torque, and power.

Solution:

The draft attempted in this rolling operation is

$$d = h_\circ - h_f$$

$$d = 25 - 22 = 3mm$$

Maximum draft

$$d_{max} = \mu^2 R$$

$$d_{max} = (0.12)^2(250) = 3.6mm$$

The contact length

$$L = \sqrt[2]{R(h_\circ - h_f)} \quad L = \sqrt[2]{250(25-22)} = 27.4 \text{ mm}$$

$$\varepsilon = \ln\frac{h_\circ}{h_f}$$

$$\varepsilon = \ln\frac{25}{22} = 0.128$$

$$\bar{Y_f} = \frac{275X0.128^{0.15}}{1+0.15} = 175.7 \text{ MPa}$$

Rolling force is determined

$$F = \bar{Y_f}\ w\ L \qquad F = 175.7(300)(27.4) = 1{,}444{,}254 \text{ N}$$

Torque required to drive each roll

$$T = 0.5FL \qquad T = 0.5(1{,}444{,}254)(27.4)(10^{-3}) = 19.786 \text{ N-m}$$

Power:

$$\text{Power (in Kw)} = \frac{\mathbf{2\pi FLN}}{\mathbf{60000}}$$

$$\text{Power (in Kw)} = \frac{2\pi X1.444.786X0.274X50}{60000} = 207.284 \text{ Kw}$$

Questions:

1. Two thick slabs of 300mm each, the first one is used in cold rolling where μ=0.08 while the second is used in cold rolling where μ=0.5. The mill roll diameter in each case is the same as 600mm. Determine the max draft (reduction) in both cases. Discuss the wide difference in results.
2. A tensile specimen of the metal of 100 mm is length stretched to a length = 157 mm during the rolling process. If the metal has a flow curve with parameters: K = 850 MPa and strain hardening exponent n = 0.30. Determine the average flow stress that the metal has been subjected to during the deformation.
3. During the rolling process the average flow stress is 20,000 lb/in^2, determine the amount of reduction in cross sectional area during the process (use n = 0.40 and K = 35,000 lb/in^2).
4. A plate of 270 mm wide and 25 mm thick from carbon steel. A two high rolling mill is used to reduce the thickness to 20 mm. Roll radius = 600 mm, and roll speed = 8 rpm. Strength coefficient = 500 MPa, and strain hardening exponent = 0.25. Determine (a) roll force, (b) roll torque, and (c) power required to perform the operation.

YouTube: https://youtu.be/Kq86U1-PvCQ