09 Rolling

Rolling: is a deformation process in which the thickness of the work is reduced by compressive forces exerted by two opposing rolls. The rolls rotate as illustrated in Figure 9.1 to pull and simultaneously squeeze the work between them.

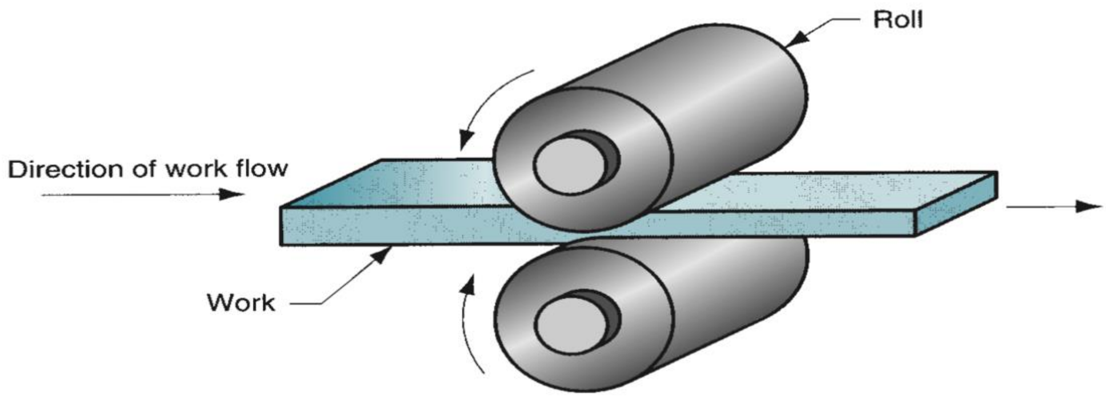

Figure 9.1 The rolling process

The basic process shown in our figure is flat rolling, used to reduce the thickness of a rectangular cross section. A closely related process is shape rolling, in which a square cross section is formed into a shape such as an I-beam.

Most rolling processes are very capital intensive, requiring massive pieces of equipment, called rolling mills, to perform them. The high investment cost requires the mills to be used for production in large quantities of standard items such as sheets and plates.

Most rolling is carried out by hot working, called hot rolling, owing to the large amount of deformation required.

Hot-rolled metal is generally free of residual stresses, and its properties are isotropic.

Disadvantages of hot rolling are that the product cannot be held to close tolerances, and the surface has a characteristic oxide scale.

The work starts out as a cast steel ingot that has just solidified.

While it is still hot, the ingot is placed in a furnace where it remains for many hours until it has reached a uniform temperature throughout, so that the metal will flow consistently during rolling.

For steel, the desired temperature for rolling is around 1200°C.

The heating operation is called soaking, and the furnaces in which it is carried out are called soaking pits.

From soaking, the ingot is moved to the rolling mill, where it is rolled into one of three intermediate shapes called blooms, billets, or slabs.

A bloom has a square cross section 150 mm × 150 mm or larger.

A slab is rolled from an ingot or a bloom and has a rectangular cross section of width 250 mm or more and thickness 40 mm or more.

A billet is rolled from a bloom and is square with dimensions 40 mm on a side or larger.

These intermediate shapes are subsequently rolled into final product shapes.

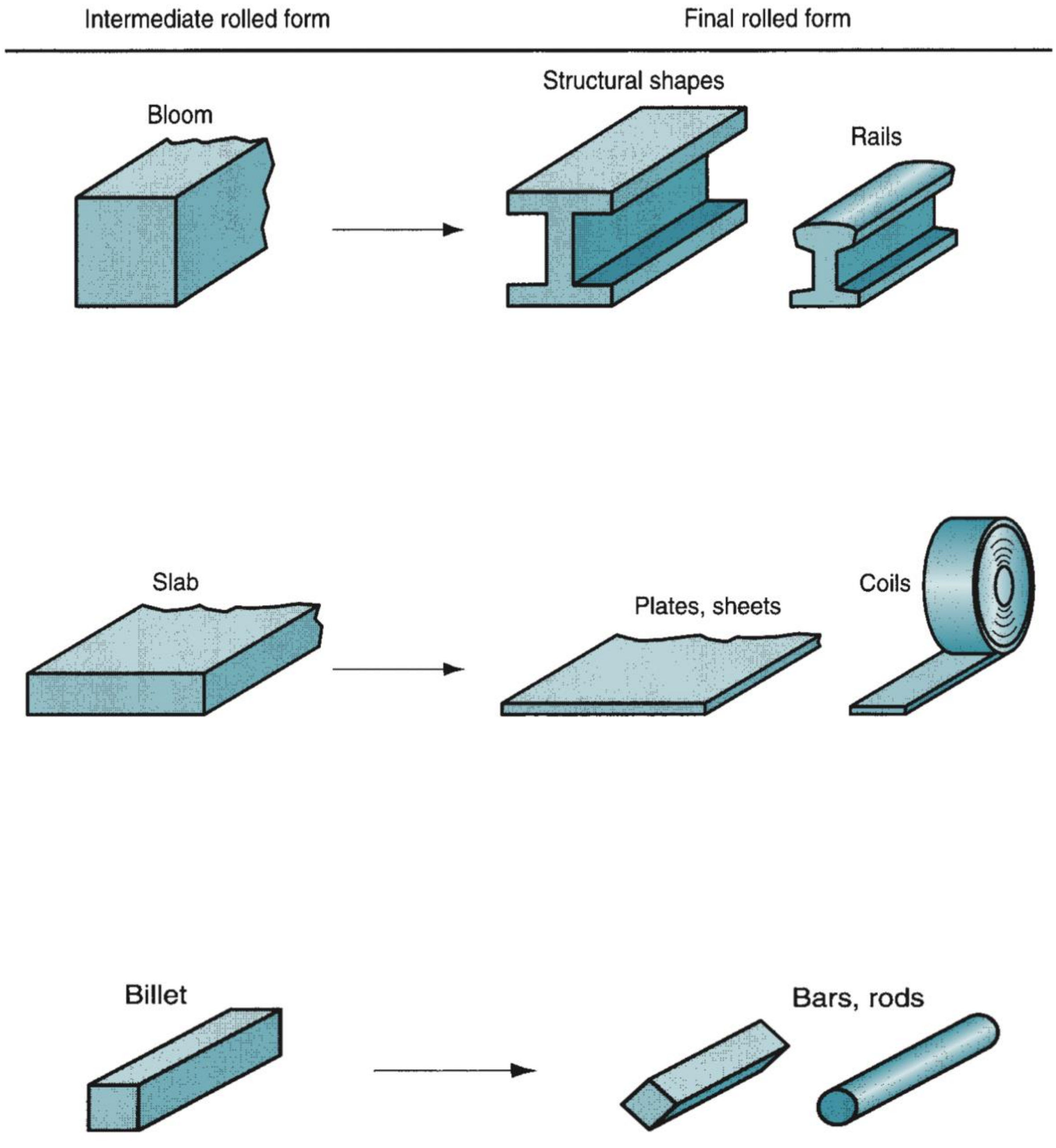

Figure 9.2 Some of the steel products made in a rolling mill.

Blooms are rolled into structural shapes and rails for railroad tracks.

Billets are rolled into bars and rods.

Slabs are rolled into plates, sheets, and strips.

Hot-rolled plates are used in shipbuilding, bridges, boilers, welded structures for various heavy machines, tubes and pipes, and many other products.

sheets are often accomplished by cold rolling, in order to prepare them for subsequent sheet metal operations.

Cold rolling strengthens the metal and permits a tighter tolerance on thickness.

In addition, the surface of the cold-rolled sheet is absent of scale.

These characteristics make cold-rolled sheets, strips, and coils ideal for stampings, exterior panels, and other parts of products ranging from automobiles to appliances and office furniture.

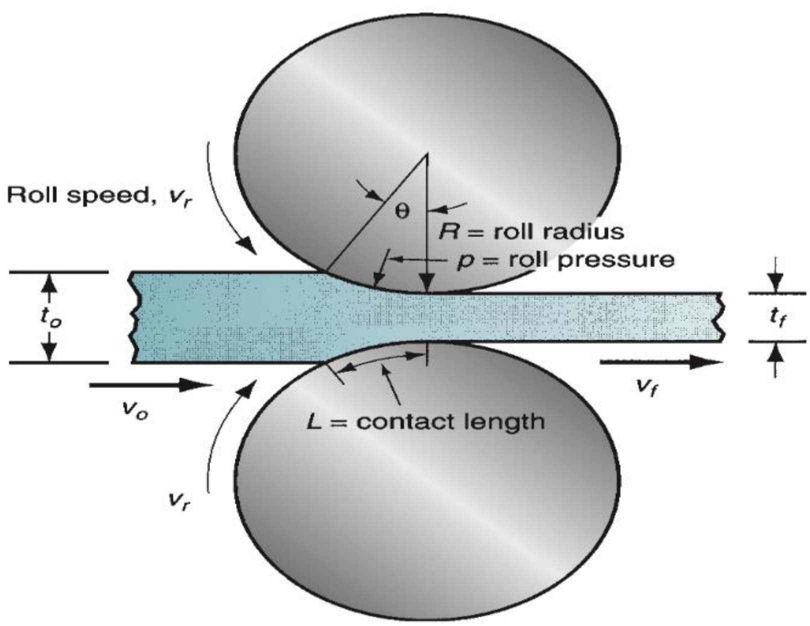

Figure 9.3 Side view of flat rolling, indicating before and after thicknesses, work velocities, angle of contact with rolls, and other features.

The draft d (mm), can be defined as follows:

$$d = t_o - t_f$$

Where t_o = initial thickness, and t_f = final thickness.

There is a limit to the maximum possible draft that can be accomplished in flat rolling with a given coefficient of friction, defined by:

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

Where d_{max} = maximum draft (mm), μ = coefficient of friction between the rolls and the work, and R = roll radius (mm).

Contact length L (mm) can be approximated by:

$$L = \sqrt{R(t_o - t_f)}$$

The true strain experienced by the work in rolling is based on before and after stock thicknesses. In equation form,

$$\epsilon = ln\frac{t_o}{t_f}$$

Where ϵ = true strain.

The true strain can be used to determine the average flow stress $\overline{Y_f}$ applied to the work material in flat rolling:

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

Where $\overline{Y_f}$ = flow stress (N/mm^2), K = strength coefficient (N/mm^2), ϵ = true strain, and n = the strain-hardening exponent.

The average flow stress is used to compute estimates of force and power in rolling.

Rolling force can be calculated as follows:

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

Where $\overline{Y_f}$ = flow stress (N/mm^2), and the product wL is the roll-work cantact area (mm^2).

The torque in rolling can be estimated as follows:

$$T = 0.5\ F\ L$$

Example 9.1

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. The work material has a flow curve defined by K = 275 N/mm^2 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, and torque.

Solution:

The draft attempted in this rolling operation is:

d = 25 - 22 = 3 mm

The maximum possible draft for the given coefficient of friction is:

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

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

Since the maximum allowable draft exceeds the attempted reduction, the rolling operation is feasible.

To compute rolling force, we need the contact length L and the average flow stress $\overline{Y_f}$. The contact length is given by:

$$L = \sqrt{R(t_o - t_f)} \qquad L = \sqrt{250(25-22)} = 27.4mm$$

$\overline{Y_f}$ is determined from the true strain:

$$\epsilon = ln\frac{t_o}{t_f} \qquad \epsilon = ln\frac{25}{22} = 0.128$$

$\overline{Y_f} = \dfrac{K\epsilon^n}{1+n}$ $\overline{Y_f} = \dfrac{275(0.128)^{0.15}}{1+0.15} = 175.7\ N/mm^2$

Rolling force is determined from:

$F = \overline{Y_f}\ w\ L$ $F = 175.7\ (300)\ (27.4) = 1445\ kN$

Torque required to drive each roll is given by:

$T = 0.5\ F\ L$

$T = 0.5\ (1445)\ (27.4 \times 10^{-3}) = 19.7\ kN.m$