Flat- and Shape-Rolling Processes

Figure 13.1 Schematic outline of various flat- and shape-rolling processes. Source: American Iron and Steel Institute.
Figure 13.2 (a) Schematic illustration of the flat-rolling process. (b) Friction forces acting on strip surfaces. (c) The roll force, $F$, and the torque acting on the rolls. The width $w$ of the strip usually increases during rolling, as is shown in Fig. 13.5.
Figure 13.3 Schematic illustration of a four-high rolling-mill stand, showing its various features. The stiffnesses of the housing, the rolls, and the roll bearings are all important in controlling and maintaining the thickness of the rolled strip.
Figure 13.4  (a) Bending of straight cylindrical rolls, caused by the roll force.  (b) Bending of rolls ground with camber, producing a strip with uniform thickness.
Figure 13.5  Increase in the width (spreading) of a strip in flat rolling (see also Fig. 13.2a). Similarly, spreading can be observed when dough is rolled with a rolling pin.
Grain Structure During Hot Rolling

Figure 13.6 Changes in the grain structure of cast or of 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 casting are converted to a wrought structure by hot working.
Roller Leveling and Defects in Flat Rolling

Figure 13.7 A method of roller leveling to flatten rolled sheets. See also Fig 15.22.

Figure 13.8 Schematic illustration of typical defects in flat rolling: (a) wavy edges; (b) zipper cracks in the center of the strip; (c) edge cracks; and (d) alligating.
Residual Stresses in Rolling

Figure 13.9  (a) Residual stresses developed in rolling with small rolls or at small reductions in thickness per pass. (b) Residual stresses developed in rolling with large rolls or at high reductions per pass. Note the reversal of the residual stress patterns.
Figure 13.10 A general view of a rolling mill. 
Source: Inland Steel.
Figure 13.11 Schematic illustration of various roll arrangements: (a) two-high; (b) three-high; (c) four-high; (d) cluster (Sendzimir) mill.
Figure 13.12 A tandem rolling operation.
Shape Rolling

Figure 13.13 Stages in the shape rolling of an H-section part. Various other structural sections, such as channels and I-beams, are also rolled by this kind of process.
Figure 13.14  (a) Schematic illustration of a ring-rolling operation. Thickness reduction results in an increase in the part diameter. (b) Examples of cross-sections that can be formed by ring rolling.
Thread-rolling processes: (a) and (c) reciprocating flat dies; (b) two-roller dies. Threaded fasteners, such as bolts, are made economically by these processes, at high rates of production.

Figure 13.16 (a) Features of a machined or rolled thread. (b) Grain flow in machined and rolled threads. Unlike machining, which cuts through the grains of the metal, the rolling of threads causes improved strength, because of cold working and favorable grain flow.
Mannesmann Process

Figure 13.17 Cavity formation in a solid round bar and its utilization in the rotary tube piercing process for making seamless pipe and tubing. (The Mannesmann mill was developed in the 1880s.)
Figure 13.18
Schematic illustration of various tube-rolling processes: (a) with fixed mandrel; (b) with moving mandrel; (c) without mandrel; and (d) pilger rolling over a mandrel and a pair of shaped rolls. Tube diameters and thicknesses can also be changed by other processes, such as drawing, extrusion, and spinning.
Spray Casting (Osprey Process)

Figure 13.19 Spray casting (Osprey process), in which molten metal is sprayed over a rotating mandrel to produce seamless tubing and pipe. Source: J. Szekely, *Scientific American*, July 1987.