Metal Rolling Processes and Equipment

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Chapter 13
Rolling

- The process of reducing the thickness or changing the cross section of a long workpiece by compressive forces applied through a set of rolls.
Flat-Rolling Process

- **FIGURE 13.2** (a) Schematic illustration of the flat-rolling process. (b) Friction forces acting on strip surfaces. (c) Roll force, \( F \), and torque, \( T \), acting on the rolls. The width of the strip, \( w \), usually increases during rolling, as shown later in Fig. 13.5.
FIGURE 13.3  Schematic illustration of various roll arrangements: (a) four-high rolling mill showing various features. The stiffness of the housing, the rolls, and the roll bearings are all important in controlling and maintaining the thickness of the rolled strip; (b) two-high mill; (c) three-high mill; and (d) cluster (or Sendzimir) mill.
Strategies to reduce roll force

- Reducing friction at the roll-workpiece interface
- Using smaller diameter rolls to reduce the contact area
- Taking smaller reductions per pass to reduce the contact area
- Rolling at elevated temperatures to lower the strength of the material
- Applying front and/or back tensions to the strip
FIGURE 13.4  (a) Bending of straight cylindrical rolls caused by roll forces. (b) Bending of rolls ground with camber, producing a strip with uniform thickness through the strip width. Deflections have been exaggerated for clarity.
FIGURE 13.5 Spreading in flat rolling. Note that similar spreading can be observed when dough is rolled with a rolling pin.
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 castings are converted to a wrought structure by hot working.
Hot and Cold Rolling

- Hot Rolling leaves a rough mill scale on surface
- Remove HR mill scale by:
  - Acid etching ("pickling")
  - Water blasting
  - Grinding
- Cold Rolling produces sheets and strips with:
  - finer surface finish (absence of mill scale)
  - better dimensional tolerances
  - enhanced mechanical properties (due to strain hardening)
Pack Rolling

- Roll two or more sheets together
  - Improved productivity
- Aluminum sheets (aluminum foil)
  - Matte, satin side – foil-to-foil contact
  - Shiny, bright side – foil-to-roll contact due to high contact stresses with polished rolls
FIGURE 13.7  (a) A method of roller leveling to flatten rolled sheets.  
(b) Roller leveling to straighten drawn bars.
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) alligatoring.
FIGURE 13.9  (a) Residual stresses developed in rolling with small-diameter rolls or at small reductions in thickness per pass. (b) Residual stresses developed in rolling with large-diameter rolls or at high reductions per pass. Note the reversal of the residual stress patterns.
Gauge (Gage) Numbers

- Thickness of sheet is identified by gauge number
- The smaller the number, the thicker the sheet
- Several numbering systems are used, depending on type of sheet metal being classified (steel, copper, aluminum, etc.)
- Rolled sheets of non-ferrous material are also identified by thickness changes during rolling, such as $\frac{1}{4}$ hard, $\frac{1}{2}$ hard, etc.
FIGURE 13.11 An example of a tandem-rolling operation.
FIGURE 13.12  Steps in the shape rolling of an I-beam part. Various other structural sections, such as channels and rails, also are rolled by this kind of process.
FIGURE 13.13  Two examples of the roll-forging operation, also known as cross-rolling. Tapered leaf springs and knives can be made by this process. Source: After J. Holub.
FIGURE 13.14  (a) Production of steel balls by the skew-rolling process. (b) Production of steel balls by upsetting a cylindrical blank. Note the formation of flash. The balls made by these processes subsequently are ground and polished for use in ball bearings.
FIGURE 13.15  (a) Schematic illustration of a ring-rolling operation. Thickness reduction results in an increase in the part diameter. (b) through (d) Examples of cross sections that can be formed by ring rolling.
FIGURE 13.16  Thread-rolling processes: (a) and (b) reciprocating flat dies; (c) two-roller dies; (d) A collection of thread-rolled parts made economically at high production rates. 

Source: Courtesy of Tesker Manufacturing Corp.
FIGURE 13.17  (a) Features of a machined or rolled thread. Grain flow in (b) machined and (c) rolled threads. Unlike machining, which cuts through the grains of the metal, the rolling of threads imparts improved strength because of cold working and favorable grain flow.
FIGURE 13.18  Cavity formation in a solid, round bar and its utilization in the rotary tube piercing process for making seamless pipe and tubing. (See also Fig. 2.9.)
FIGURE 13.19  Schematic illustration of various tube-rolling processes: (a) with a fixed mandrel; (b) with a floating mandrel; (c) without a mandrel; and (d) pilger rolling over a mandrel and a pair of shaped rolls. Tube diameters and thicknesses also can be changed by other processes, such as drawing, extrusion, and spinning.
Rolling Summary

- Process of reducing thickness or changing cross section by compressive forces applied through a set of rolls
- CR or HR
- Rolling Mills may have a variety of roll configurations; three-high, tandem, etc.
- Continuous casting into semi-finished products has economic benefits
- Integrated mills are large, expensive facilities with complete sequence of rolling and forming activities. Minimills utilize scrap metal.