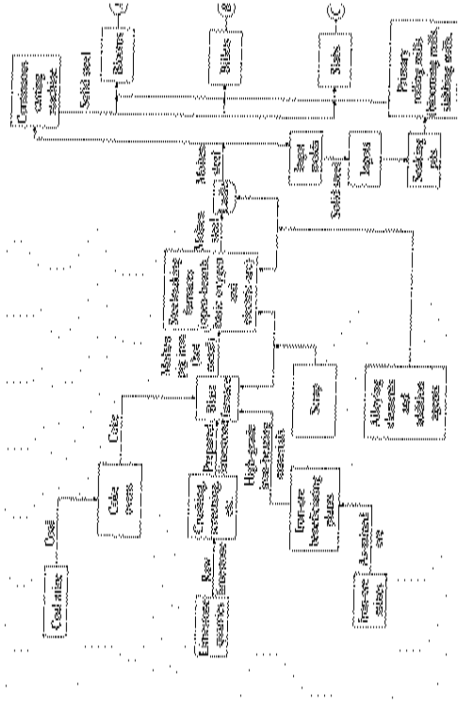
ROLLING THEORY AND PRACTICE

6.1.1 Introduction

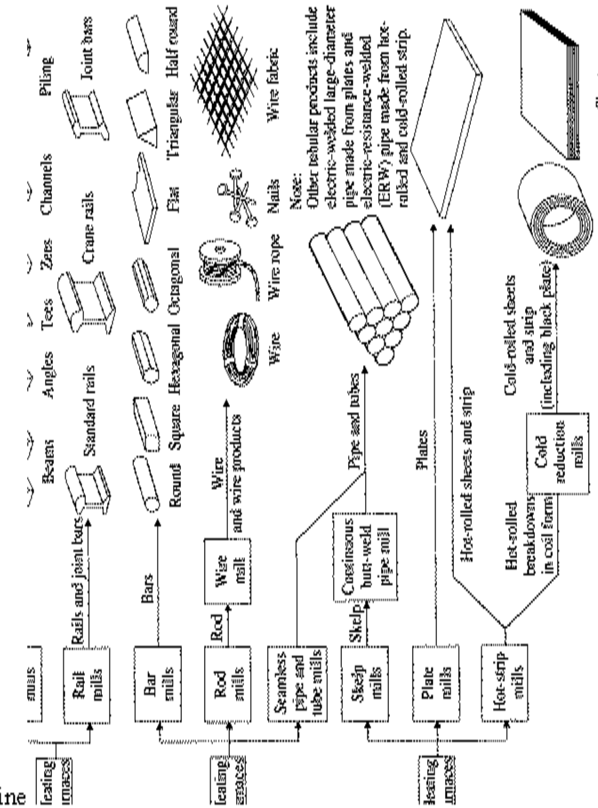
In the section on the classification of metalworking processes, they were classified as primary and secondary processes. The function of the primary processes is to provide the semifinished shapes that have the necessary configuration, dimensions, and properties that will be suitable for the subsequent, secondary processing whether by additional forming, welding, machining, heat treating, or whatever. The secondary metalworking processes are subsequent processes that will produce the final configuration of the desired part.

Since the term "primary" has the connotation of "first," hot rolling of a steel or an aluminum alloy to a slab or plate may be considered as the primary process for subsequent hot and cold rolling to sheets, which might provide the stock for a deep-drawing operation, for example. One simplification is to adopt the classification used by the process engineer of (1) originating process or operation and (2) the principal process or operation. The originating process is one that produces the general configuration of the workpiece. The originating process of a steel forging may be a hot-rolled bar, whereas the originating process for the machining of a connecting rod for an internal combustion engine may be either a forging or a nodular (ductile) cast-iron casting. The principal or main Process by which the connecting rod is produced would be metal cutting or "chining.

One very important primary metalworking process, that is used for both hot- and cold-working, is rolling. Rolling is a mechanical process whereby the Plastic deformation of the metal is achieved by passing it between rotating rolls. "the most widely used of all metalworking processes. About 90 percent of all **-Ut**



steel, aluminum, and copper produced annually in the world is rolled. It would be difficult to



6.1 Continued

imagine how our present-day society could exist without rollpri plates, sheets, bars, and structural shapes. The primary steelworking processe are those that are performed first to provide the semifinished shapes such as blooms, billets, slabs, plates, bars, structural shapes, etc., with acceptable mechanical properties, etc., for subsequent use in subsequent secondary processes or a series of processes.

An overall flow diagram showing the principal processes involved in convening raw materials into mill products is shown in Fig. 6.1. The steelmaking aspects of the overall process are discussed in other books, whereas the theory and practice of metalworking aspects are discussed here.

As can be seen from Fig. 6.1 all the semifinished shapes and many large tonnage products such as structural shapes, rails, bars, pipe, plates, hot-rolled sheets and strip are hot rolled. Some hot-rolled sheets in turn are pickled and otherwise processed and then cold rolled to produce cold-rolled sheet such as for automobile bodies and cans. The semifinished shapes, plates, and bars for nonferrous metals are also hot rolled; however, a much greater percentage of nonferrous, finished products are cold rolled. The difference between hot and cold rolling is essentially the same as the difference between other metalworking processes discussed elsewhere.

The main difference between hot and cold rolling is that in hot rolling the workpiece is initially at, or is heated to, some temperature appreciably above room temperature, and in some cases to near the solidus temperature (the temperature of incipient melting). As contrasted to cold rolling, the workpiece is initially at ambient temperature. In case of hot rolling of plain, low-carbon steel, it may be heated to 2350°F (1288°C). Medium carbon steel may be heated to 2000-2100°F (1093-1148°C), and high carbon steel to a temperature of 1950-2050°F (1006-1121°C). On the other hand aluminum alloys may be heated to a temperature of 850-1200°F (450-650°C). At elevated temperatures the metal will have an appreciably lower flow stress, and it is usually much less prone to cracking as a result of rolling.

Hot rolling is much more dependent on the temperature of the workpiece and the strain rate. During hot rolling the metal is continuously being annealed.

Strainhardening does not occur in hot rolling as in cold rolling, although a lag in the development in Strainhardening during cold rolling may exist. Also, a much higher coefficient of friction exists, as expected, in hot rolling which results in a larger angle of bite or draft during hot rolling. The workpiece and the work rolls in cold rolling may be lubricated such as with substitute palm oil, so that the type of friction in cold rolling is described as sliding in contrast to sticking friction in hot rolling.

6.1.2 The Rolling Mill

Rolling is done with a device called a *rolling mill.* The rolls, whose periphery may be flat or grooved, are mounted in a housing such as is shown in Fig. 6.2.

The assembly of rolls and housing is called a *stand.* A rolling mill may consist of one stand or a series of stands. Typical arrangements of rolls in a stand are shown in Fig. 6.3.

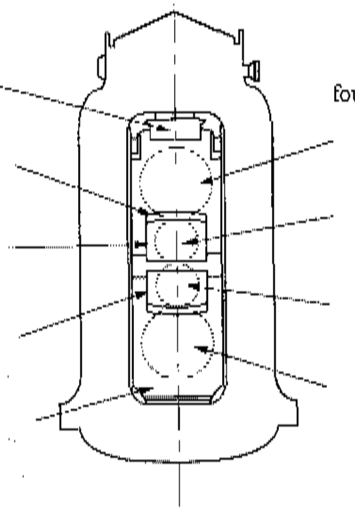
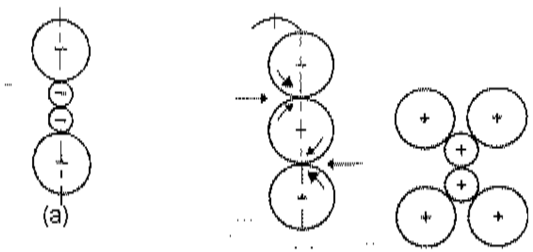


FIGURE 6.2
Components of a four-high rolling mill or stand [6.11].

A stand having two rolls is called a *two-high mill.* A *three-high mi* four rolls, etc. The rolls in contact with the



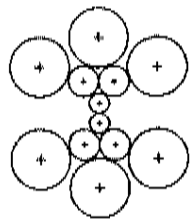


FIGURE 6.3
Typical arrangements of rolls in a stand for a rolling mill. *(a)* 2-high single pass or pull over; *(b)* high reversing mill; (c) 3-high; *(d)* 4-high; (e) and (/) 6- and 12-high roll cluster mills. A 20-high Sendzimir cluster mill is available. *(Adapted from J. A. Schey, The More Common Fabrication Processes, '" Techniques of Metals Research, R. F. Bunshah, Ed., Vol. 1, Part 3, Interscience Publishers, 1968, P- 1448.)*

steel are called the *work rolls,* while those that idle against and support the work rolls are called *backup rolls. As* will be seen later, there are definite advantages for using small diameter work rolls; however, they lack rigidity and may deflect vertically and/or laterally, so that the backup rolls are necessary to provide support to counteract this deflection. A four-high mill would counteract only vertical deflection, whereas a six-high mill would counteract both vertical and lateral deflection. Some mills also have vertical rolls, so as to roll the metal at the sides or edges, and are called *universal mills.* Such a mill may produce *universal plate* as opposed to *sheared-edge plate,* which is cross-rolled and sheared, so as to have more uniform directional properties, and sharper edges and more accurate width dimensions.

The rolling procedure and sequence depends on a number of factors such as the type and amount of metal to be rolled, the amount of reduction, the shape to be rolled, the type and arrangement of equipment available, the mechanical properties desired, etc.

The working rolls rotate at the same speed but in opposite directions. If the metal to be rolled is placed at one side of a mill and if it is rolled through to the other side, this operation is called a *pass.* Some mills, called *reversing mills, can* be reversed after each pass, so that the metal can be rolled back and forth decreasing the distance of separation between the rolls when necessary. An