Lecture 3. Forming processes

Forming is a broad term covering many different manufacturing processes. In general, you may think of forming as any process that changes the shape of a given raw stock without changing its phase (i.e. without melting it). In general, these processes involve beating with a hammer, squeezing, bending, pulling/pushing through a hole, etc.

No matter where you are standing, you can probably see some object that is made by a forming process. Some examples include: aluminum/steel frame of doors and windows, coins, springs, elevator doors, cables and wires, almost all sheet-metal, etc.

3.1. Rolling

Rolling is a process in which the metal is squeezed between two hard rollers. The effect is to change the thickness (and since volume as conserved, the length is increased). The figure below shows a schematic. The main use of rolling is in plants where the metal is made. For example, in Steel-making plants, liquid iron is first formed in a blast furnace by reducing the iron oxide. After further processing the liquid metal, including converting the iron to steel, it is cast by a process called ***continuous casting*** into raw stock shapes. These are very large pieces of steel (several tons each), with typical cross-sections including rectangle (bloom, billet, slab), circle (rounds), or I-sections (beams). These pieces are too large to be directly used – they are rolled in rolling mills that squeeze them into much smaller, but usable shapes. These usable shapes are the raw stock for almost all types of manufacturing that uses steel.

Rolling mills are categorized as ***Hot-rolling*** or ***Cold-rolling*** mills; in hot rolling, the metal is heated to just below its melting point before being fed into the rollers. This is useful, for example, if the initial billet is in a brittle form, e.g. cast iron; the hot-rolled steel cools down with finer grains in the crystalline microstructure, and is stronger and less brittle (**wrought iron**). Rolling mills can also use a variety of roller shapes to get different cross-sections of the rolled bars. Typical process flows are shown in the following figure.

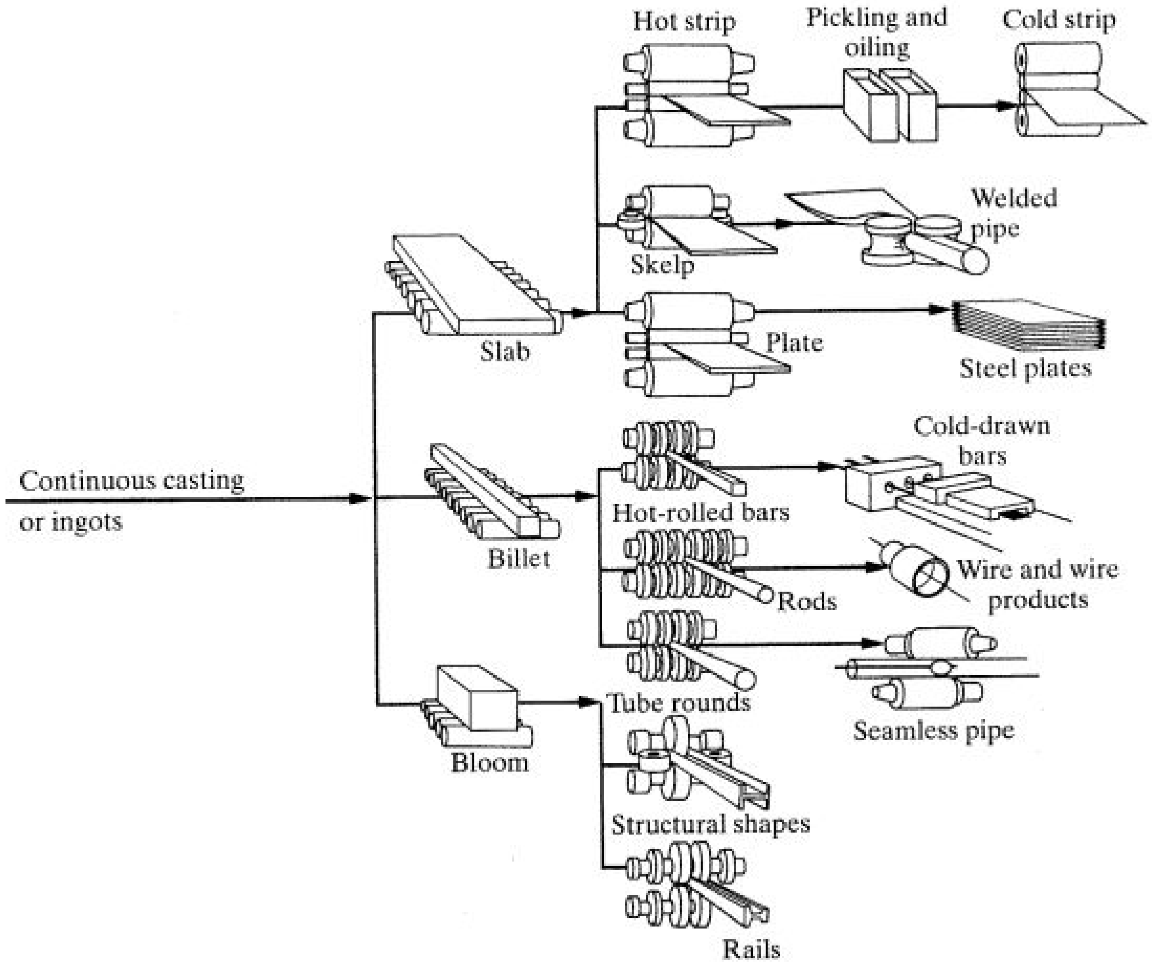

Figure 1. Different types of flat- and shaped-rolling processes [P 321]

In each stage of rolling, the raw stock is reduced in thickness by a small percentage; therefore, typical rolling mills have several stages, where the each stage successively reduces the thickness of the stock until the desired cross section is achieved (see figure below). A very important use of the rolling process is in the making of screws and bolts – the threads of the screw are made by rolling a cylindrical stock between two dies that form the thread-shapes on the stock. A single rolling machine of this type can produce tens of screws per second (which is why they are so cheap).

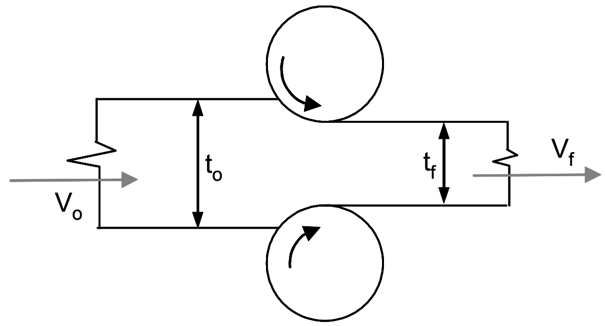

Figure 2. Schematic of a flat rolling process

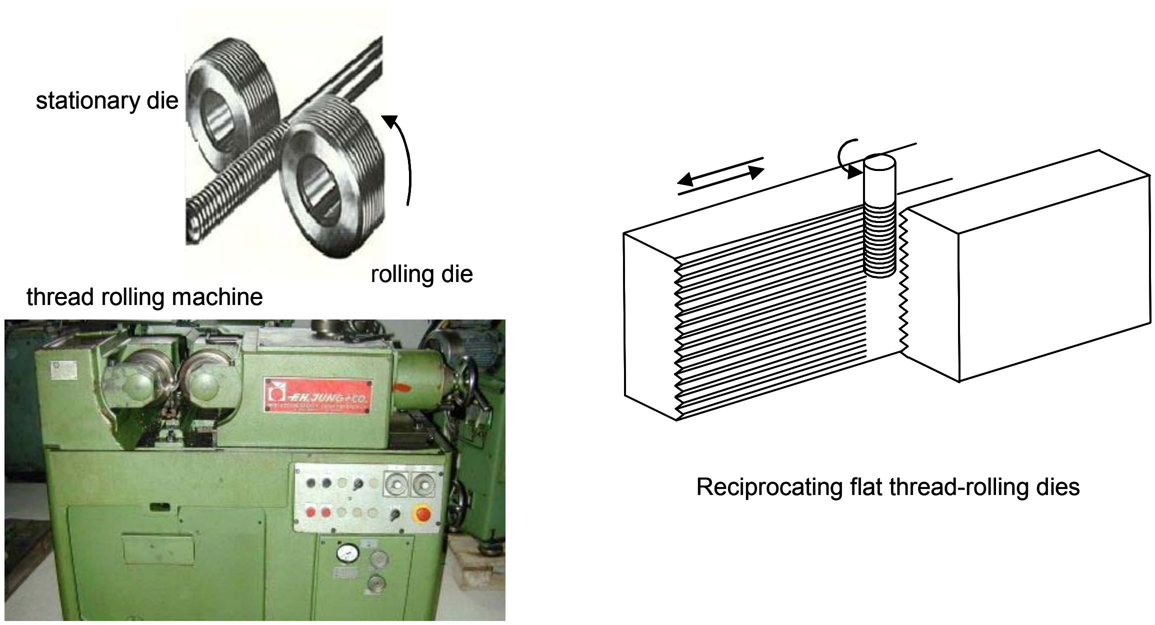

Figure 3. Two types of thread rolling processes (a) dual-roller dies (b) reciprocating flat dies

3.2. Forging

Forging is the process where (heated) metal is beaten with a heavy hammer to give it the required shape. For example, ancient sword-making uses flat hammers beating on a heated strip of metal kept on a flat piece of iron called an anvil (you may have seen this action in many movies). However, forging is used to make many more complex shapes – and to let the metal form into such shapes, the hammer and the supporting pieces are cut into the reverse of the required shape – in other words, they form the forging dies.

Figure 4. A simple forging press; note the red hot bar stock in place

The figure above shows an **open-die forging** process. If we desire to hammer down the stock to a well defined shape, then it is customary to se a **closed-die forging process**; in this process, the hammer-head and the anvil are basically hardened dies with the inverse of the shape we want. The figure below shows a schematic of the dies and stock in the closed-die forging process. Usually, the stock volume is a little in excess of the part volume; this ensures that the entire die cavity gets filled properly. However, the excess material flows out through the gap between the dies; this excess is called flash, and must later be machined away (this operation is called trimming). If the stock and the final part are very different in shape, then the forging is done in several stages. The figure shows an example of a common forged part – a connecting rod. this part is used in almost all petrol engines. The part is made from bar stock in four stages, marked in the figure as (i) edging, (ii) blocking, (iii) finishing, and (iv) trimming. Note that only the dies for the third stage are exactly the inverse, geometrically, of the final part shape.

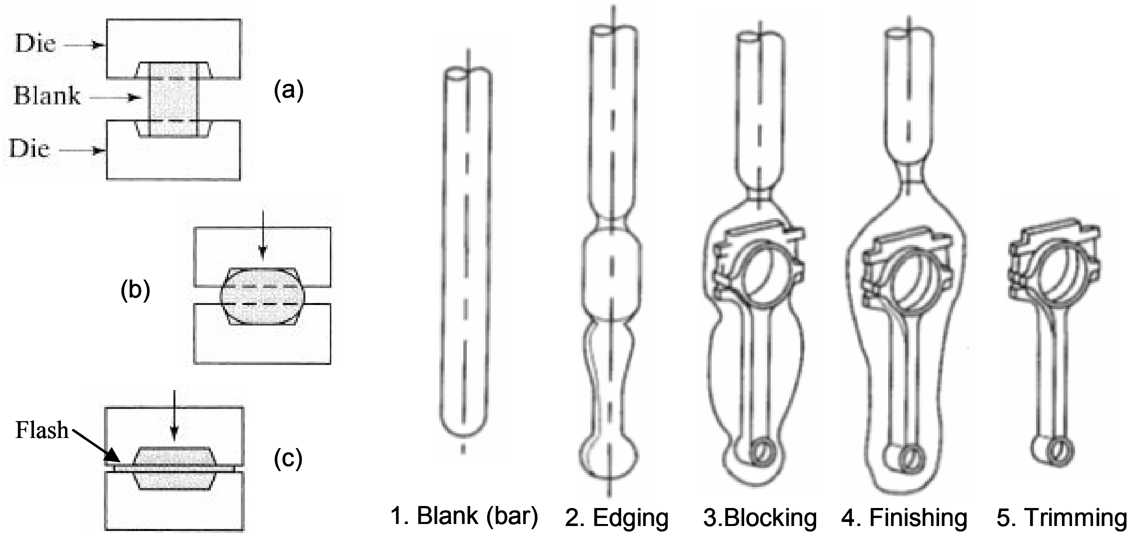

Figure 5.

(a) Schematic of closed-die forging (b) Stages of forging a connecting rod

In some modern applications, the volume of the stock and the precision of the last-stage dies are controlled very tightly. Such applications are sometimes called precision forging. One form of precision forging is used to make coins. If you look closely at a newly manufactured coin, you can see very high quality details in the forging; usually, good quality coins may need between three and five stages of forging. This is because in coin-making, no lubricant or oil can be applied to the die surface; these may get trapped in the tiny cavities of the design and lead to poor feature definition in the forged coin.

Quality of forged parts: usually forged parts are much stronger/tougher than cast or machined parts made from the same material. This is because the hammering process arranges the micro-structure of the metal so that the crystal grains get aligned along the part profile. This leads to an increase in strength. It is therefore common to use forging to make parts that will carry very high stresses during their use, rather than casting.

3.3. Extrusion

Extrusion is a process in which metal is forced, or squeezed, out through a hole (die). The process is similar to squeezing toothpaste out of the tube. This process is used mostly for metals that are ductile, including copper, steel, aluminum and magnesium; it is also used for some plastics and rubbers. Common examples of parts made by extrusion are the aluminum frames of white-boards, door- and window-frames, etc. Usually, long strips of the required cross-section are extruded and sold as raw-stock. Any hardware store will have between ten and hundred different cross-section bars – almost all are made by extrusion. The process can be used to make hollow as well as solid cross-sections, as seen from the example parts in the figure below.

Figure 6. Examples of parts made by extrusion (each part is cut from a long length)

The extrusion press has a pressure chamber into which the raw stock is loaded; the die is made of hardened steel, with a hole that is the shape of the required cross-section. The metal is then squeezed out of the die hole by the use of a high pressure hydraulic piston. The schematic below shows the basic process, and the images show two examples of aluminum extrusion dies.

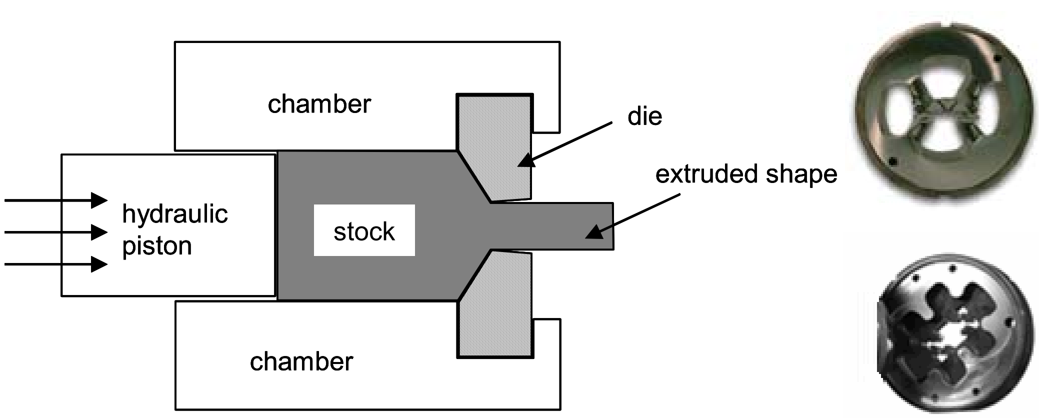

Figure 7. Schematic of extrusion and examples of extruding dies

3.4. Drawing

Drawing is the process most commonly used to make wires from round bars; this process is very similar to extrusion, except that instead of pressure from the back end, in drawing, the wire is pulled from the side where it emerges from the circular die. A schematic is shown below. It is possible to generate cross-sections other than circle using different dies in drawing, though these applications are relatively rare. Dies are made of specially hardened tool steels, or tungsten carbide. Diamond dies are used for drawing very fine wires. Both, extrusion and drawing may be hot (i.e. the stock is heated to a high temperature for processing, or cold (i.e. the stock is not heated).

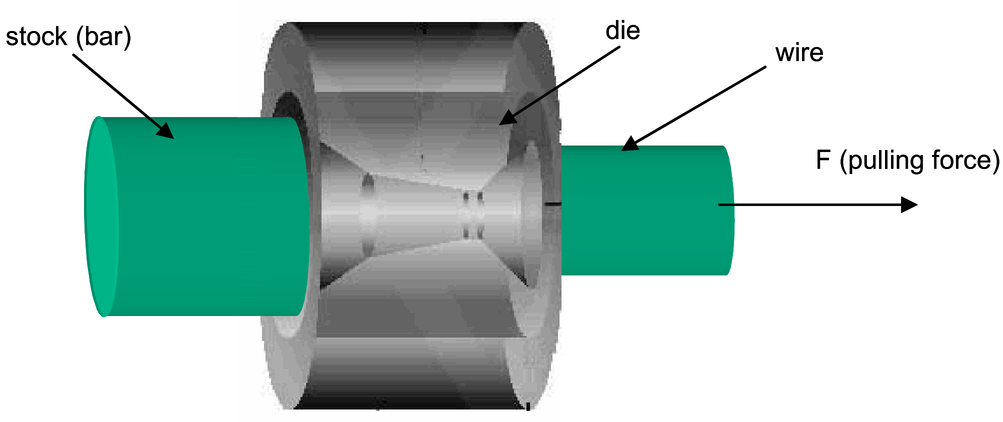

Figure 8. Schematic of the drawing process; the die is shown as semi-transparent to show the interior shape of the die hole