Forming processes

Forming is a broad term covering many different manufacturing processes. In general, **forming** is 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, sheet-metal parts etc.

FORMING PROCESSES

1- HOT WORKING PROCESSES

1-1 Rolling

- Rolling of Structural Shapes
- Rolling of Screw manufacture

1-2 Forging

1-2-1 Open Die Hammer or Smith Forging

1-2-2 Impression-Die Drop or Closed-Die Forging

1-2-3 Press Forging

1-2-4 Upset Forging

1-2-5 Roll Forging

1-2-6 Draw out forging

1-2-7 Squeeze forging

1-3 Extrusion

1-3-1 Direct extrusion (hot),

1-3-2 Indirect extrusion (hot),

1-3-3 Impact extrusion (usually cold).

1-3-4 Extrusion of Tubes

2- COLD WORKING PROCESSES

2-1 Squeezing processes

2-1-1 Cold Rolling

2-1-2 Cold Forging

2-1-3 Extrusion

- Forward Extrusion
- Backward Extrusion

  Both may be use open or closed dies

- Cold - Impact Extrusion

2-1-4 Coining

2-1-5 Surface Improvement (Peening)

2-2 Sheet metal forming

2-2-1 Shearing Processes

2-2-2 Punching Processes

- Piercing and Blanking
- Rod Shearing

2-2-3 Bending Processes

- Angle Bending
- Tube Bending
- Roll Bending
- Cold Roll-Forming
- Seaming Joining

2-2-4 Drawing Processes

- Bar Drawing
- Tube Drawing
- Wire Drawing
- Deep Drawing (Shell Drawing)

2-3 High energy rate forming processing

- Underwater explosions
- Spark discharge method
- Pneumatic-mechanical and combustion techniques
- Electromagnetic forming (EMF)
- Electroforming
- Explosive Forming

1- HOT WORKING PROCESSES

Hot working is the plastic deformation of metals above their recrystallization temperature. Hot working occurs under conditions of temperature and strain rate such that recrystallization occurs simultaneously with deformation.

- **Plastic deformation** is a permanent deformation, obtained by applying forces great enough to exceed the elastic limit of the material.
- **Recrystallization temperature** is the temperature at which new, unstrained crystals from the original distorted grains are formed after being plastically deformed.

Table (1): Lowest recrystallization temperature of common metals

Metal	Temperature [°C (°F)]
Aluminum	150 (300)
Copper	200 (390)
Gold	200 (390)
Iron	450 (840)
Lead	Below room temperature
Magnesium	150 (300)
Nickel	590 (1100)
Silver	200 (390)
Tin	Below room temperature
Zinc	Room temperature

Advantages of Hot Working

1. The yield strength of metals decreases as temperature increases, and the ductility increases. Thus it becomes possible to alter the shape of metals drastically by hot working without causing them to fracture and without the necessity for using excessively large forces.
2. Hot working does not produce strain hardening. Therefore, it does not cause any increase in yield strength or hardness, or corresponding decrease in ductility.
3. The elevated temperatures promote diffusion that can remove chemical inhomogenities, pores can be welded, shut or reduced in size during deformation and the metallurgical structure can be altered to improve the final properties.
4. Undesirable coarse or columnar grains may be eliminated and a fine, randomly oriented grain structure may be obtained. Metals with fine grain structures have superior strength, ductility and toughness.
5. Impurities which are located around grain boundaries are often reoriented into a "crack-arrestor" configuration, perpendicular to crack propagation.

Disadvantages of Hot Working

1. The high temperatures may promote undesirable reactions between the metal and surroundings,
2. Tolerances are poorer due to thermal contractions and possible non uniform cooling,
3. Metallurgical structure may also be non-uniform.

Important Applications:

Steel Plants, Raw stock production (sheets, tubes, Rods, etc.), Screw manufacture

2- COLD WORKING PROCESSES

Cold working is the plastic deformation of metals below their recrystallization temperature. It is generally performed at room temperature.

In cold working, after completing the deformation and releasing the force, the workpiece tries to return back to its original shape, and some amount of strain on the workpiece is recovered, i.e. the strain decreases.

The amount of decrease in the strain is called **spring back**. Cold working tools (e.g. dies) should be designed by considering the spring back effects.

Spring back

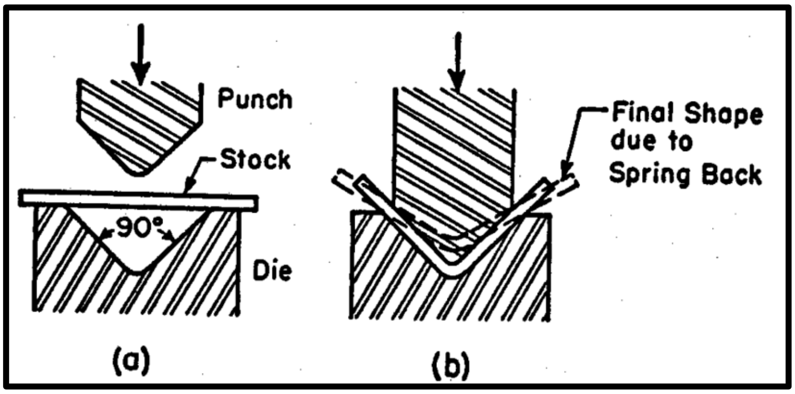


Figure (1): Spring back in bending operations

Advantages of Cold Working

1. No heating is required.
2. Better surface finish is obtained.
3. Superior dimension control.
4. Better reproducibility and interchangeability of parts.
5. Improved strength properties.
6. Directional properties can be imparted.
7. Contamination problems are minimized.

Disadvantages of Cold Working

1. Higher forces are required for deformation.
2. Heavier and more powerful equipment is required.
3. Less ductility is available.

4. Metal surfaces must be clean and scale-free.
5. Strain hardening occur.
6. Imparted directional properties may be detrimental.
7. May produce undesirable residual stresses.

1-HOT WORKING PROCESSES

1-1 Rolling

Rolling usually is the first step in converting cast material (ingot) into finished wrought products. Hot rolled products, such as sheets, plates, bars, and strips, serve as input material for further processes, such as cold forming or machining.

Hot Rolling is a process in which the heated metal is passing and squeezing between two hard rollers that revolve in opposite directions, the size of the gap between the rolls being somewhat less than the thickness of the entering metal. 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, 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.

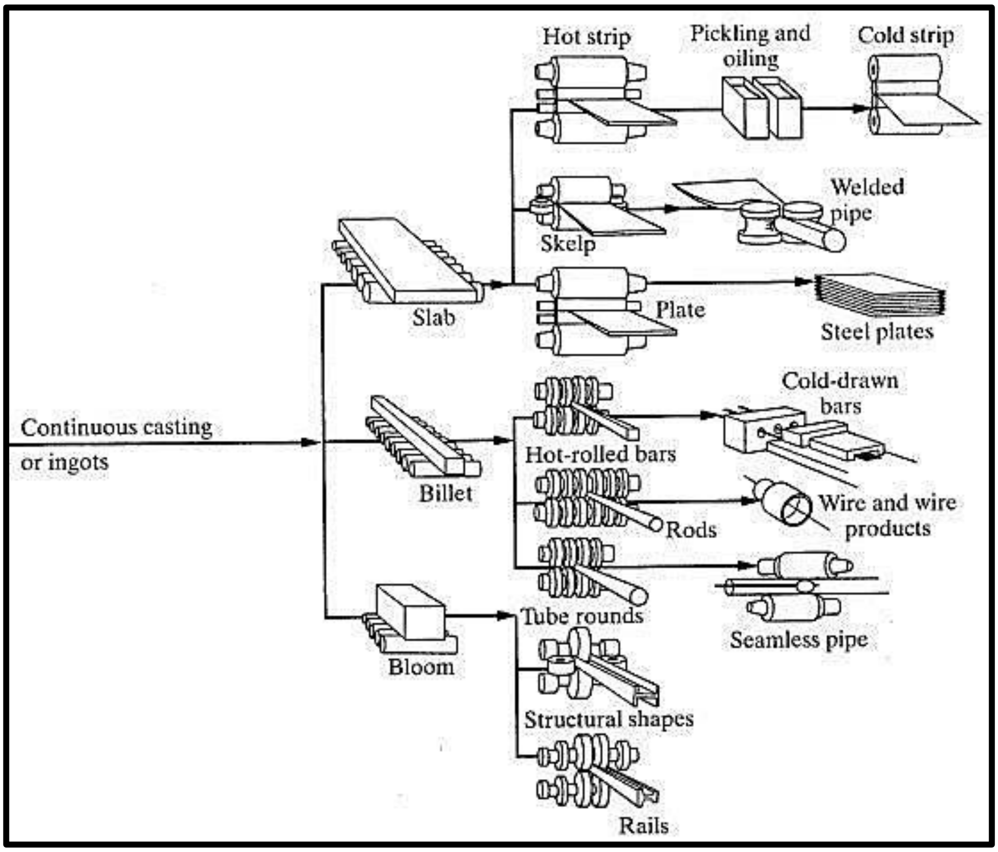


Figure (2): Different types of flat- and shaped-rolling processes

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).

Important Applications:

Steel Plants, Raw stock production (sheets, tubes, Rods, etc.)

Screw manufacture

Rolling Basics

Sheets are rolled in multiple stages (why ?)

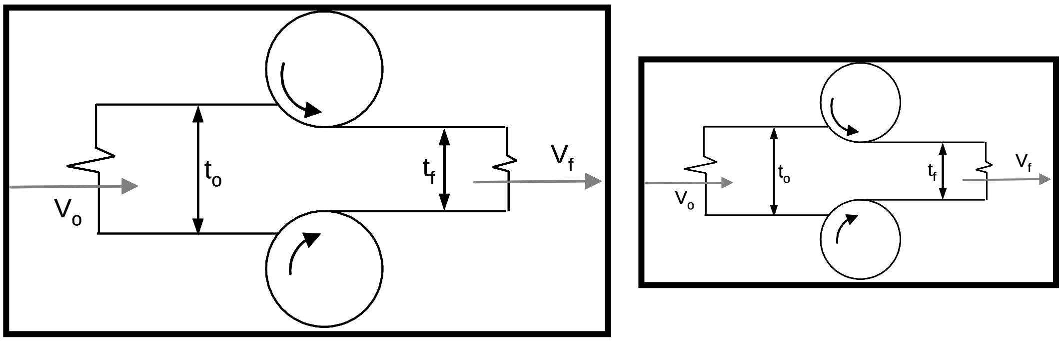


Figure (3): Schematic of a flat rolling process

- **Rolling of Screw manufacture**

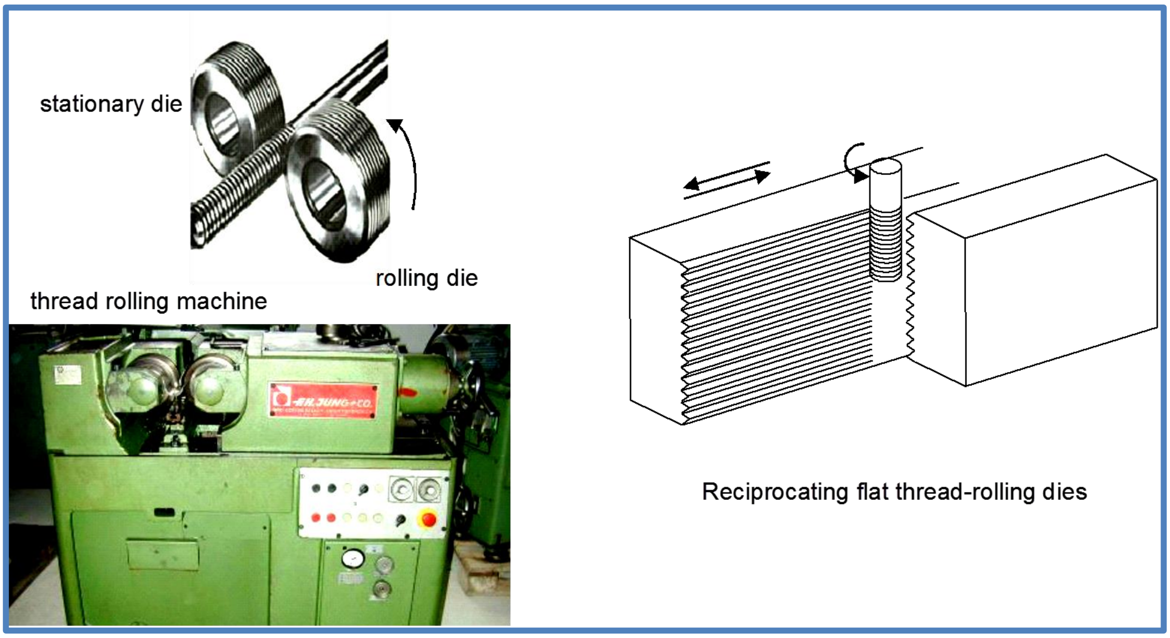
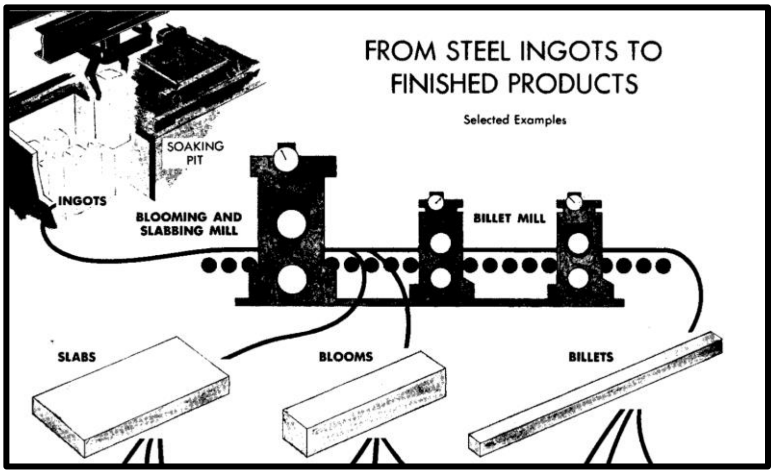
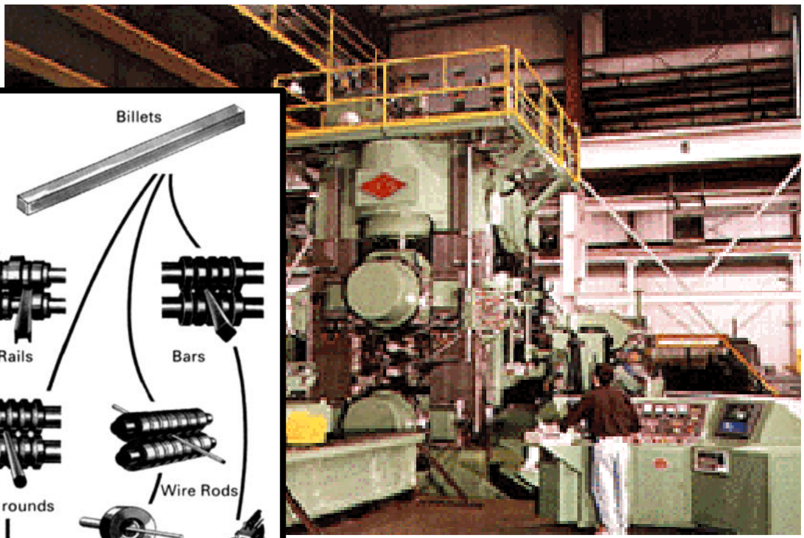
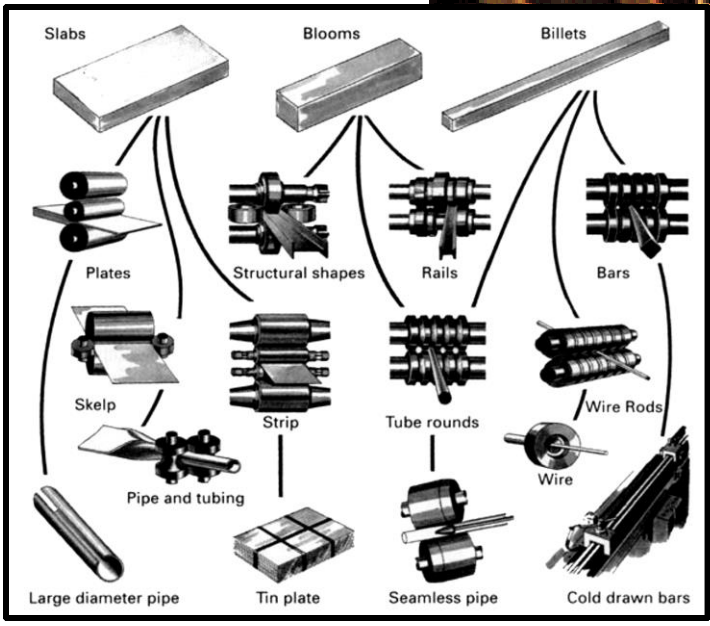
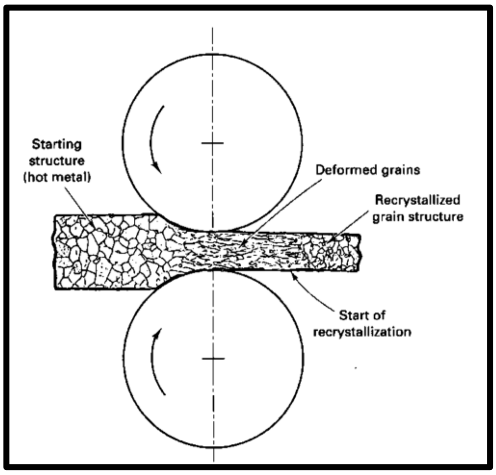


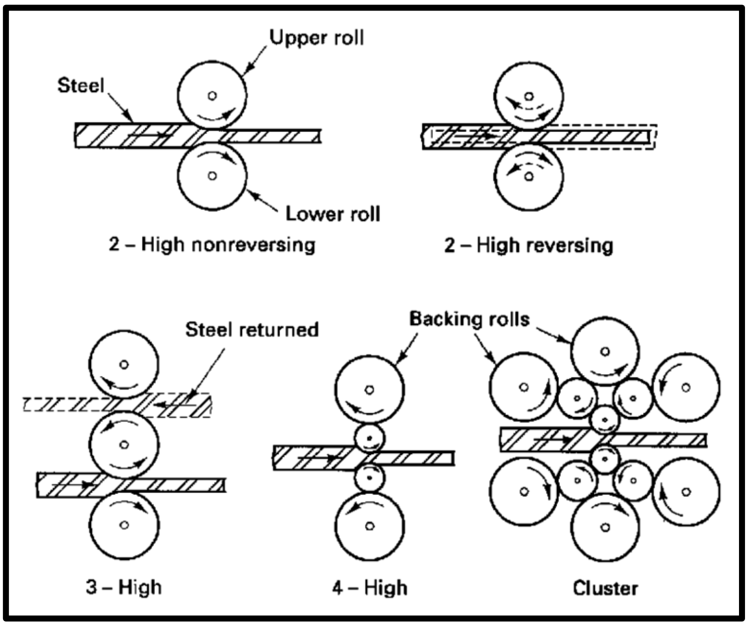
Figure (4): Two types of thread rolling processes (a) dual-roller dies (b) reciprocating flat dies


FROM STEEL INGOTS TO
FINISHED PRODUCTS
Selected Examples
SOAKING PIT
INGOTS
BLOOMING AND SLABBING MILL
BILLET MILL
SLABS
BLOOMS
BILLETS

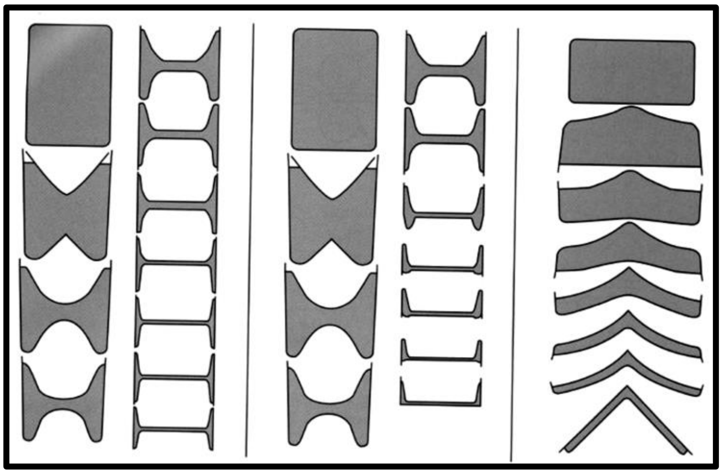



Slabs
Blooms
Billets
Plates
Structural shapes
Rails
Bars
Skelp
Strip
Tube rounds
Wire Rods
Pipe and tubing
Wire
Large diameter pipe
Tin plate
Seamless pipe
Cold drawn bars


Starting structure (hot metal)
Deformed grains
Recrystallized grain structure
Start of recrystallization


Upper roll
Steel
Lower roll
2 – High nonreversing
2 – High reversing
Steel returned
Backing rolls
3 – High
4 – High
Cluster

- **Rolling of Structural Shapes**



Characteristics, Quality, and Tolerances of Hot Rolled Products

1. Because they are rolled and finished above the recrystallization temperature, hot rolled products have minimum directional properties and are relatively free of residual stresses,
2. Generally free of voids, cracks or laminations,
3. Surfaces are slightly rough and covered with high temperature oxide known as mill scale,
4. Dimensional tolerances vary with the kind of metal and the size of the product. For most products the tolerance is from 2 to 5 % of the size (height or width).