FORMING PROCESSES

1.1 INTRODUCTION

Forming In general 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 through a hole, etc. Some examples include: aluminum/steel frame of doors and windows, coins, springs, elevator doors, cables and wires, almost all sheet-metal parts etc.

Main Forming processes are:

1- HOT WORKING PROCESSES

Rolling, Forging, Extrusion

2- COLD WORKING PROCESSES

- **Squeezing processes**

  Cold Rolling, Cold Forging, Extrusion, Coining, Surface Improvement (Peening)

- **Sheet metal forming**

  Bending Processes, Drawing Processes

- **High energy rate forming processing**

  Underwater explosions, Electromagnetic forming (EMF), Electroforming, Explosive Forming

1.2 HOT WORKING PROCESSES

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

Advantages

1. The yield strength of metals decreases as temperature increases, and the

ductility increases.

2. It is possible to alter the shape of metals drastically without causing fracture and without the necessity for using excessively large forces.

2. Hot working does not produce strain hardening.

3. Remove chemical inhomogeneity, pores can be welded, shut or reduced in size during deformation.

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.

Disadvantages

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

1.3 COLD WORKING PROCESSES

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

Advantages of Cold Working

1. No or less 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

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.

1.3 HOT WORKING PROCESSES

1.3.1 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.

Applications:

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

Characteristics, Quality, and Tolerances of Hot Rolled Products

1. 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.

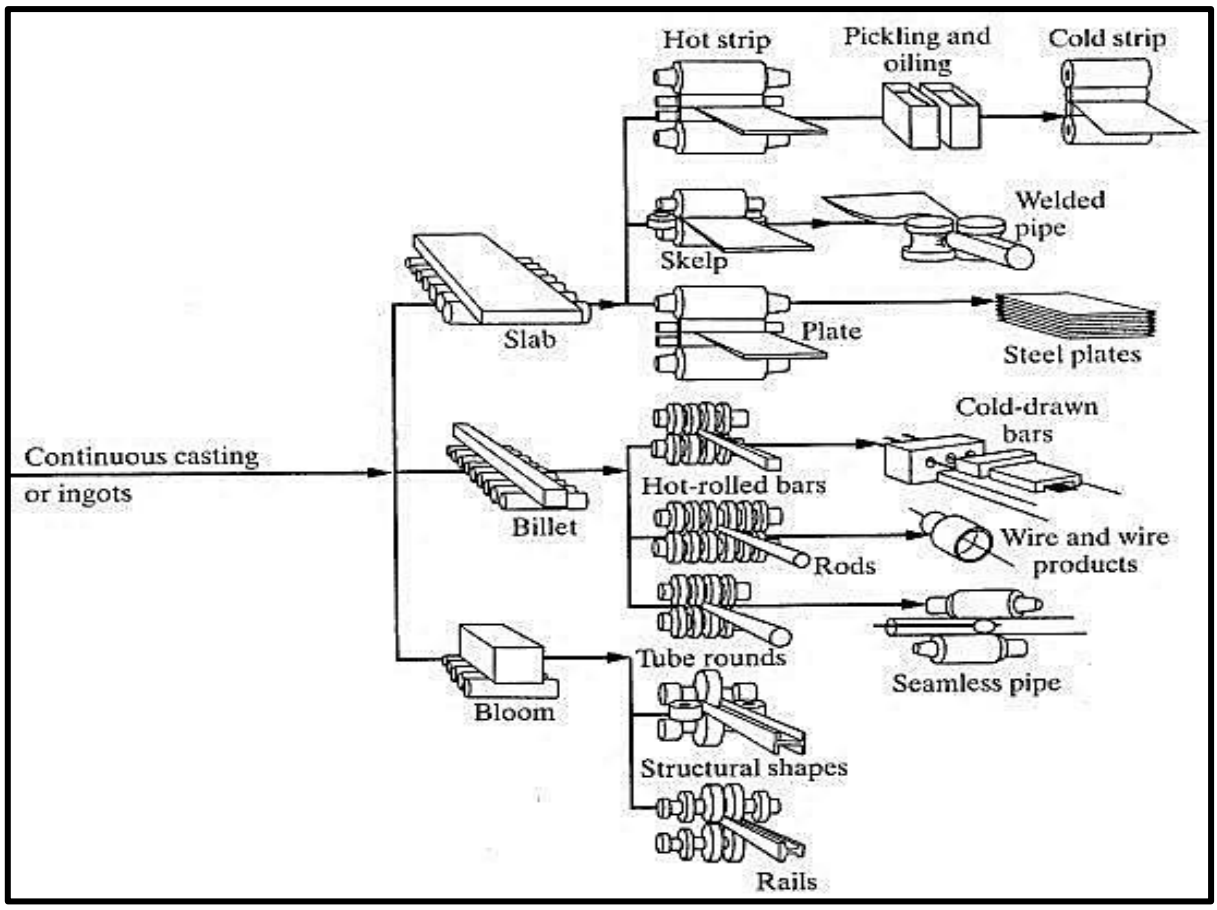


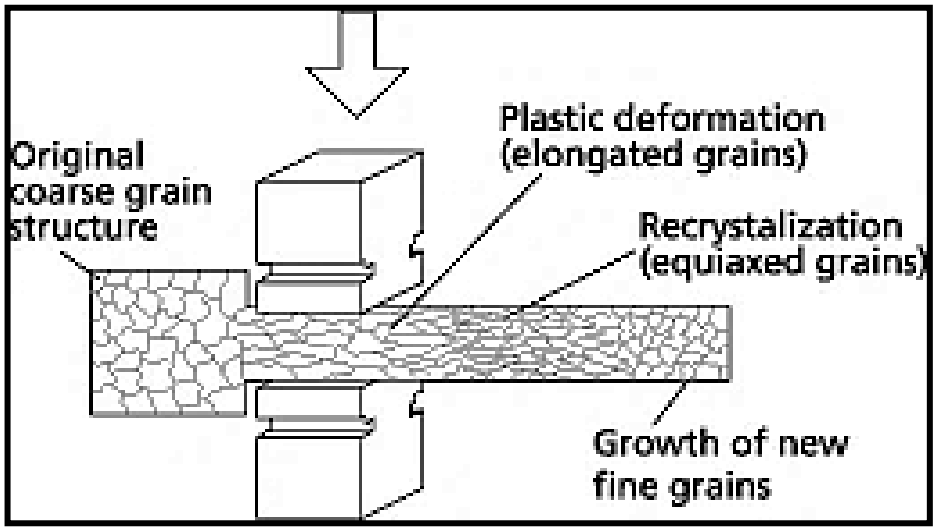
Figure (2): Different types of flat- and shaped-rolling processes

1.3.2 Forging

Forging is the process where (heated) metal is beaten with a heavy hammer, presses, or special forging machines to give it the required shape.

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.



1.3.2.1 Open Die Hammer or Smith Forging

The same type of forging done by the blacksmith of old, but now massive mechanical equipment is used. The hammer and anvil often being completely flat. The operator obtains the desired shape by manipulating the workpiece between blows.

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.

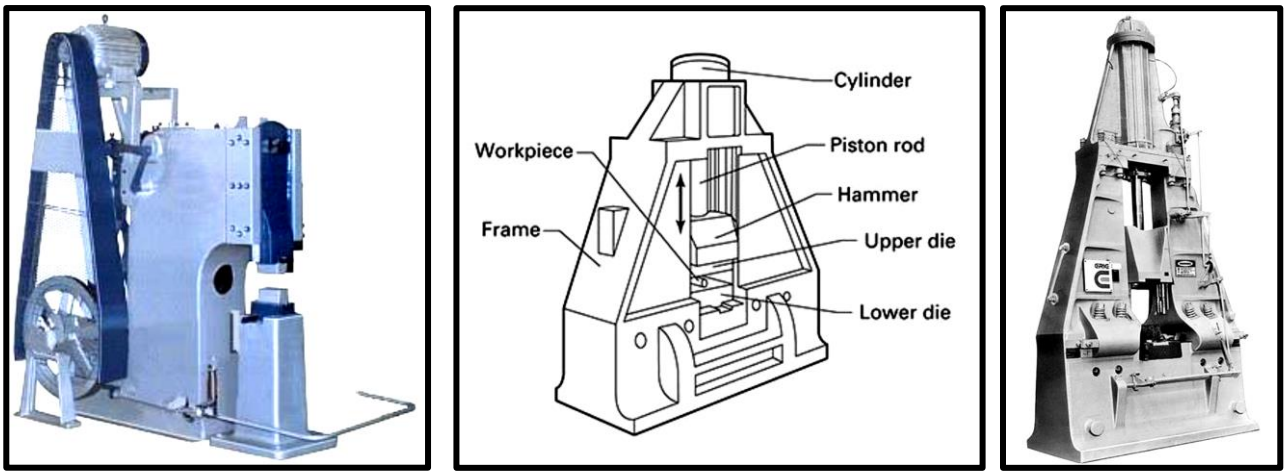


Figure (1): open-die forging press

1.3.2.2 Closed-Die Forging

The open-die hammer is not practical for large-scale production because it is slow and the resulting size and shape of the workpiece are dependent on the skill of the operator.

Closed-die forging overcomes these difficulties by using shaped dies to control the flow of metal to make many more complex shapes, the hammer and the supporting pieces are cut into the reverse of the required shape.

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.

Stages in Closed-Die Forging

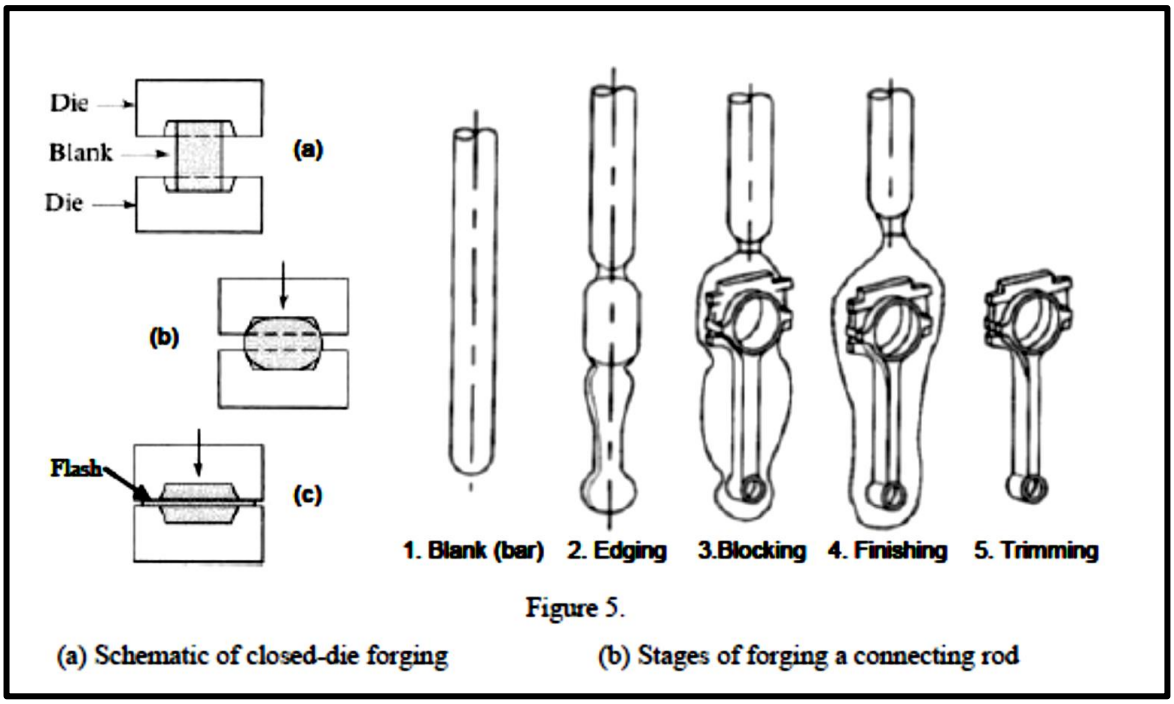


Figure 5.

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

1.3.3 Extrusion

Extrusion is a process in which metal is compressively forced, or squeezed, to flow out through a suitably shaped hole (die). The process is similar to squeezing toothpaste out of the tube.

This process is used mostly for metals that are ductile, including, lead, copper, aluminum, magnesium, and their alloys, taking advantage of the relatively low yield strengths and extrusion temperatures. 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 as seen from the example parts in the figure below.

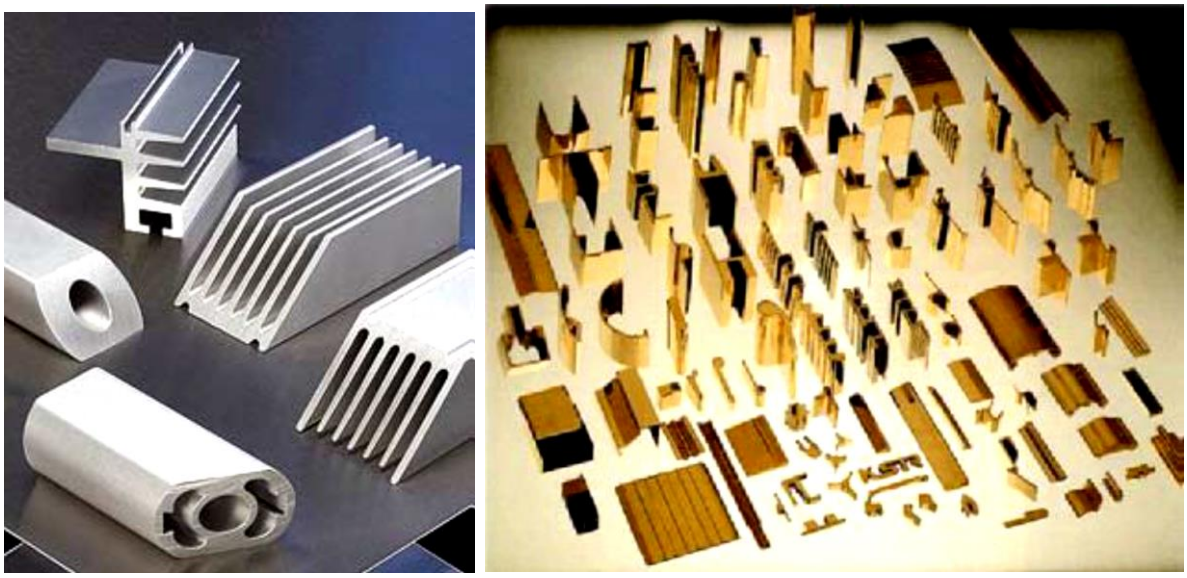


Figure (2): Examples of parts made by extrusion

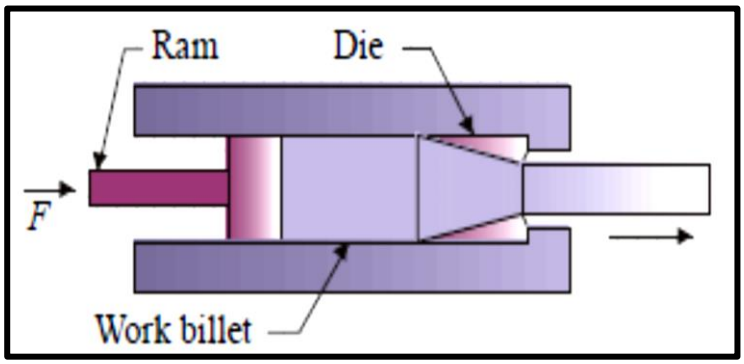
Main specification

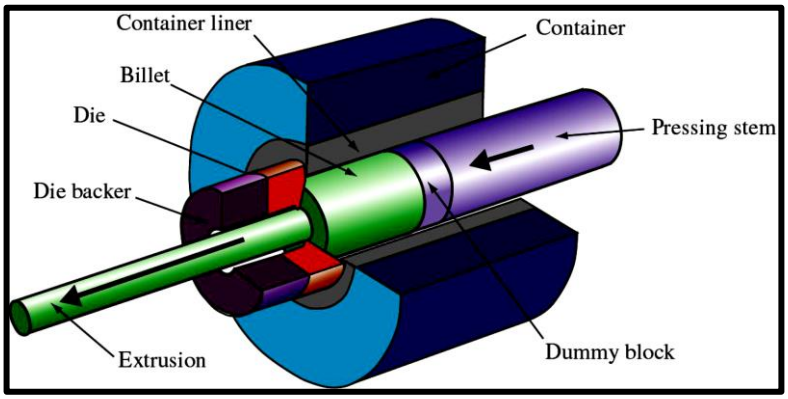
- The amount of reduction in a single step is limited by the equipment capacity.
- Extrusion dies are relatively inexpensive.
- Product changes require only a die change, so small quantities of a desired shape can produced economically.
- The dimensional tolerances of extrusions are very good.

Extrusion Methods

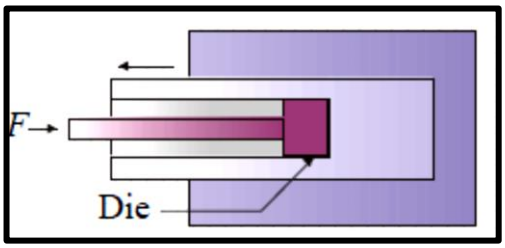
1. Direct extrusion (hot),

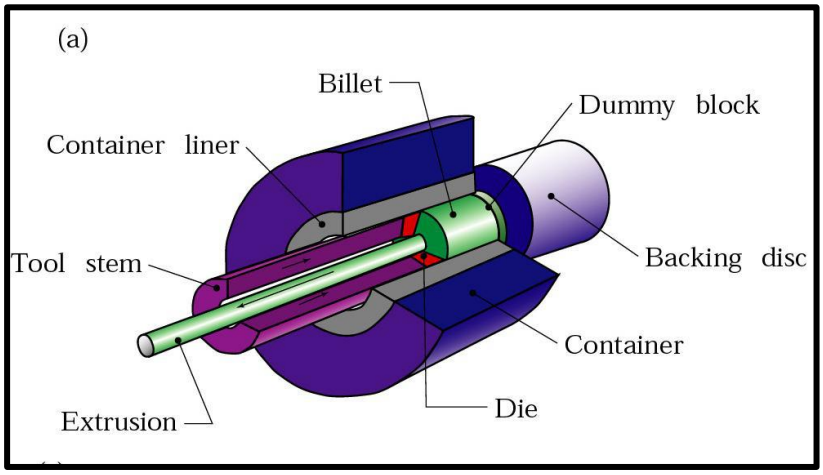
Although the indirect extrusion configuration reduces friction between the billet and chamber wall, but need complexity equipment and restricted length of product favors the direct method.





2. Indirect extrusion (hot),

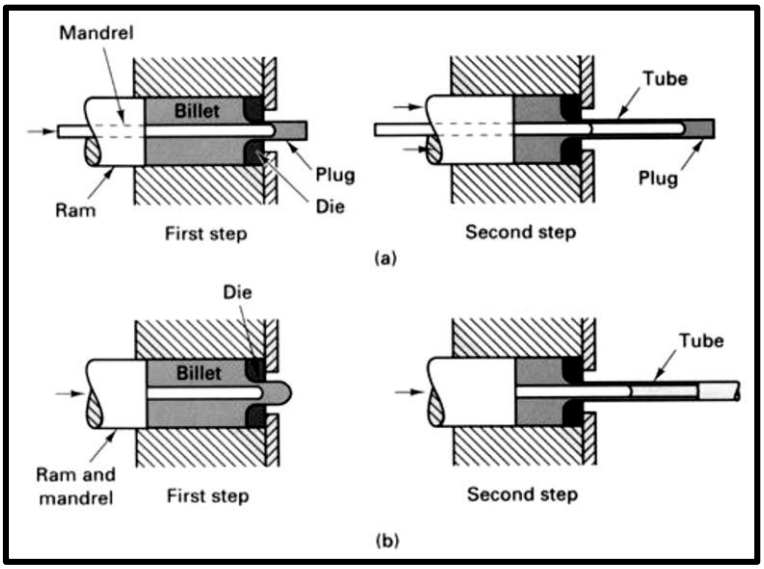




3. Impact extrusion (usually cold).

4. Extrusion of Hollow Shapes

For tubular products, the stationary or moving mandrel processes are often employed.



1.4 COLD WORKING PROCESSES

1.4.1 Squeezing processes

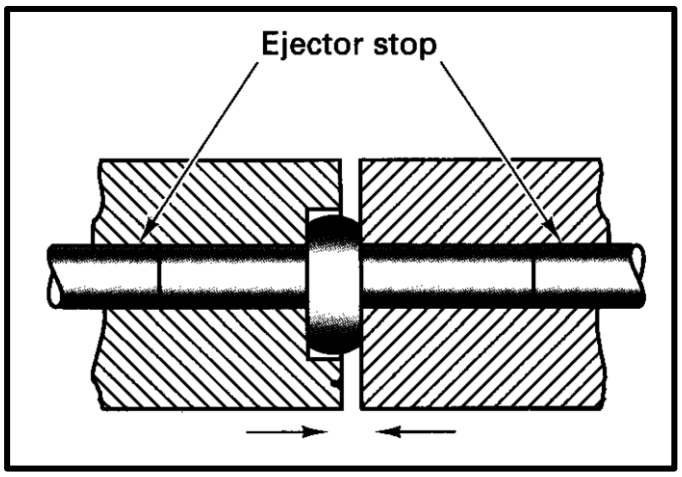
The primary reasons for deforming cold rather than hot are to obtain better dimensional accuracy and surface finish. In many cases the equipment is basically the same, except that it must be more powerful.

1- Cold Rolling

Sheets, strips, bars and rods are cold rolled to obtain products that have smooth surfaces and dimensions.

2- Cold Forging

The metal is squeezed into a die cavity that imparts the desired shape. It is known as cold heading if used for making enlarged sections on the ends of a piece of rod or wire, such as the heads on bolts, nails, rivets, and other fasteners.



Parts Made by Cold Forging

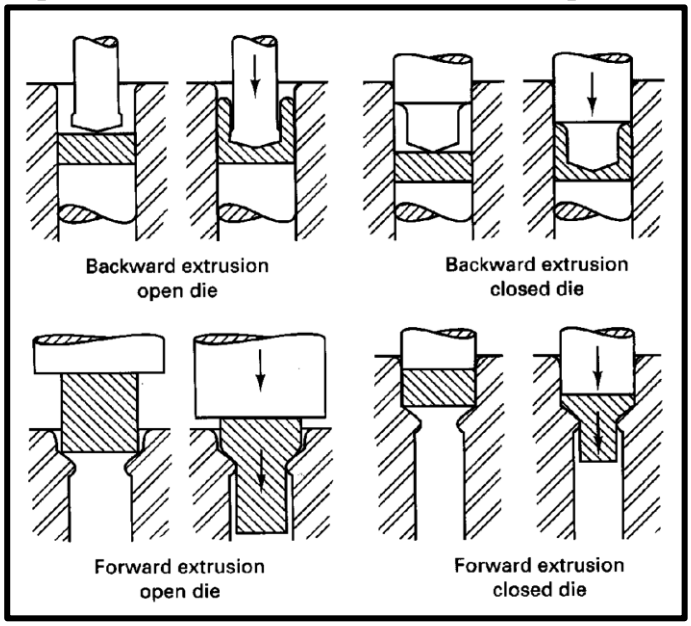
3- Extrusion

Products like collapsible tubes for toothpaste, medications, and so forth; small cans such as are used for shielding in electronics and electrical apparatus; and larger cans for food are made by using the process which is often called as impact extrusion. There are:

- **Forward Extrusion**
- **Backward Extrusion**

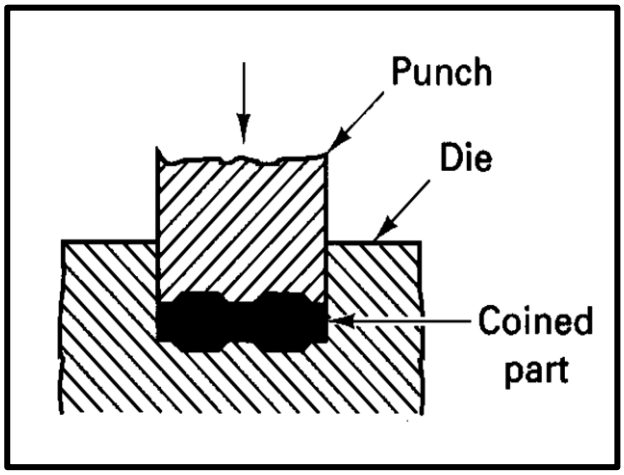
Both may be use open or closed dies

- **Cold - Impact Extrusion**



Coining

It is used to produce coins, medals and other products where exact size and fine detail are required. Metal is confined within a set of dies by means of the positive displacement of the punch, and very high pressure is required.

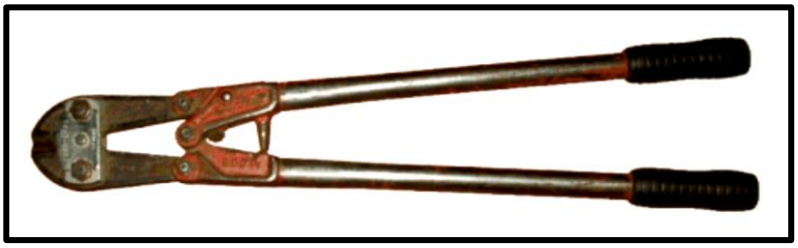


1.5 Sheet metal forming

Sheet metal processing is an important process for the largest manufacturers of products such as home appliances (fridge, washer, dryer, vacuum cleaners etc.), electronics (DVD- and CD-players, stereos, radios, amplifiers etc.), toys and PC's. Most of these products have metal parts that are made by cutting and bending sheet metal.

1- Shearing Processes

Shearing is the mechanical cutting of sheet or plate without the formation of chips or use of burning or melting. When the two cutting blades are straight, the process is called shearing.



Processes in which the shearing blades are in the form of the curved edges of punches and dies, are called by other names, such as blanking, piercing, notching, shaving, trimming, etc.

Figure 1. (a) Hydraulic sheet metal shearing machine (b) A CNC turret-type sheet metal punching machine

2- Punching Processes

In a sheet metal punching machine – the cutting tool is a punch, a piece of hard tool steel which is punched down on the sheet to cut a hole. The punch is a rotating tool holder that can hold tens of different shapes and sizes of punching dies.

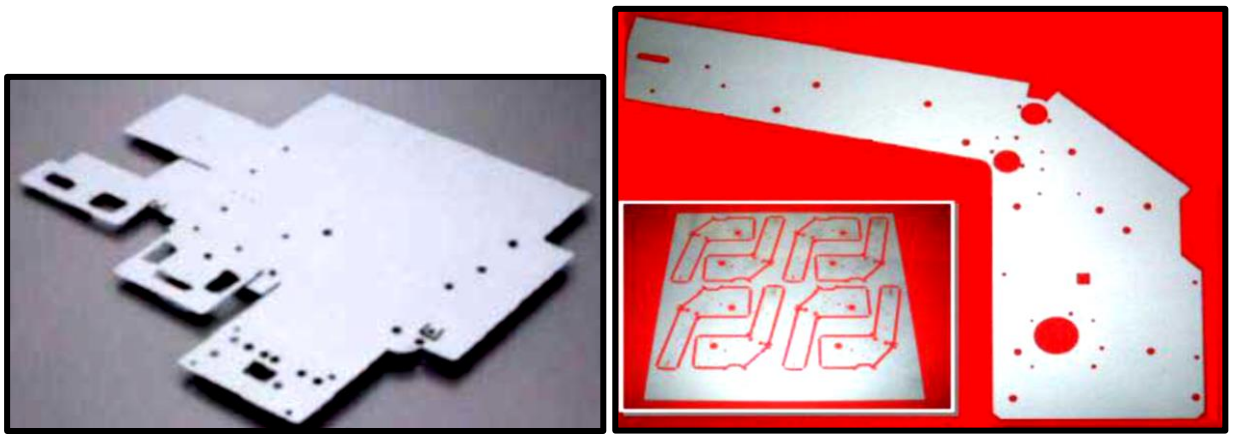


Figure (2): Typical punched part.

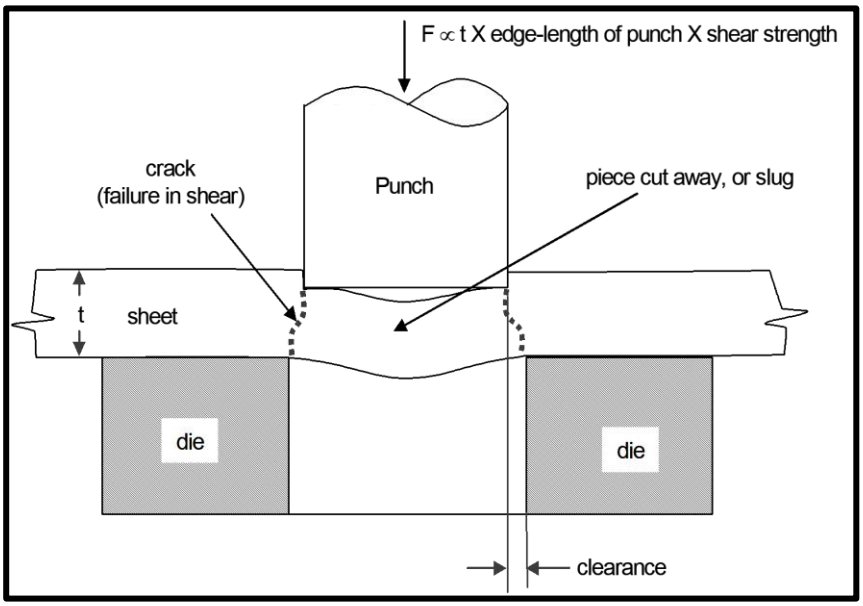
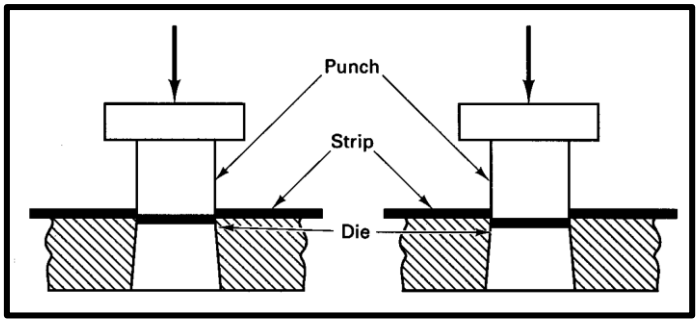
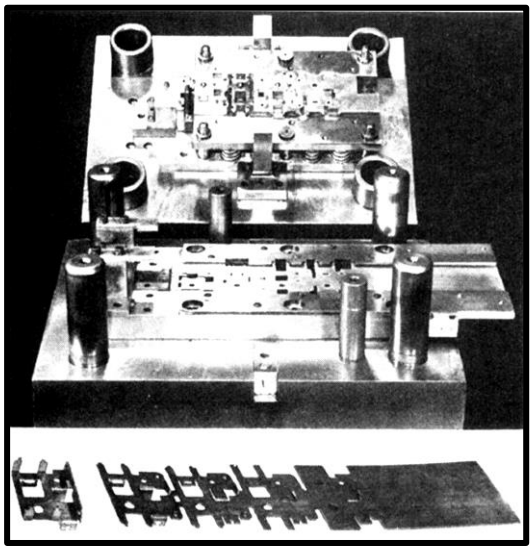


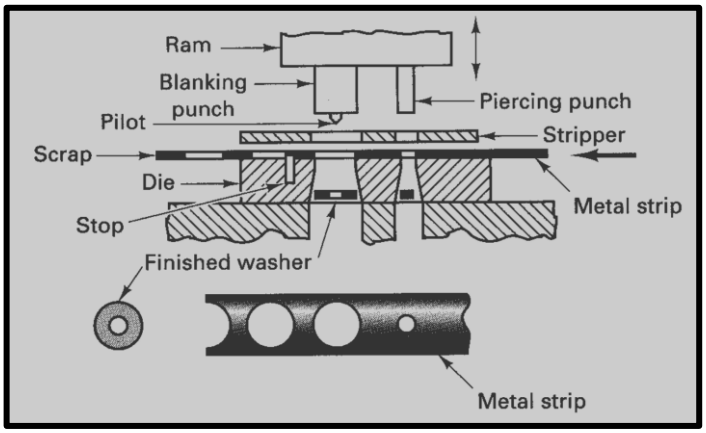
Figure (3):Schematic of the shearing process

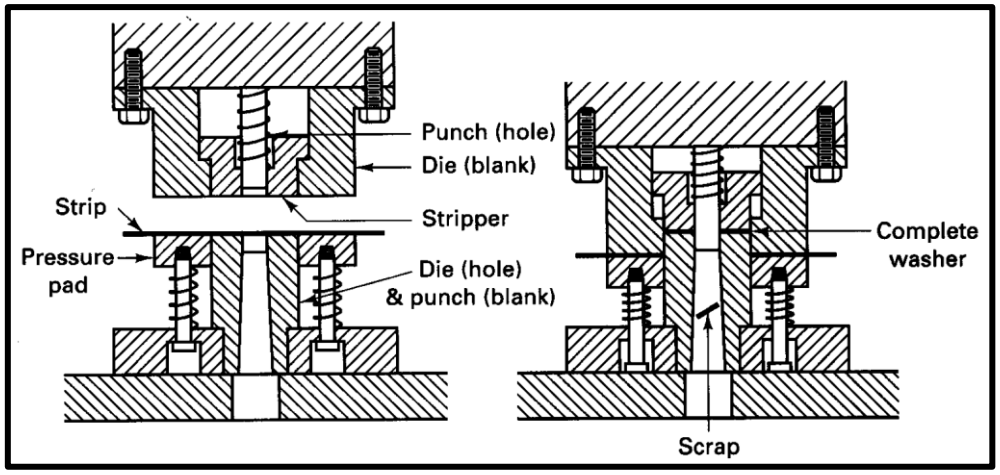
3- Piercing and Blanking

Piercing and blanking are usually done by some type of mechanical press.



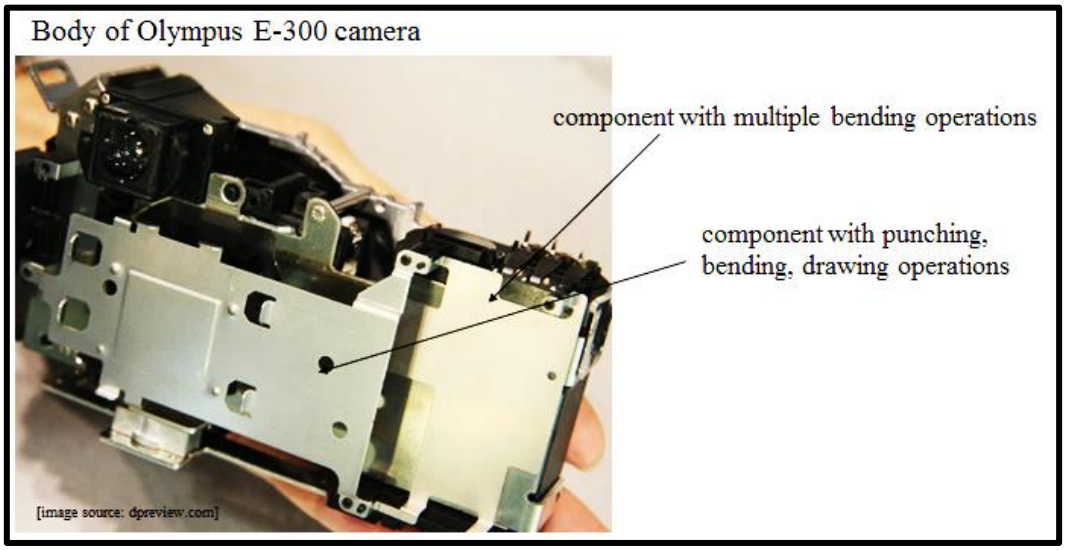




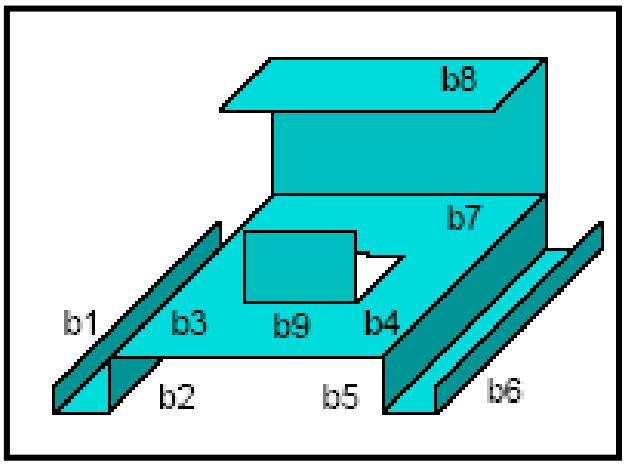


4- Bending Processes

A large percentage of sheet metal parts are bent along some lines to get them into the desired shape for use (for example, think of the metal case for a computer).

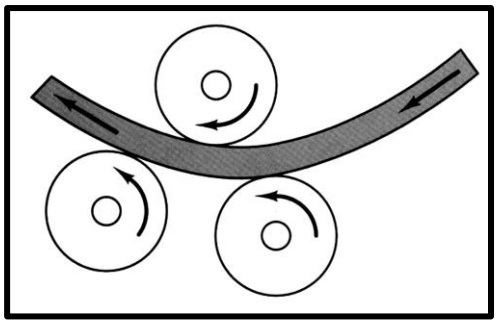


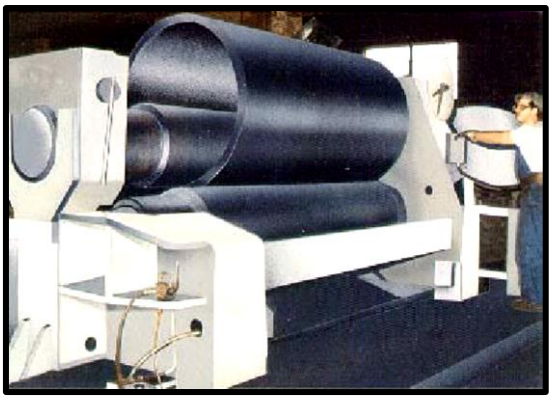
The following figure shows a simple bend on a rectangular blank. Planning problem: what is the sequence in which we do the bending operations?



Roll Bending

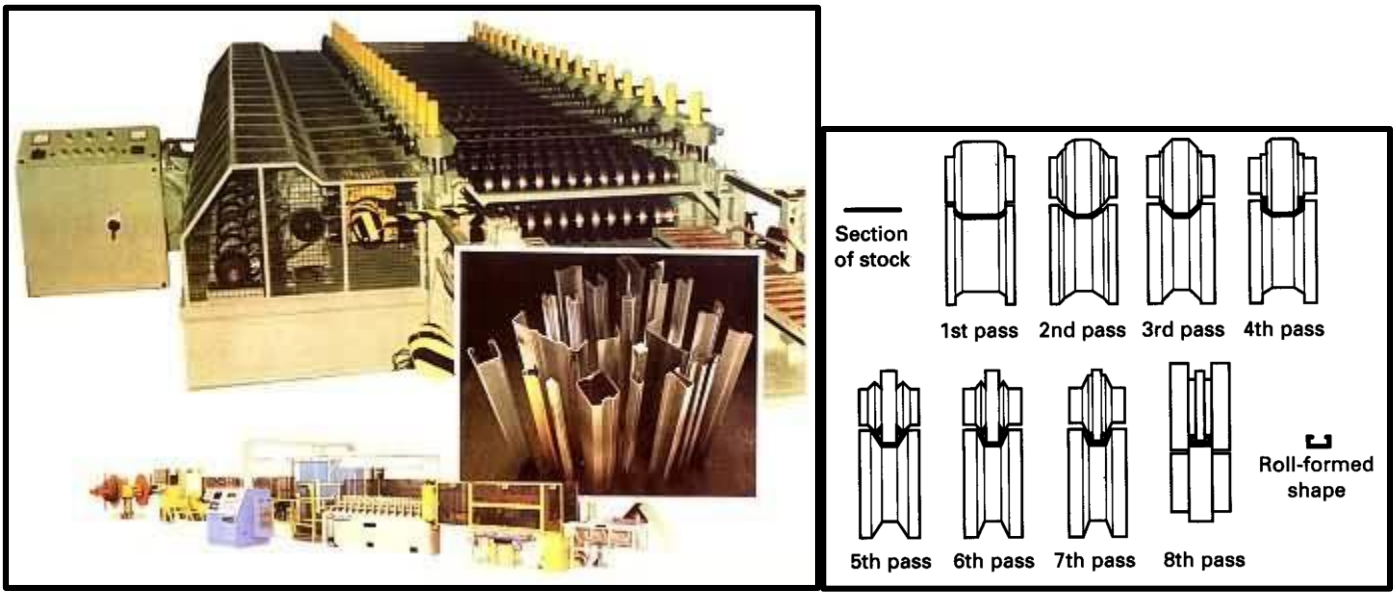
Plates, heavy sheets and rolled shapes can be bent to a desired curvature on forming rolls. These usually have three rolls in the form of a pyramid, with the two lower rolls being driven and the upper roll adjustable to control the degree of curvature.





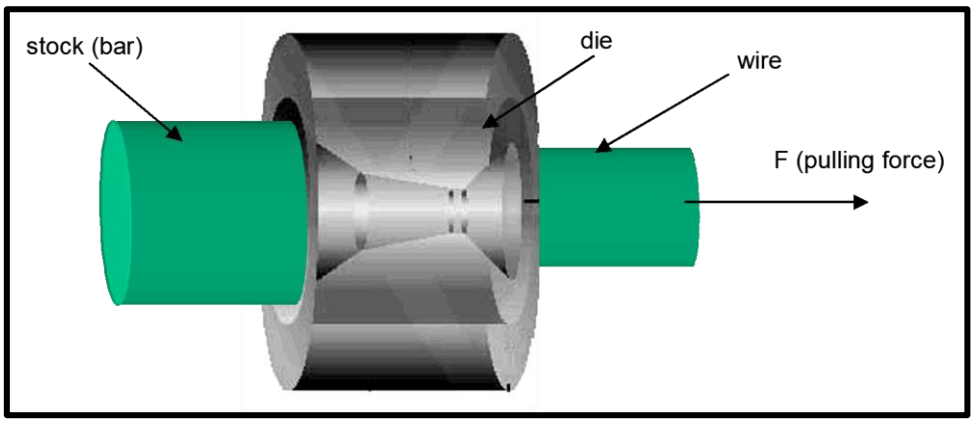
Cold Roll-Forming

Involves the progressive bending of metal strip as it passes through a series of forming rolls. By changing the rolls, a single machine can be adapted to the production of many different shapes.



5- Drawing Processes

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 Dies are made of specially hardened tool steels, or tungsten carbide. Diamond dies are used for drawing very fine wires.



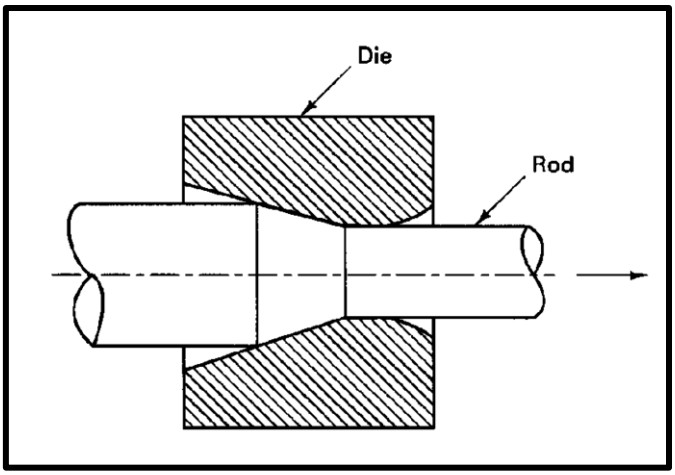
Schematic of the drawing process

If the stock is bar, tube, wire, or rod, cold drawing refers to the process of reducing the cross section and increasing the length of the metal by pulling it through a die.

Bar Drawing

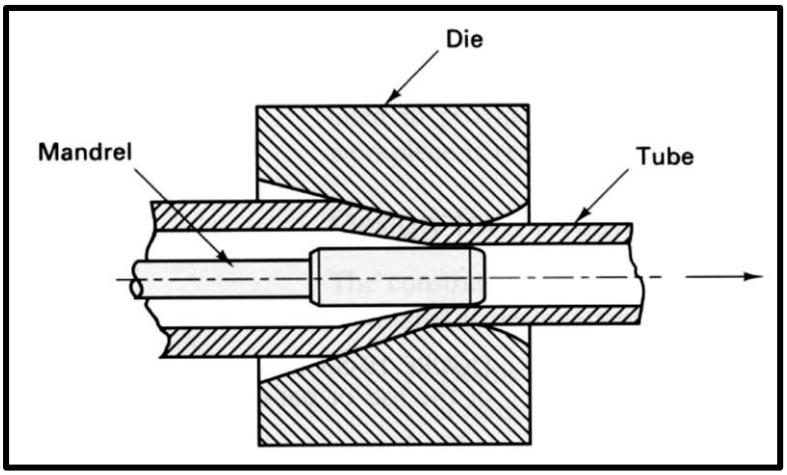
One end of a bar is reduced or pointed, inserted through a die of somewhat

smaller cross section than the original bar, grasped by grips and pulled in tension, drawing the remainder of the bar through the die. Intermediate annealing may be necessary to restore ductility and enable further working.



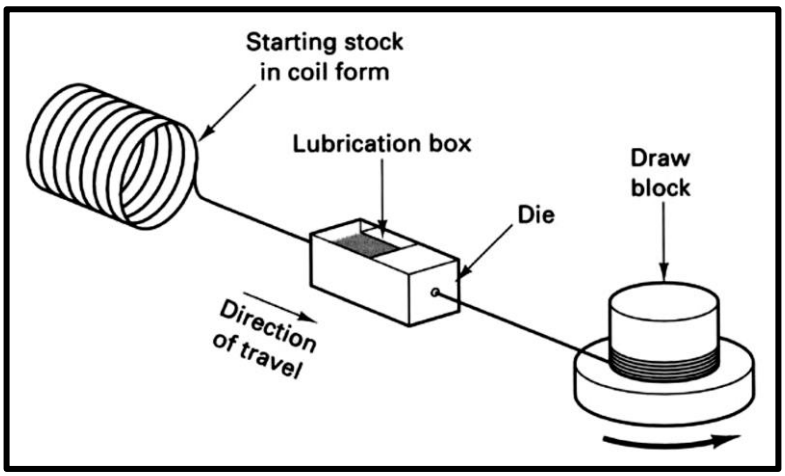
Tube Drawing

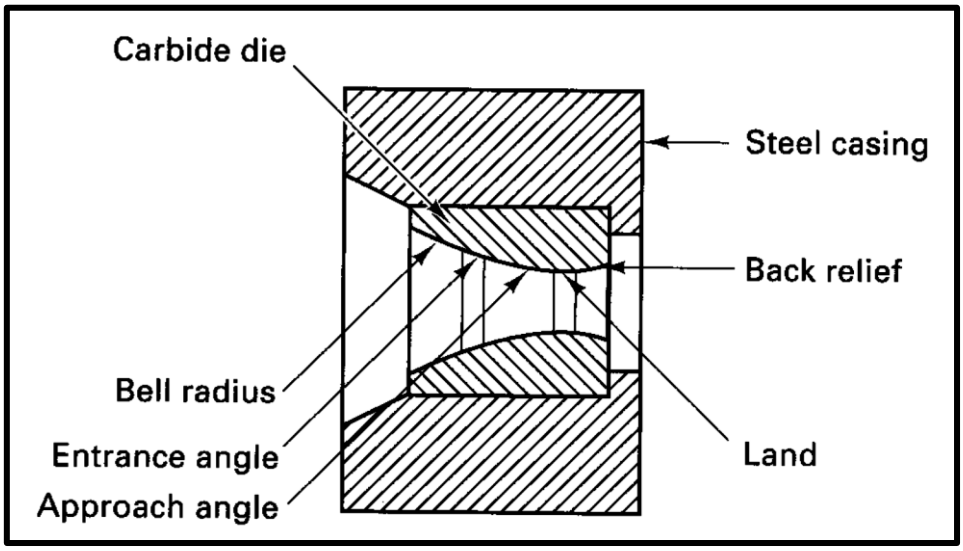
Tube drawing is used to produce seamless tubing. Mandrels are used for tubes from about 12.5 mm to 250 mm in diameter.



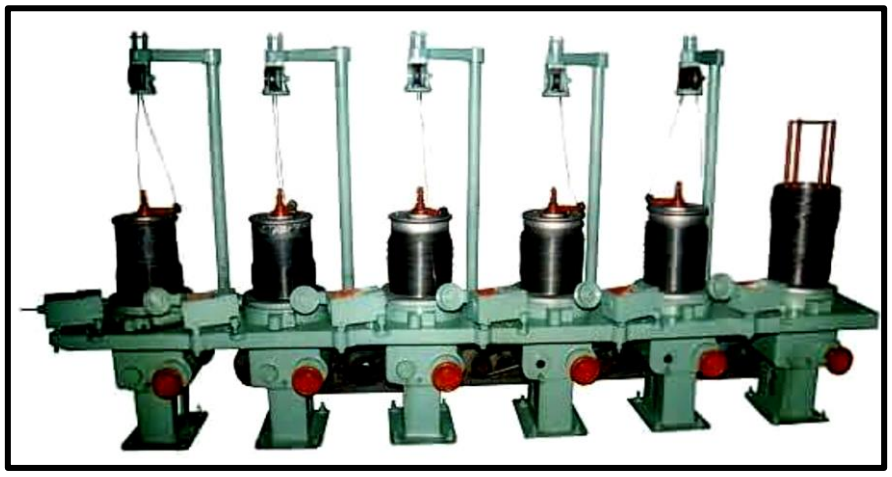
Wire Drawing

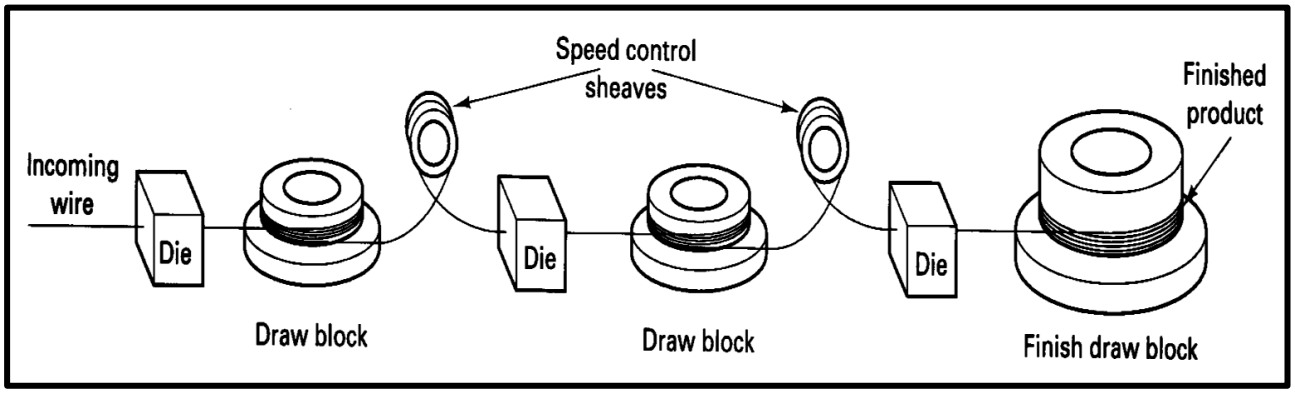
Wire drawing is essentially the same as bar drawing except that it involves smaller diameters and is generally done as a continuous process through a succession of drawing dies.





Small diameter wires are usually drawn on tandem machines which contain 3 to 12 dies, each held in water-cooled die blocks.





Deep Drawing

Deep drawing is a method of great importance, drawing of closed cylindrical or rectangular containers, or a variation of these shapes, with a depth greater than

the narrower dimension of their opening. It is commonly used to manufacture cooking utensils and other containers made from metal.

Figure below show the deep drawing process. As the punch pushes the blank down into the die cavity, and finally retracts; the part is finally ejected out of the cavity by an ejection pin.