2-2-4 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 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).

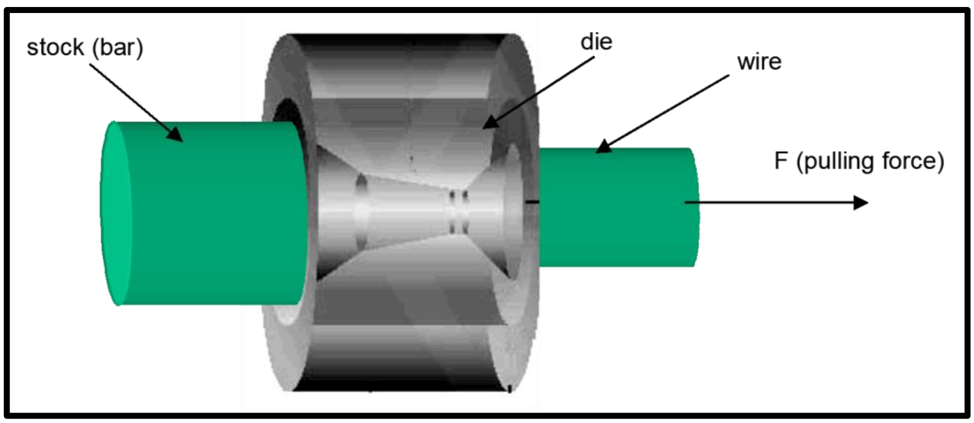


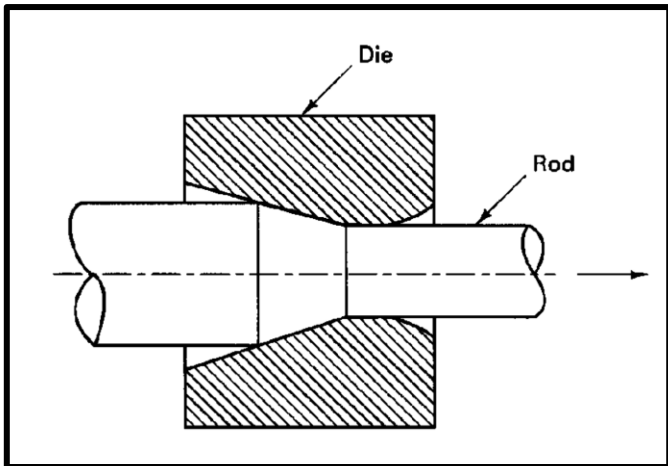
Figure (8): Schematic of the drawing process; the die is shown as semi-transparent to show the interior shape of the die hole

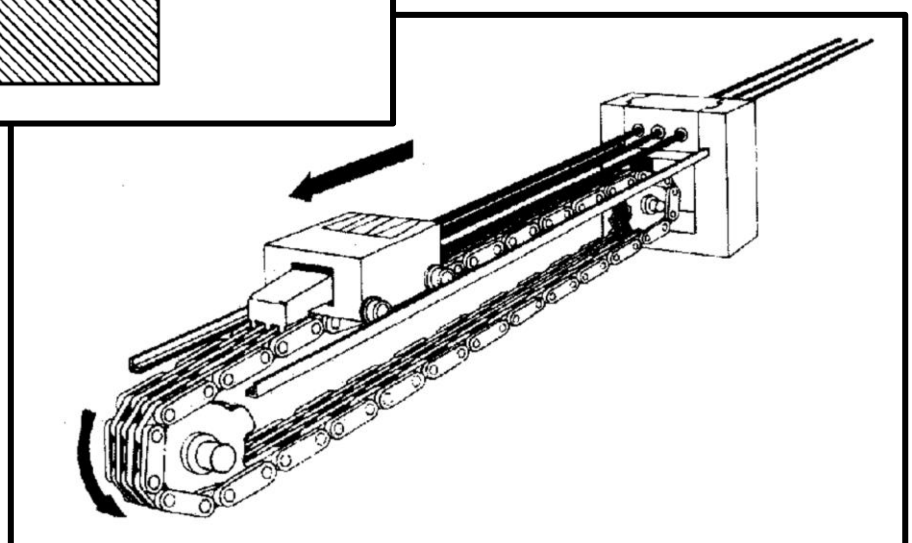
Cold drawing is a term that can refer to two somewhat different operations.
If the stock is in the form of sheet metal, cold drawing is the forming of three-dimensional parts wherein plastic flow occurs over a curved axis. This type of cold drawing is similar to hot drawing.

On the other hand, 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**

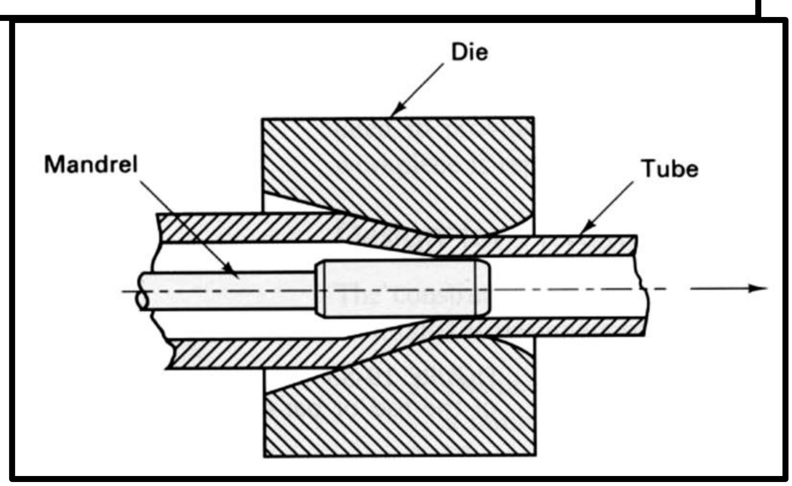
One end of a bar is reduced or pointed, inserted through a die of somewhat smaller cross section than the original bar, grasped by grips and pulled in tension, drawing the remainder of the bar through the die. Intermediate annealing may be necessary to restore ductility and enable further working.

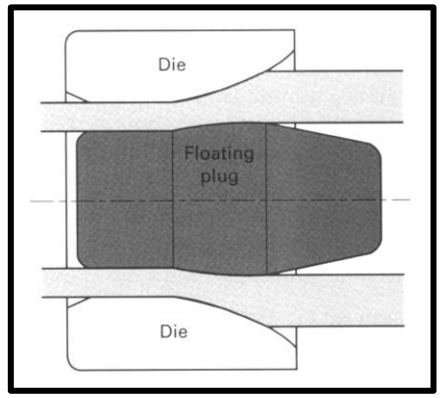


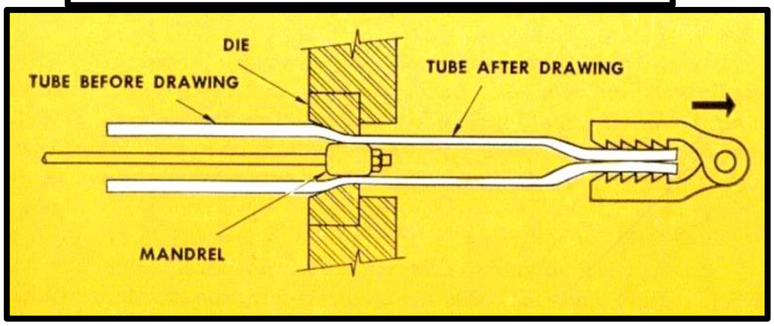


- **Tube Drawing**

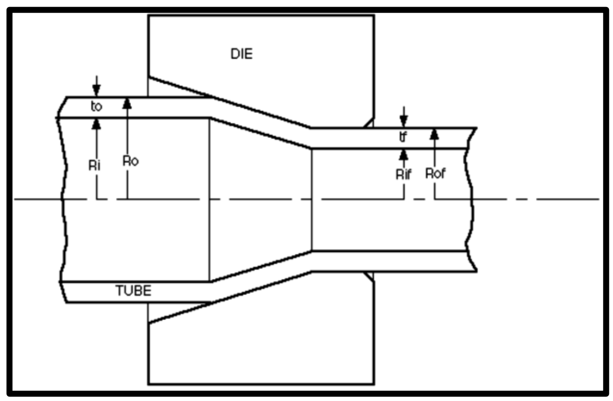
Tube drawing is used to produce seamless tubing. Mandrels are used for tubes from about 12.5 mm to 250 mm in diameter.





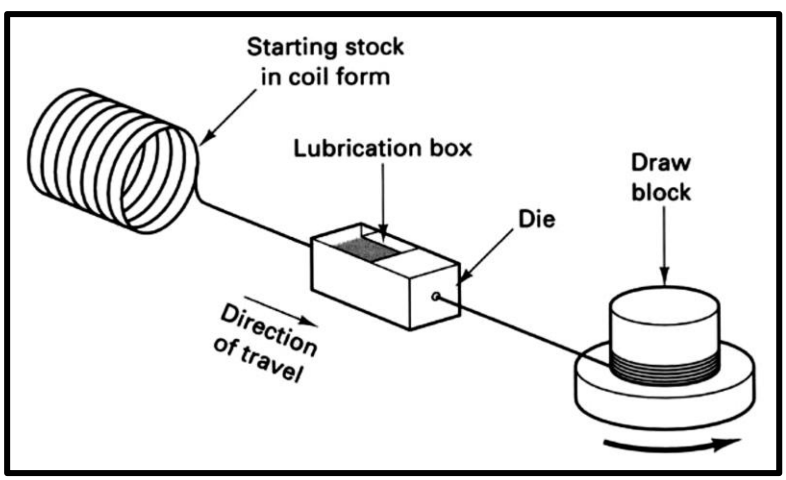


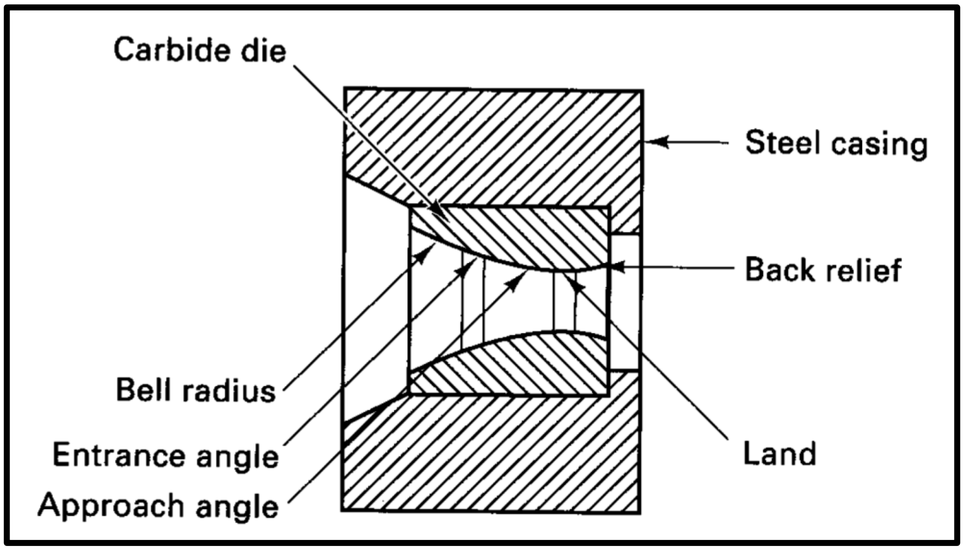
Heavy-walled tubes and those less than 12.5 mm in diameter are often drawn without a mandrel in a process known as tube sinking.



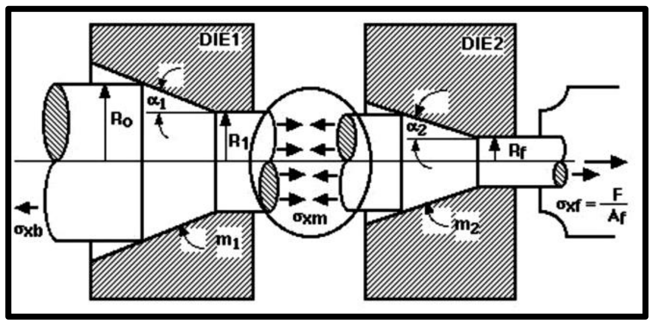
- **Wire Drawing**

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.

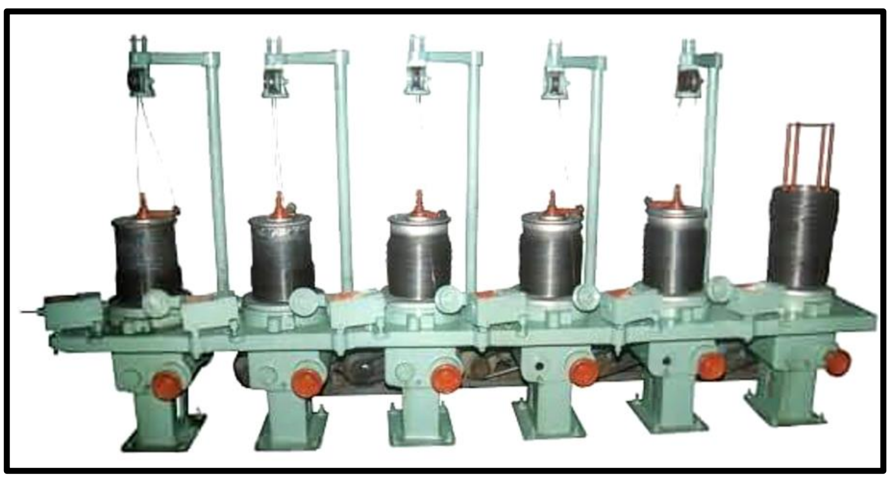


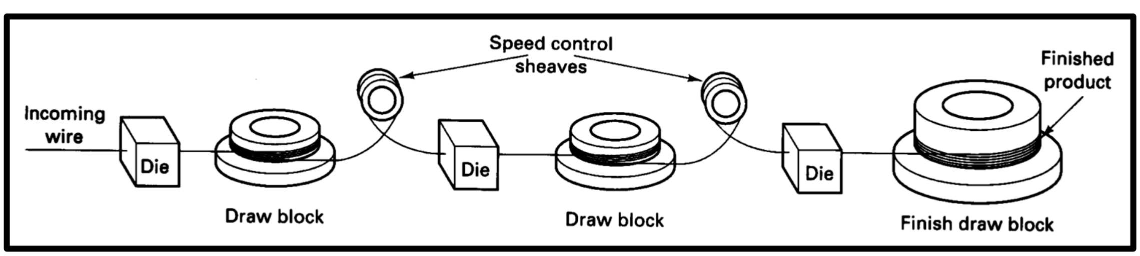


- **Carbide Wire Drawing Die**



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



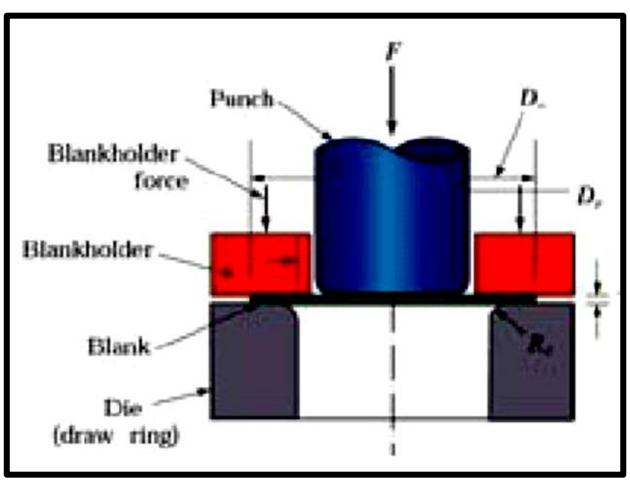


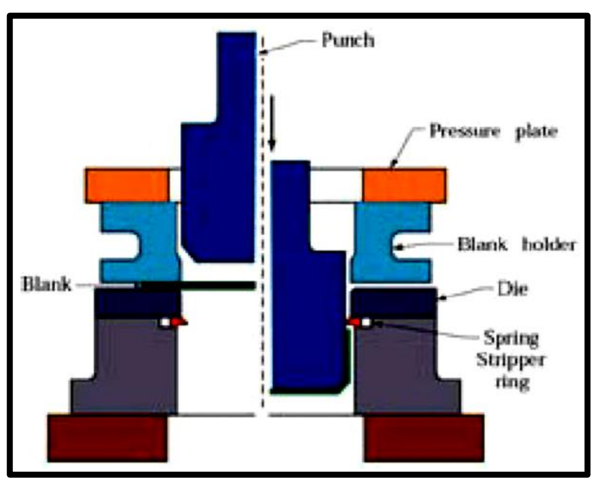
- **Deep Drawing (Shell Drawing)**

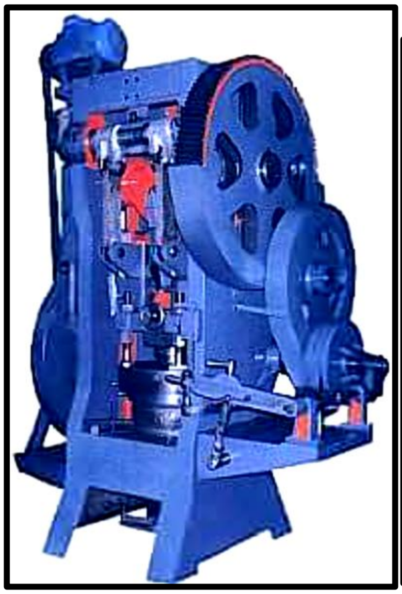
Deep drawing is a method of great importance, drawing of closed cylindrical or rectangular containers, or a variation of these shapes, with a depth greater than the narrower dimension of their opening. Because the process had its earliest uses in manufacturing artillery shells and cartridge cases, it is sometimes called shell drawing, which is commonly used to manufacture cooking utensils and other containers made from metal.

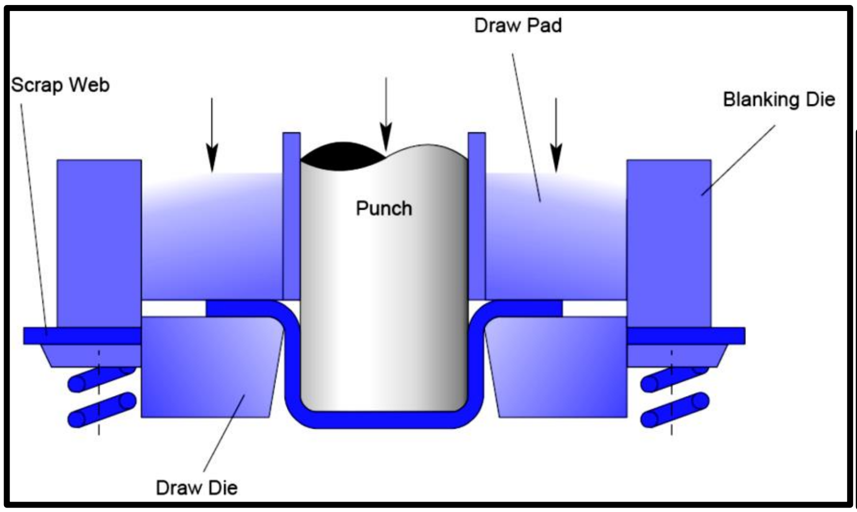
When the depth of the drawn part is less than the diameter, or minimum surface dimension of the blank, the process is considered to be shallow drawing.

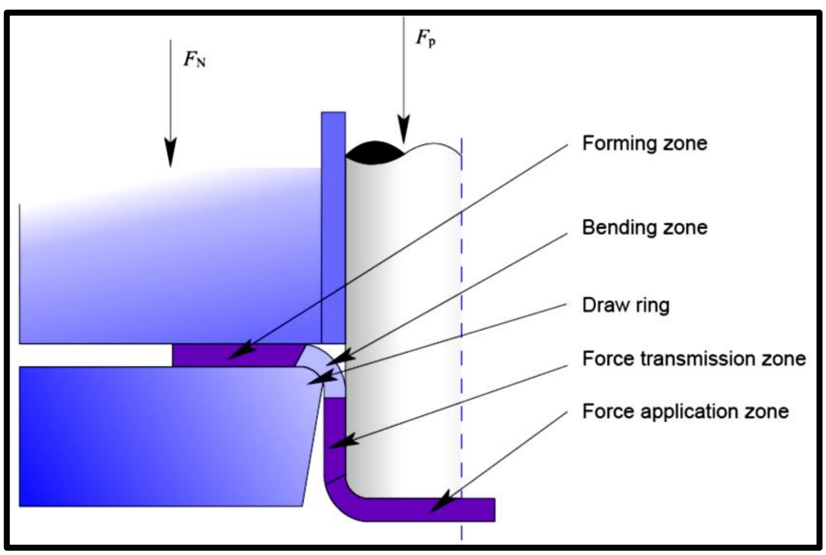
Another is deep drawing,. Figures below show the deep drawing process in several steps, as the punch pushes the blank down into the die cavity, and finally retracts; the part is finally ejected out of the cavity by an ejection pin (not shown in the figures). The blank is a piece of sheet-metal cut to the required shape. The die has a cavity in the shape that is required (the most common shape is cylindrical). The punch is of the same shape, but the difference in the size of the punch and the cavity is just sufficient to allow the sheet to be pushed by the punch into the die. As the punch pushes the sheet into the cavity, the upper portions of the sheet will tend to deform in wrinkled shapes – this is avoided by keeping the top part of the sheet pressed down by a blank holder.








Draw Pad
Scrap Web
Blanking Die
Punch
Draw Die


F_N
F_p
Forming zone
Bending zone
Draw ring
Force transmission zone
Force application zone

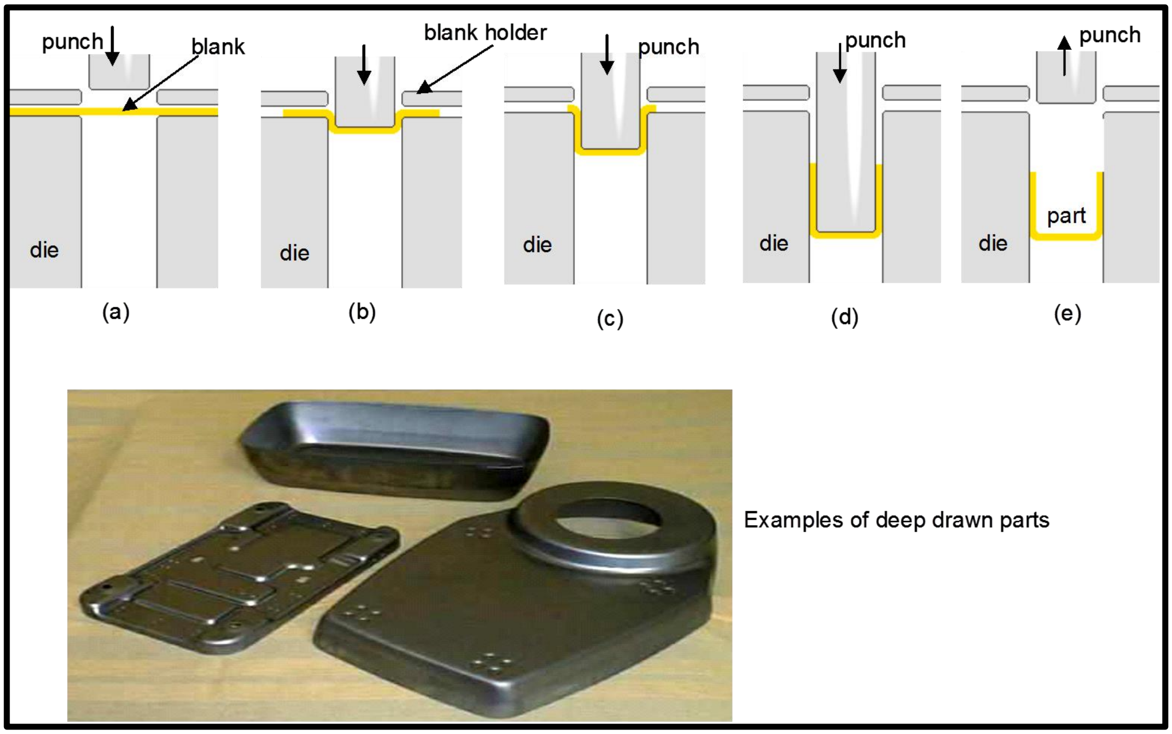


Figure (9): (top) stages of the deep drawing process and (bottom) some example parts Common applications

2-3 High energy rate forming processing

High Energy Rate Forming Processes:

A number of methods have been developed to form metals through the application of large amounts of energy in a very short time interval. They are known are High energy rate forming processes (HERF). Many metals tend to deform more rapidly under the ultra-rapid load application rates, used in these processes. The schematic of the HERF process and its variants are shown in Fig. 5.1.1.

High energy rates can be obtained by five distinct methods:

1. Due to explosions made underwater.
2. Due to underwater spark discharge (electro-hydraulic techniques)
3. By some pneumatic (mechanical) means.
4. Due to the internal combustion of mixture of gases.
5. By the use of rapid force magnetic fields (electromagnetic techniques).

Major Advantages:

- It is possible to form large workpieces and difficult to form metals, with less expensive equipment and tooling than would otherwise be required.
- Another advantage of HERF is that there is less difficulty related to spring back. This is associated with the following two factors:
  1. High compressive stresses are set up in the metal when it is forced against the die, and
  2. Some slight elastic deformation of die occurs under the ultra-high pressure. The latter results in a slight over forming of the workpiece and appears like no spring-back has occurred.

- **Underwater explosions:**

Three commonly used procedures under this are: (i) free forming, (ii) cylinder forming and (iii) bulk-head forming. While these can be used for a wide range of products, they are particularly suited for parts of thick materials like 10 feet diameter elliptical dome, only a tank of water in the ground is required, with about six feet of water above the workpiece. The female die can be made up of inexpensive material such as wood, plastic or low-melting temperature material.

- **Spark discharge method:**

This method uses the energy from electrical discharges to shape the metal. Electrical energy is stored in large capacitor banks and is then released in a controlled discharge, either between two electrodes or across an exploding bridge wire. High energy shockwaves propagate through a pressure transmitting medium and deform the workpiece material. The initiating wire can be preshaped and shockwave reflectors can be used to adapt the process to a variety of components.

The space between the workpiece and the die is usually evacuated before the discharge occurs, to prevent the possibility of puckering due to entrapped air. The schematic of this process is shown in Fig. 5.1.2.

The spark discharge methods are most often used for bulging operations in small parts, but parts up to 1.3 m in diameter have been formed. Compared to explosive forming, the discharge techniques are easier and safer, use smaller tanks and need not be performed in remote areas.

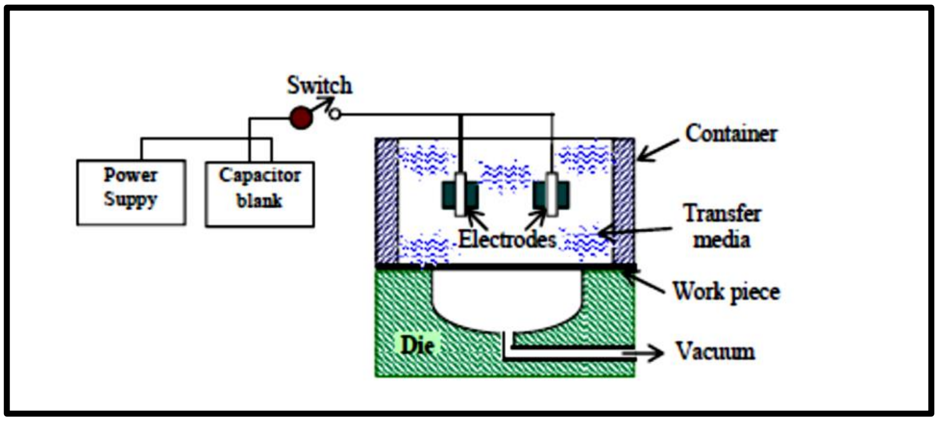


Figure (10): Schematic of the Spark discharge method of HERF

- **Pneumatic-mechanical and combustion techniques:**

These are preferred when the HERF methods are applied to mass production within a plant. In a pneumatic mechanical press, one portion of the forming die is attached to the stationary bolster of the press bed and the other to the movable piston. Low pressure gas acts on the entire bottom area of the piston, holding it up against a small area seal. High pressure gas is then applied to the other side of the seal and the pressure is steadily increased.

As the force pushing down (high pressure on a small area) exceeds that pushing up (low pressure on a large area), the seal is broken and the entire areas of the piston is exposed to high pressure gas. The piston moves rapidly downwards, bringing the dies into contact.

Internal combustion presses operate on the same principle as that of an automobile engine. A gaseous mixture is exploded within a cylinder, causing a piston to be driven downward in a rapid fashion. The upper segment of the forming die is attached to the bottom of the piston. Internal combustion pistons can produce die velocities upto 50 feet per second and cycle rates up to 60 strokes per minute. Either single or repeated blows can be used to form a part.

- **Electromagnetic forming (EMF):**

The electromagnetic forming process is based on the principle that the EM field of an induced current always opposes the electromagnetic field of the inducing current. A large capacitor bank is discharged, producing a current surge through a coiled conductor.

If the coil has been placed within a conductive cylinder, around a cylinder or adjacent to a flat sheet of metal, the discharge induces a secondary current in the workpiece, causing it to be repelled from the coil and conformed to a die or mating workpiece. The process is very rapid and is used primarily to expand or contract tubing or to permanently assemble component parts Coining, forming and swaging can also be performed with electromagnetic forces.

- **Electroforming:**

In electroforming process, the metal is electroplated onto a pre-shaped pattern or mandrel that has been fashioned from a material such as plastic, glass, pyrex, or other metal, such as aluminum or stainless steel. If the pattern material is non-conductive, a conductive coating is first applied. Then, metals such as nickel, iron, copper or silver are plated in thickness up to 15 mm. The workpiece is stripped from the mandrel as soon as the desired thickness is obtained.

- **Explosive forming**

Applications:

- Explosive forming can be utilized to form a wide variety of metals, from aluminum to high strength alloys, replacing the punch by an explosive charge.
- As in case of hydro-forming metal stamping process, HERF process exerts even force over the entire surface of the metal blank. The HERF process is capable of producing components large in size, with great details to very fine tolerances.
- The HERF process is employed in Aerospace and aircraft industries apart from the production of automotive components.

Explosives Used:

Explosives are substances that undergo rapid chemical reactions during which heat and large quantities of gaseous products are evolved. Explosives are either solid (TNT 'tri-nitro toluene'), liquid (Nitroglycerine) or Gaseous mixtures. Explosives are divided into two classes; Low Explosives are those in which ammunition is burnt out very rapidly without exploding, hence the pressure build up is not very large and High Explosives are those which have very high rates of reaction along with large pressure build ups. In guns and rockets for missile propulsions, low explosives are commonly used. Table-5.1.1 shows the features of these explosives.

These explosives are in the form of granules. The typical explosives used are Blasting gelatin, RDX (Cyclotrimethylene trinitramine, $C_3H_6N_6O_6$), TNT ($C_7H_5N_3O_6$), PETN (Pentaerythritol tetranitrate, $C_5H_8N_{12}O_4$), Tetryl (Trinitrophenylmethylinitramine, $C_7H_5O_8N_5$). These explosives have detonation velocities in the range of 7000-8400 m/s and the energy liberated is in terms of thousands of killo Joules per kilogram of explosive used.

Die Materials:

Different materials are used for manufacture of dies for explosive working, for instance, high strength tool steels, plastics, concrete etc. Relatively low strength

Table(2): Features of Low and High Explosives

Property	High Explosives	Low Explosives
Method of initiation	Primary HE–ignition, spark, flame, or impact Secondary HE-detonator, or detonator + booster	Ignition
Conversion time+	Microseconds	Milliseconds
Pressure	upto about 40,00,000 psi	upto about 40,000 psi

+ Time required for converting a working amount of high explosive into high-pressure gaseous products.

dies are used for short run items and for parts where close tolerances are not critical, while for longer runs, high strength die materials are required. Kirksite and plastic (fiber glass) faced dies are employed for light forming operations requiring low pressures and used for fewer parts. Ductile iron is used in high pressures and for mass production, whereas concrete is used for medium pressure and large part requirements.

Explosive Forming Characteristics:

- Used in very large sheets with relatively complex shapes of preferably axis-symmetric sections.
- It has low tooling costs, but high labor cost.
- It is suitable for low-quantity production.
- It has long cycle times.

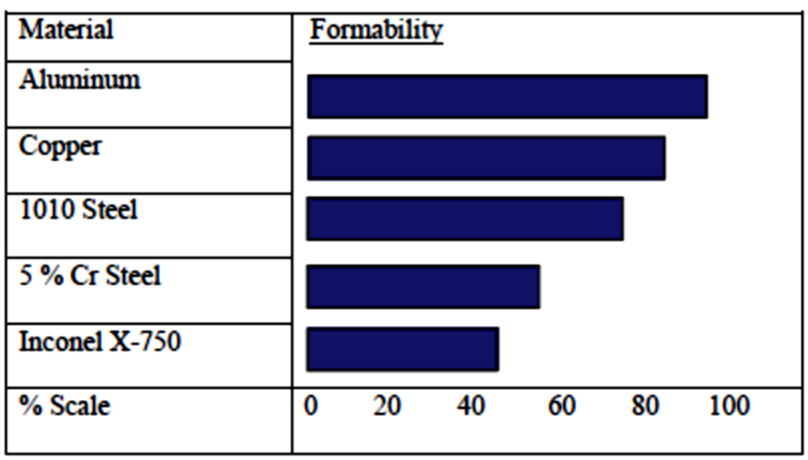
Transmission Medium:

Energy released by the explosive is transmitted through medium like air, water, oil, gelatin, liquid salts. Water is one of the best media for explosive forming since it is available readily, inexpensive and produces excellent results. The transmission medium is important regarding pressure magnitude at the workpiece. Water is more desirable medium than air for producing high peak pressures to the workpiece.

Formability Aspects:

Formability has been defined as the ability of a sheet metal to be deformed by a specific sheet metal forming process from its original shape to a defined shape without failure. In normal explosive forming operations, the major characteristics of the work metal that determine formability are ductility and toughness. It is general practice not to exceed the elongation as determined by the tension testing in forming a part from the same metal. Table (3) shows a comparison of formability of some metals, using annealed aluminum as a basis.

Table (3): Formability of different materials by explosive forming



Advantages of Explosion Forming

- If properly controlled, it can maintain tolerances.
- It eliminates costly welds.

- It can control the smoothness of contours.
- It reduces tooling costs.
- It is a less expensive alternative to super-plastic forming.

Limitations:

- The process has high initial cost due to special equipment, dies and energy used.
- In general, HERF is restricted to few materials.
- The die material should be strong enough to withstand the sudden shocks.
- Explosives used can be tremendously hazardous if the reactions are not controlled or handled properly.
- The surface finish and tolerances are not very high.