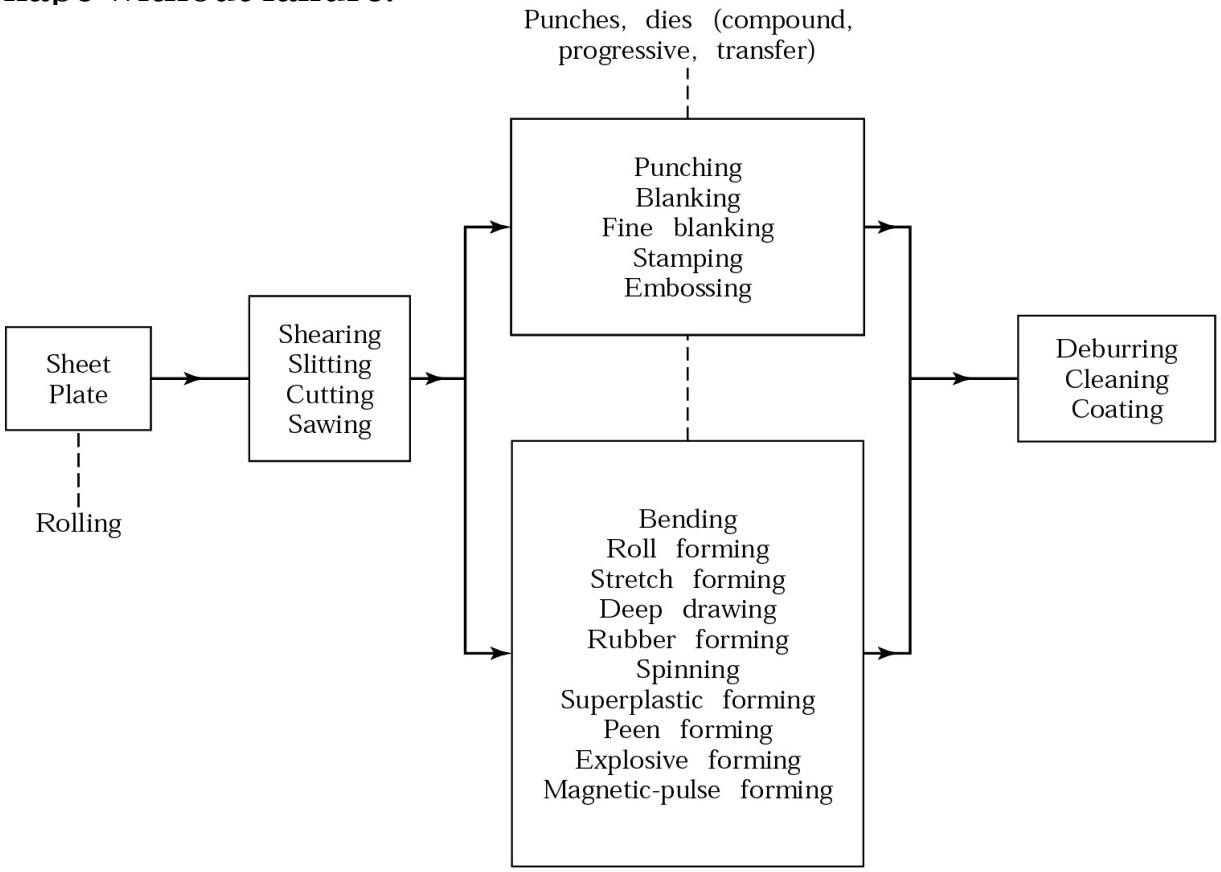
# Sheet Metal Forming

# Introduction

Sheet metal forming is a grouping of many *complementary processes* that are used to form sheet metal parts. One or more of these processes is used to take a flat sheet of ductile metal, and mechanically apply deformation forces that alter the shape of the material. Before deciding on the process(es), one should determine whether a particular sheet metal can be formed into the desired shape without failure.



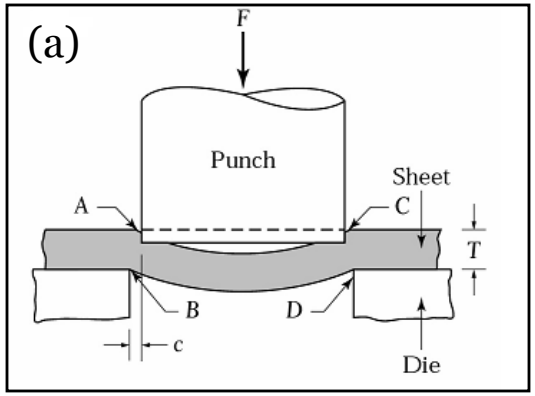

Outline of sheet-metal forming processes

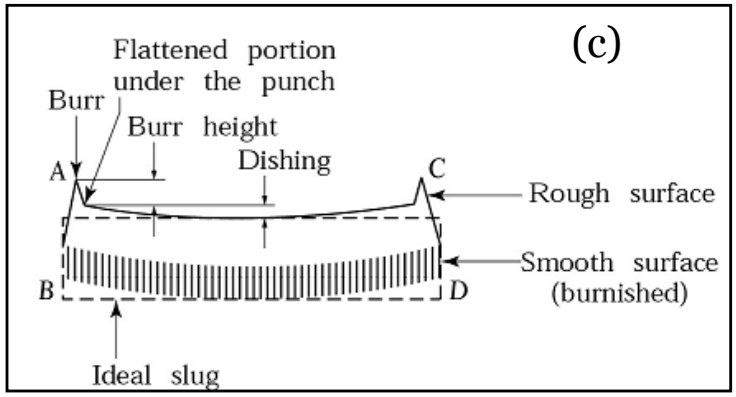
# Shearing

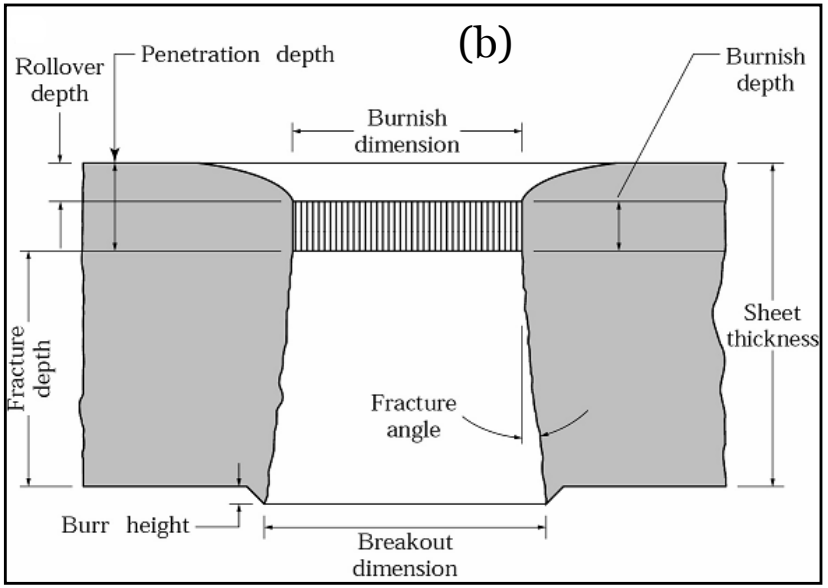
- Sheet metal subjected to shear stress developed between a punch and a die is called *shearing*
- Shearing usually starts with formation of cracks on both the top and bottom edges of the work piece. These cracks meet each other and separation occurs

## Process parameters :

- Shape of the material for the punch and die
- Speed of the punching ,lubrication and clearance




(a) Schematic illustration of shearing with a punch and die, indicating some of the process variables. Characteristic features of (b) a punched hole and (c) the slug.

# Sheet Metal Operations

The sheet metal operations done on a press may be grouped into two categories, cutting operations and forming operations.

**Cutting (shearing) operation**: In this operation, the workpiece is stressed beyond its ultimate strength. The stresses caused in the metal by the applied forces will be shearing stresses. The cutting operations include: blanking, punching (piercing), notching, perforating, trimming, shaving, slitting, lancing, and nibbling.

**Forming operation:** In this operation, the stresses are below the ultimate strength of the metal. In this operation, there is no cutting of the metal but only the contour of the workpiece is changed to get the desired product. The forming operations include: bending, drawing and squeezing.

Typical forming processes include:

- Roll forming
- Stretch forming
- Drawing
- Stamping
- Rubber forming
- Spinning
- Super-plastic forming
- Peen forming
- Explosive forming
- Magnetic-pulse forming

# Characteristics of Sheet Metal Forming Processes

| Process | Characteristics |
|---|---|
| Roll forming | • long parts with constant complex cross-sections;<br>• good surface finish;<br>• high production rates;<br>• high tooling costs. |
| Stretch forming | • large parts with shallow contours;<br>• suitable for low-quantity production;<br>• high labor costs;<br>• tooling and equipment costs. |
| Drawing | • shallow or deep parts with relatively simple shapes;<br>• high production rates;<br>• high tooling and equipment costs. |
| Stamping | • includes a variety of operations, such as punching, embossing, bending, flanging, and coining;<br>• simple or complex shapes formed at high production rates;<br>• tooling and equipment costs can be high, but labor cost is low. |
| Rubber forming | • drawing and embossing of simple or complex shapes;<br>• sheet surface protected by rubber membranes;<br>• flexibility of operation;<br>• low tooling costs. |

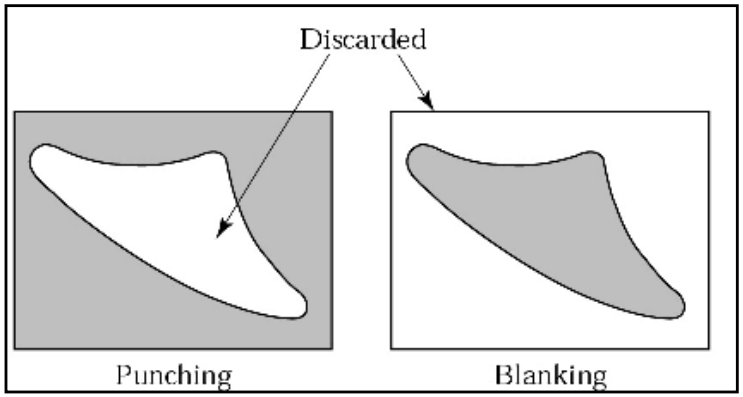
# Characteristics of Sheet Metal Forming Processes

| | |
|---|---|
| Spinning | • small or large axisymmetric parts;<br>• good surface finish; low tooling costs, but labor costs can be high unless operations are automated. |
| Super-plastic forming | • complex shapes, fine detail and close tolerances;<br>• forming times are long, hence production rates are low;<br>• parts not suitable for high-temperature use. |
| Peen forming | • shallow contours on large sheets;<br>• flexibility of operation;<br>• equipment costs can be high;<br>• process is also used for straightening parts. |
| Explosive forming | • very large sheets with relatively complex shapes, although usually axisymmetric;<br>• low tooling costs, but high labor cost;<br>• suitable for low-quantity production;<br>• long cycle times. |
| Magnetic-pulse forming | • shallow forming, bulging, and embossing operations on relatively low-strength sheets;<br>• most suitable for tubular shapes;<br>• high production rates;<br>• requires special tooling. |

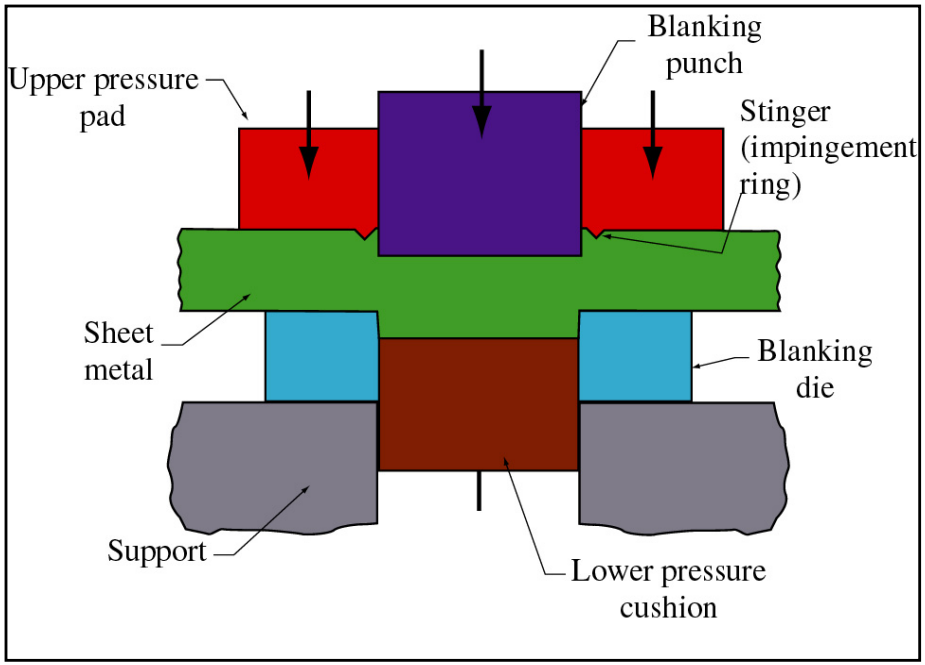
# Shearing Operations

Punching (piercing): It is a cutting operation by which various shaped holes are made in sheet metal. Punching is similar to blanking except that in punching, the hole is the desired product, the material punched out to form the hole being waste.

Blanking: Blanking is the operation of cutting a flat shape sheet metal. The article punched out is called the blank and is the required product of the operation. The hole and metal left behind is discarded as waste.




Punching (piercing) and blanking.




Schematic illustration of one setup for fine blanking.

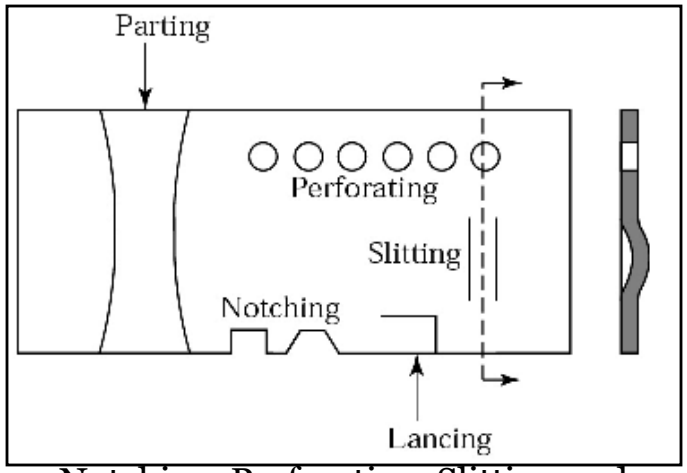
# Shearing Operations

**Notching** This is cutting operation by which metal pieces are cut from the edge of a sheet, strip or blank.

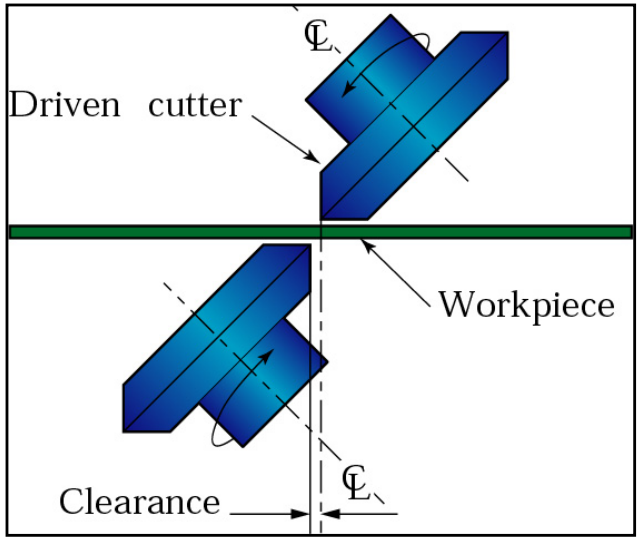
**Perforating** This is a process by which multiple holes which are very small and close together are cut in flat work material.

**Slitting** It refers to the operation of making incomplete holes in a workpiece.

**Lancing** This is a cutting operation in which a hole is partially cut and then one side is bent down to form a sort of tab. Since no metal is actually removed, there will be no scrap.




Notching, Perforating, Slitting and Lancing



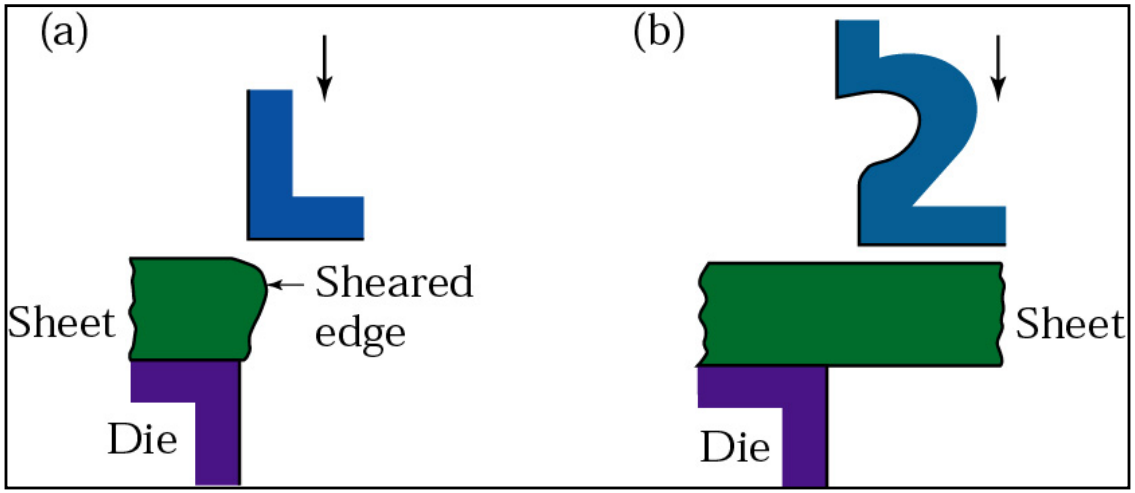

Slitting with rotary knives. This process is similar to opening cans

# Shearing Operations

**Shaving** The edge of blanked parts is generally rough, uneven and unsquare. Accurate dimensions of the part are obtained by removing a thin strip of metal along the edges.

**Trimming** This operation consists of cutting unwanted excess material from the periphery of previously formed components.

**Nibbling** The nibbling operation which is used for only small quantities of components, is designed for cutting flat parts from sheet metal. The flat parts range from simple to complex contours. This operation is generally substituted for blanking.




Schematic illustrations of the shaving of a sheared edge. (a) Shaving a sheared edge. (b) Shearing and shaving, combined in one stroke.

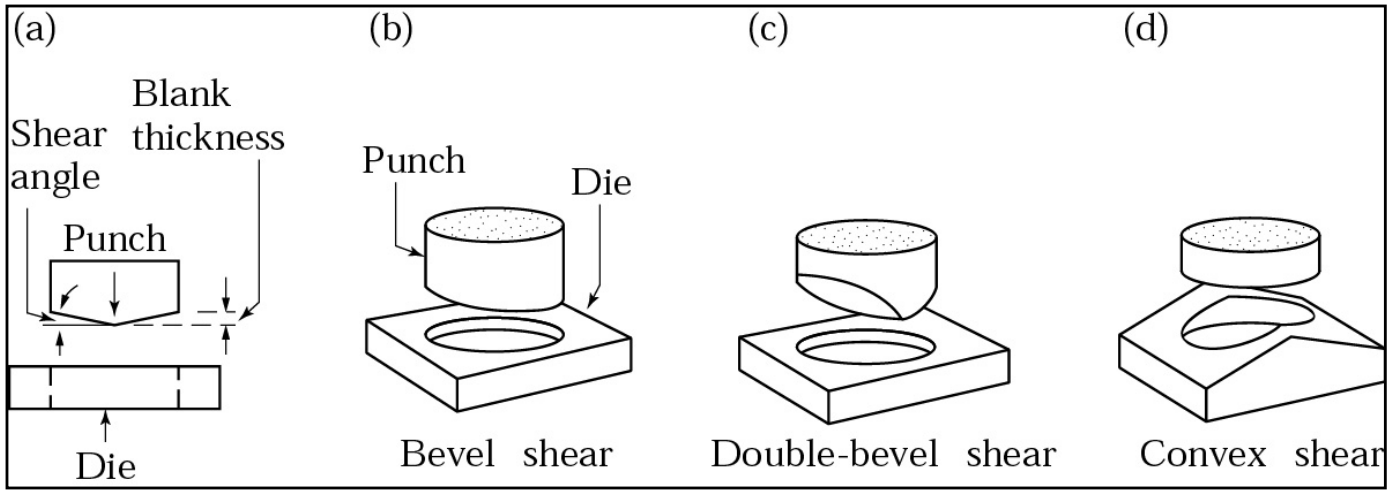
# Shearing Dies

**Clearance** : function of type of material,its temper and its thickness and of the size of the blank and its proximity to the edges

- Clearance of soft materials are less than harder grades

**Punch & die shapes:**

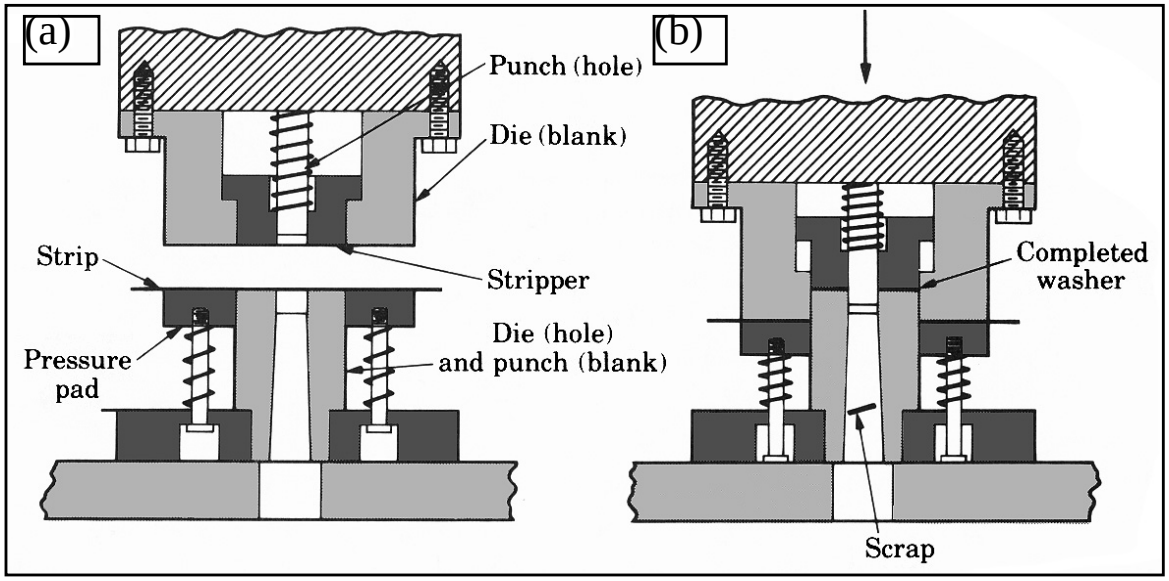
- Surfaces of punch and die are flat
- Punch force builds rapidly and entire thickness is sheared at same time.
- Bending is suitable for shearing thick surfaces




Examples of the use of shear angles on punches and dies.

# Shearing Dies

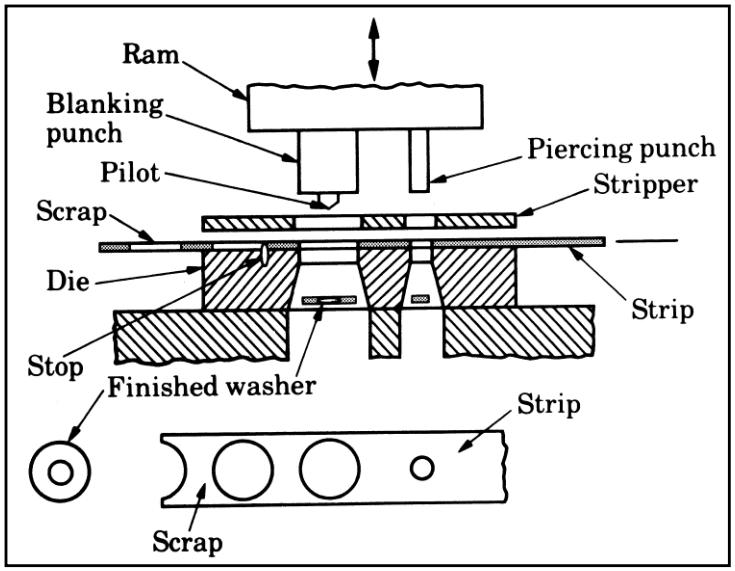
**Compound Dies:** Several operations on the same strip may be performed in one stroke with a compound die in one station. These operations are usually limited to relatively simple shearing because they are somewhat slow and the dies are more expensive than those for individual shearing operations.



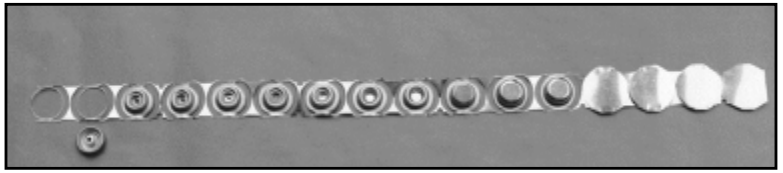

Schematic illustrations: (a) before and (b) after blanking a common washer in a compound die. Note the separate movements of the die (for blanking) and the punch (for punching the hole in the washer).

# Shearing Dies

**Progressive Dies:** Parts requiring multiple operations, such as punching, blanking and notching are made at high production rates in progressive dies. The sheet metal is fed through a coil strip and a different operation is performed at the same station with each stroke of a series of punches.




(a)

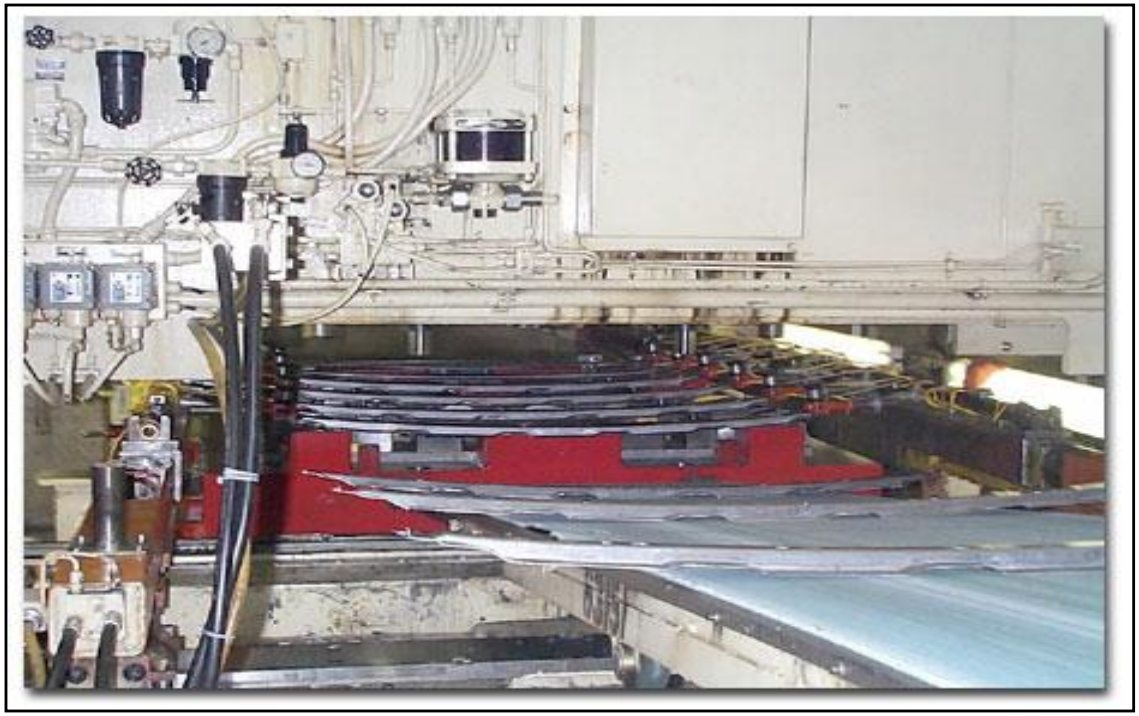


(b)

(a) Schematic illustration of making a washer in a progressive die. (b) Forming of the top piece of an aerosol spray can in a progressive die.

# Shearing Dies

**Transfer Dies:** In a transfer die setup, the sheet metal undergoes different operations at different stations, which are arranged along a straight line or a circular path. After each operation, the part is transfer to the next operation for additional operations.



**Tool and Die Material :** Carbides are used for high production rates.

# Forming Operations

**Bending** In this operation, the material in the form of flat sheet or strip, is uniformly strained around a linear axis which lies in the neutral plane and perpendicular to the lengthwise direction of the sheet or metal.

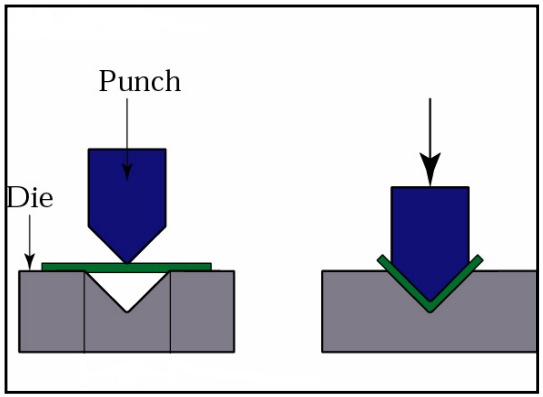
**Drawing** This is a process of a forming a flat workpiece into a hollow shape by means of a punch, which causes the blank to flow into die cavity.

**Squeezing** Under this operation, the metal is caused to flow to all portions of a die cavity under the action of compressive forces.

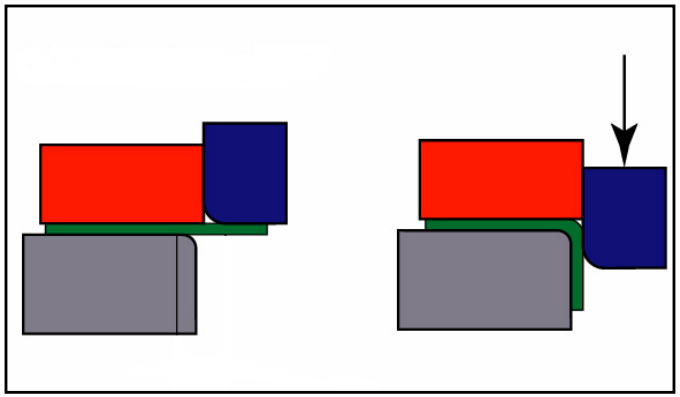
## Bending operations

- V-bending
- Edge bending
- Roll bending
- Air bending
- Flanging
- Dimpling
- Press break forming
- Beading
- Roll forming
- Tube forming
- Bulging
- Stretch forming

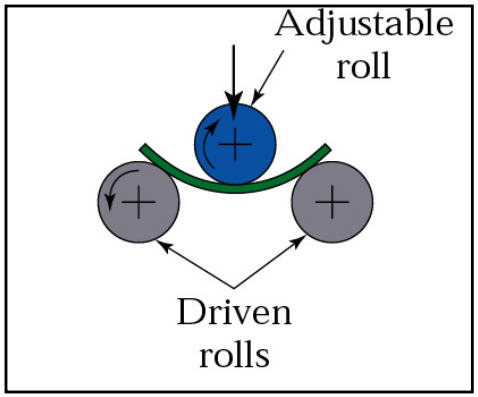
# Bending Operations



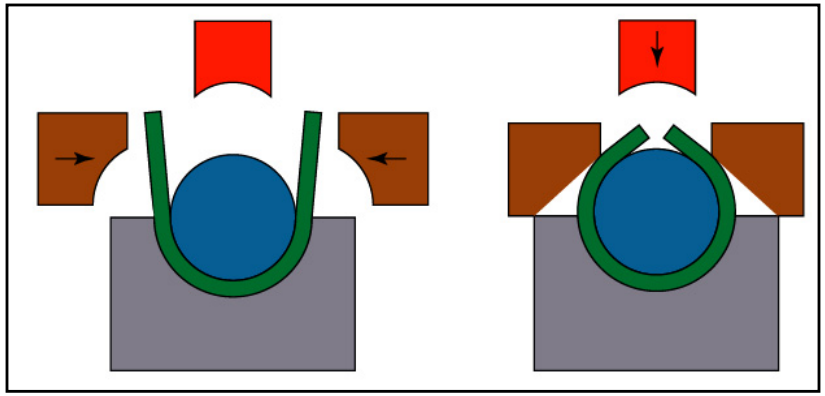

V-bending



Edge bending

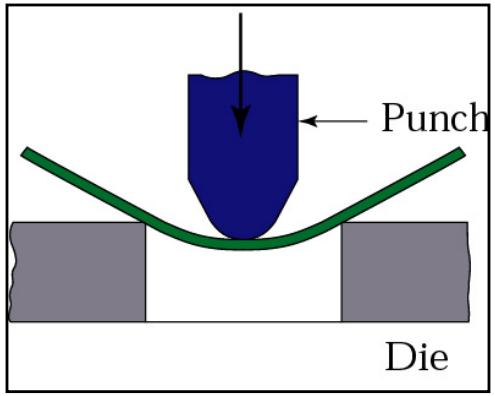



Roll bending



Bending in 4-slide machine

- Used for short pieces
- Controlled and synchronized with vertical die movements to form the part of desired shape




Air bending

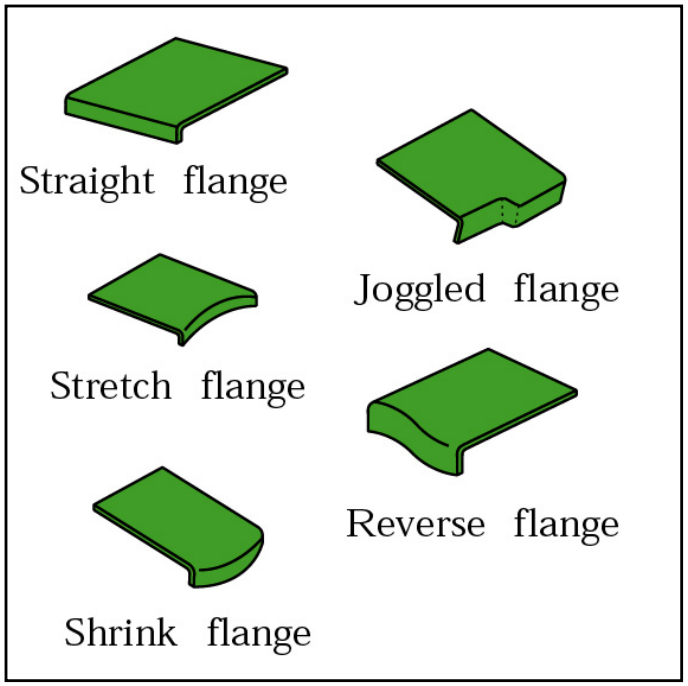
# Bending Operations

**Flanging :**Flanging is a process of bending the edges of sheet metals to 90°

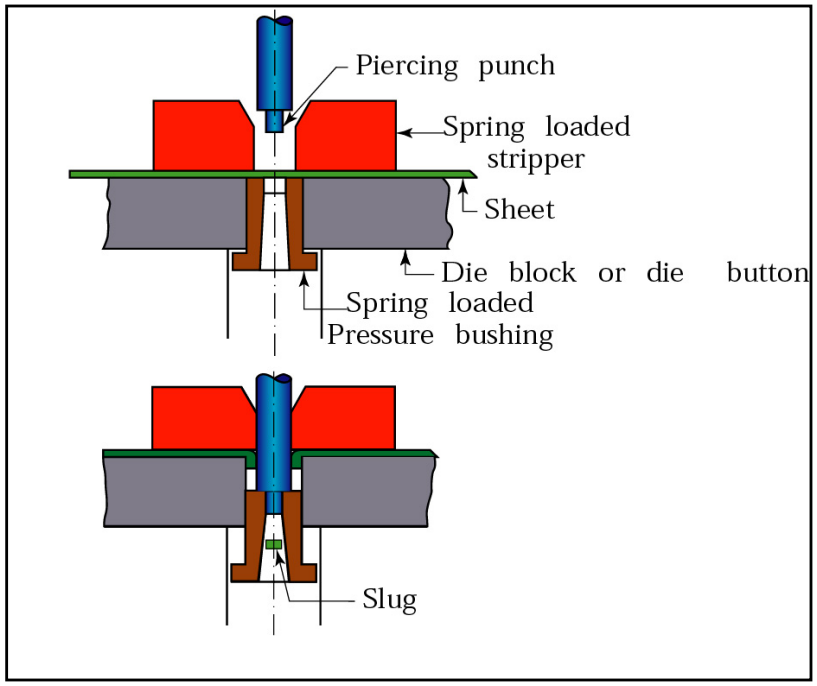
- Shrink flanging – subjected to compressive hoop stress.
- Stretch flanging –subjected to tensile stresses

**Dimpling :**

- First hole is punched and expanded into a flange
- Flanges can be produced by piercing with shaped punch
- When bend angle < 90 degrees as in fitting conical ends its called flanging



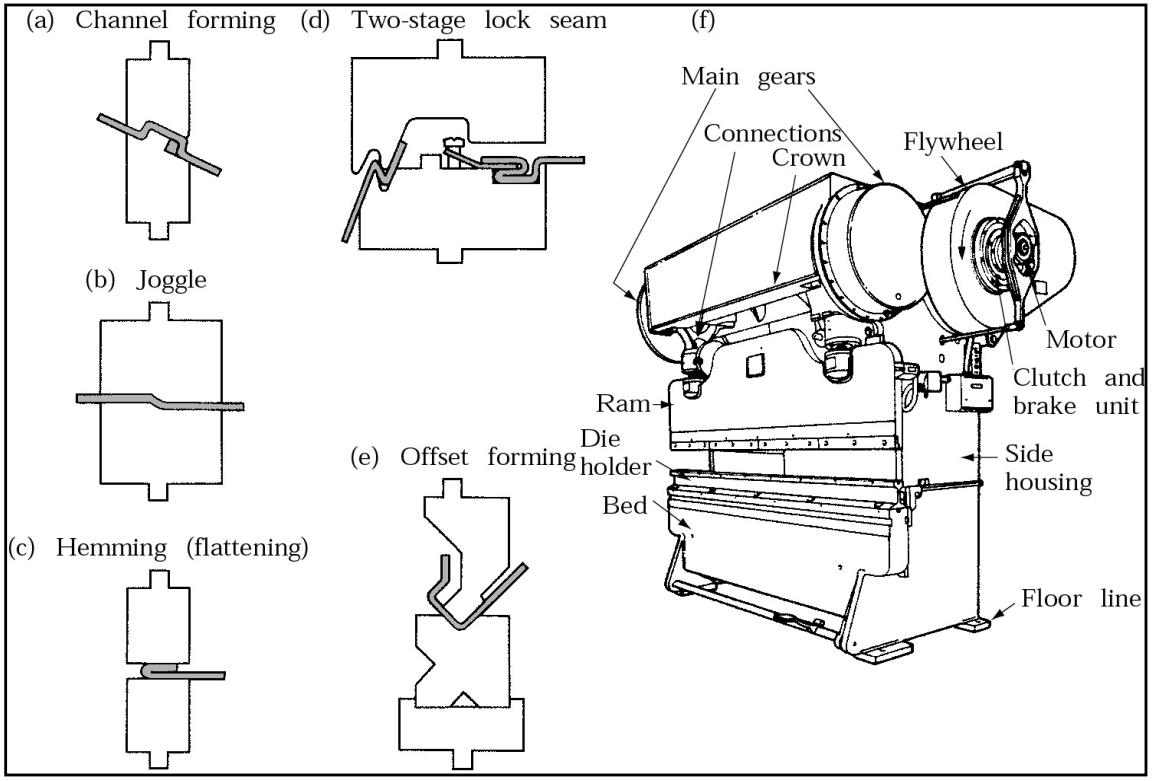

Flanging




Dimpling

# Bending Operations

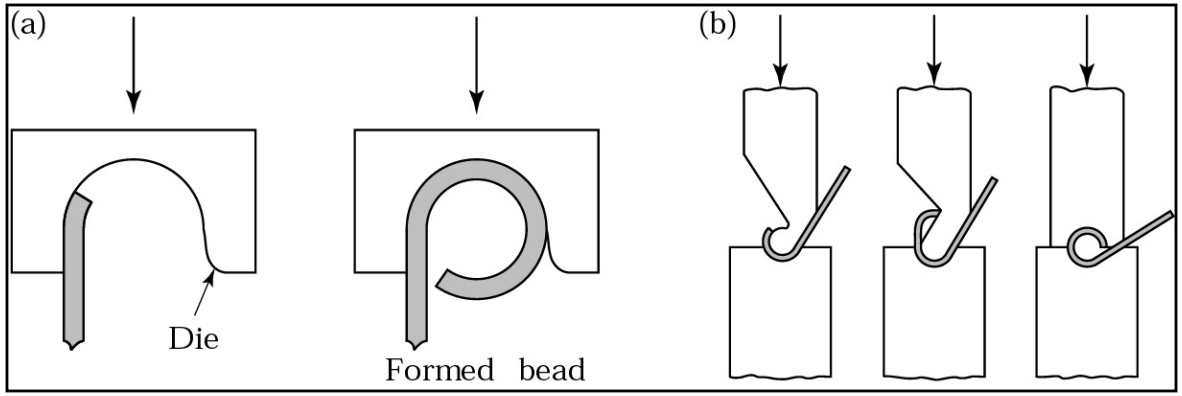
**Press break forming:** Sheet metal or plate can be bent easily with simple fixtures using a press. Long and relatively narrow pieces are usually bent in a press break. This machine utilizes long dies in a mechanical or hydraulic press and is suitable for small production runs. The tooling is simple and adaptable to a wide variety of shapes.




(a-e) Schematic illustrations of various bending operations in a press brake. (f) Schematic illustration of a press brake.

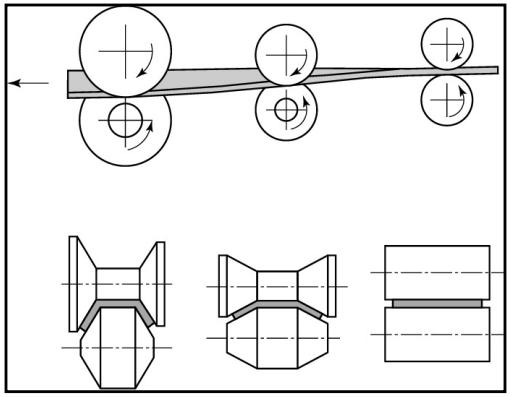
# Bending Operations

**Beading**: In beading the edge of the sheet metal is bent into the cavity of a die. The bead gives stiffness to the part by increasing the moment on inertia of the edges. Also, it improves the appearance of the part and eliminates exposed sharp edges




(a) Bead forming with a single die. (b) Bead forming with two dies, in a press brake.

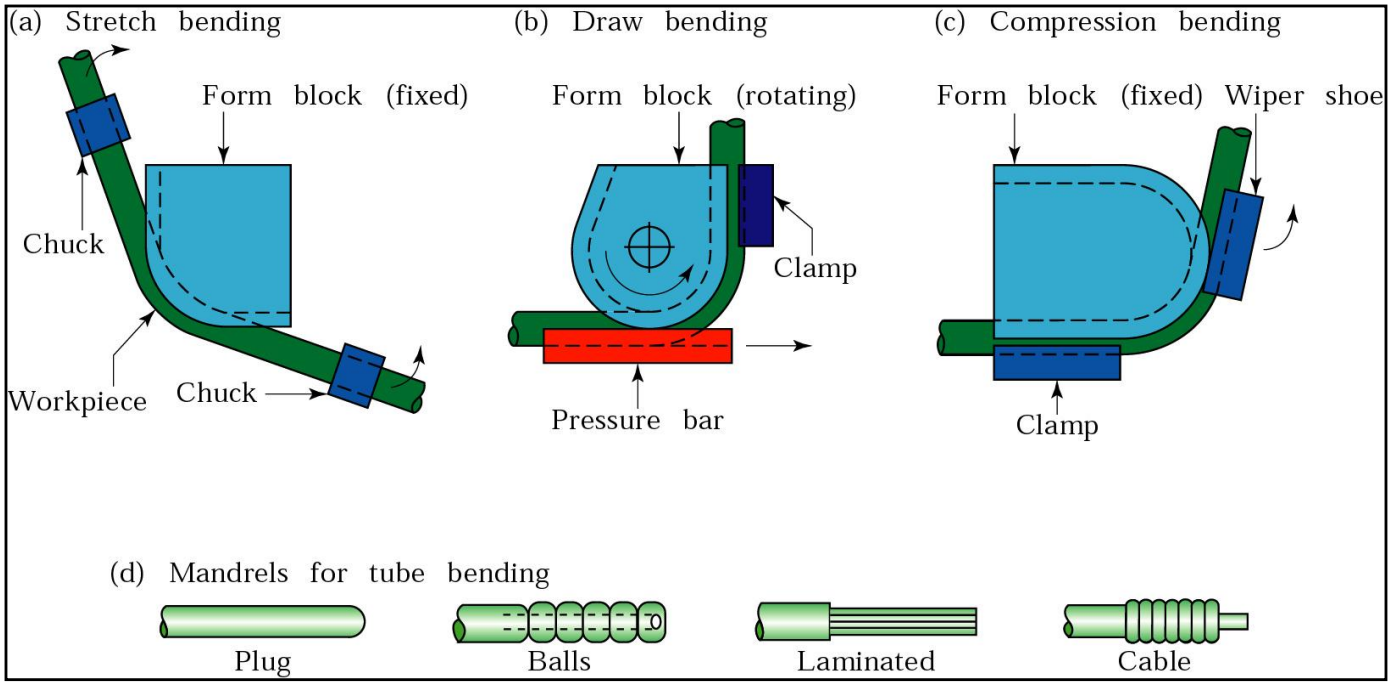
**Roll forming**: For bending continuous lengths of sheet metal and for large production runs, roll forming is used. The metal strip is bent in stages by passing it through a series of rolls.



Roll-forming process.

# Bending Operations

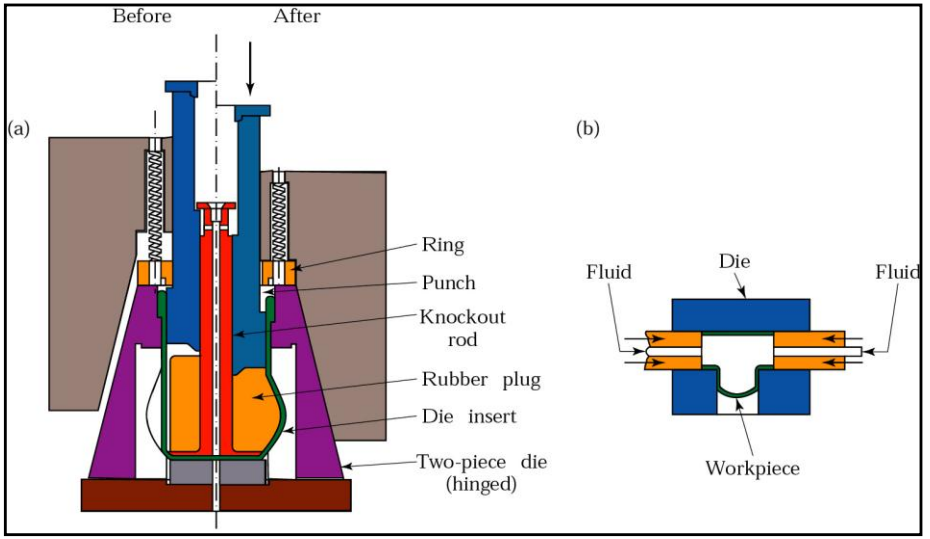
**Tube Bending:** Bending and forming tubes and other hollow sections require special tooling to avoid buckling and folding. The oldest method of bending a tube or pipe is to pack the inside with loose particles, commonly used sand and bend the part in a suitable fixture. This techniques prevents the tube from buckling. After the tube has been bent, the sand is shaken out. Tubes can also be plugged with various flexible internal mandrels.



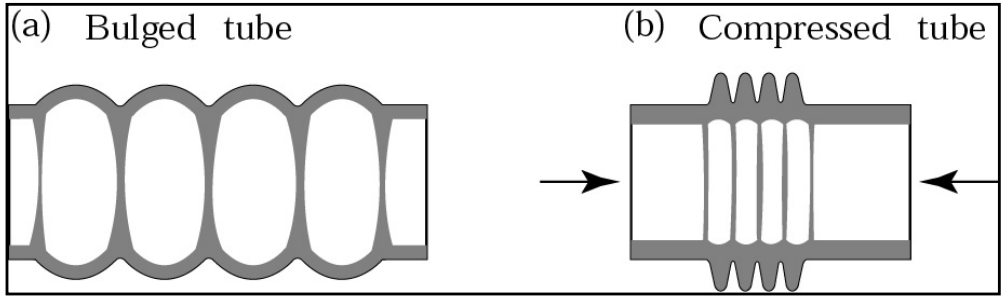

Methods of bending tubes. Internal mandrels,or the filling of tubes with particulate materials such as sand,are often necessary to prevent collapse of the tubes during bending .Solid rods and structural shapes can also be bent by these techniques

# Bending Operations

**Bulging**: The basic forming process of bulging involves placing tabular, conical or curvilinear part into a split-female die and expanding it with, say, a polyurethane plug. The punch is then retracted, the plug returns to its original shape and the part is removed by opening the dies.




(a) Bulging of a tubular part with a flexible plug. Water pitchers can be made by this method. (b) Production of fittings for plumbing, by expanding tubular blanks under internal pressure. The bottomof the piece is then punched out to produce a "T."

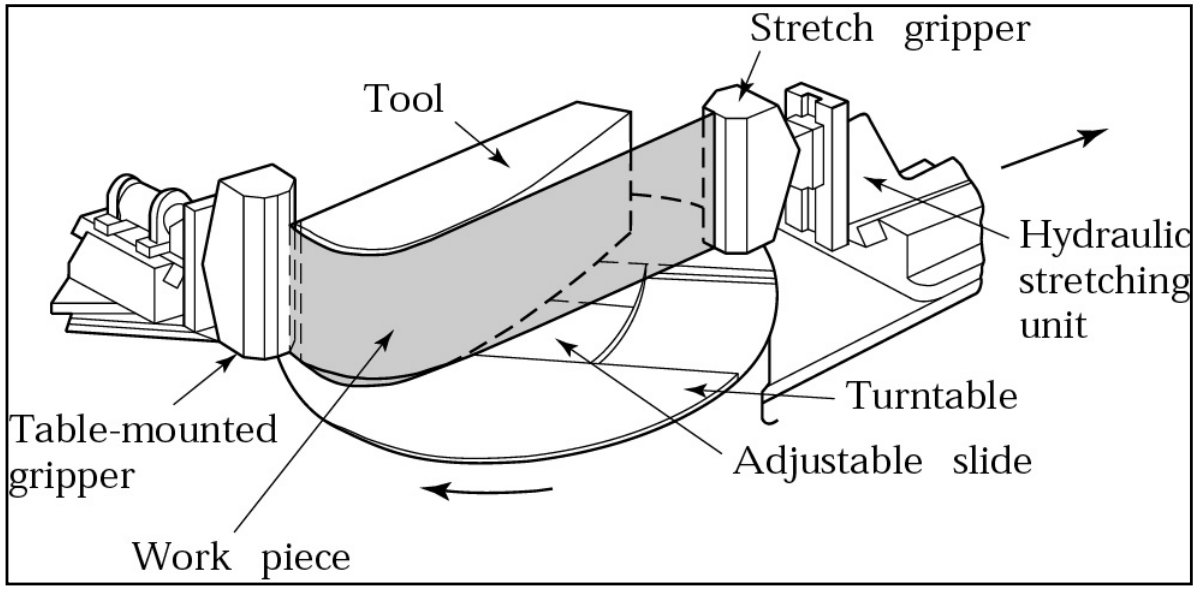



Manufacturing a bellows

# Bending Operations

**Stretch Forming**:

- Sheet metal clamped along its edges and stretched over a die or form block in required directions.
- Punch forces a flat sheet metal into a deep die cavity
- Round sheet metal block is placed over a circular die opening and held in a place with blank holder & punch forces down into the die cavity

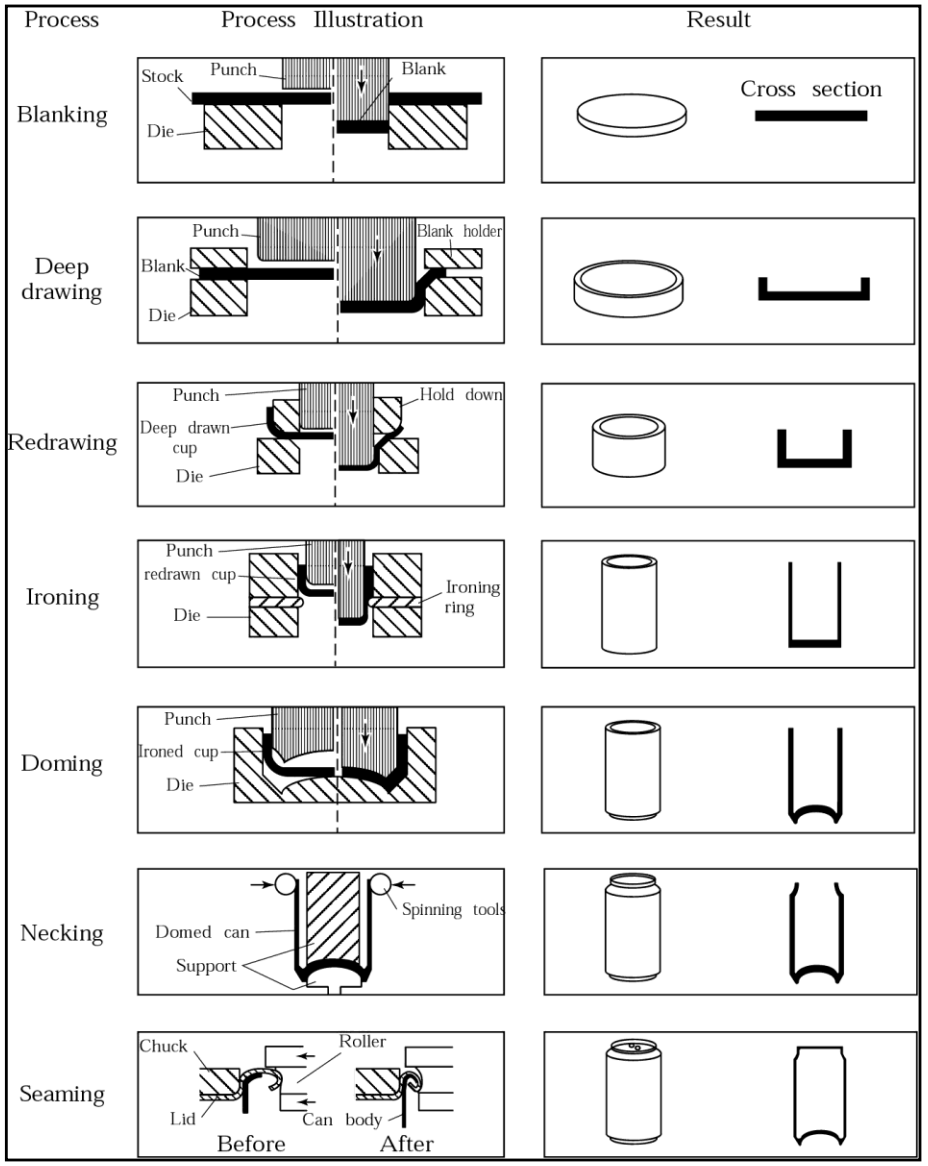



Stretch-forming process. Aluminum skins for aircraft can be made by this method.

# Manufacturing an Aluminum Can

## Steps in Manufacturing an Aluminum Can

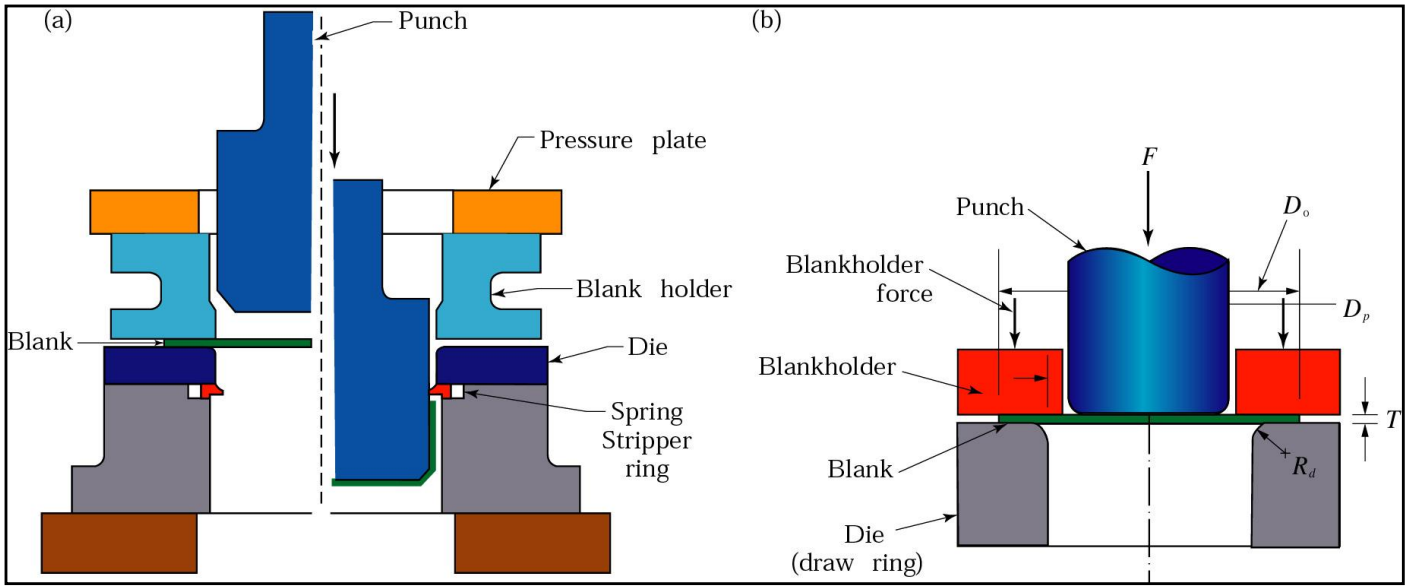
The metal-forming processes involved in manufacturing a two-piece aluminum beverage can



# Drawing Operations

**Deep Drawing:** Drawing operation is the process of forming a flat piece of material (blank) into a hollow shape by means of a punch, which causes the blank to flow into the die-cavity . Round sheet metal block is placed over a circular die opening and held in a place with blank holder & punch forces down into the die cavity. Wrinkling occurs at the edges.

- Shallow drawing: depth of formed cup ≤ D/2
- Deep or moderate drawing: depth of formed cup > D/2



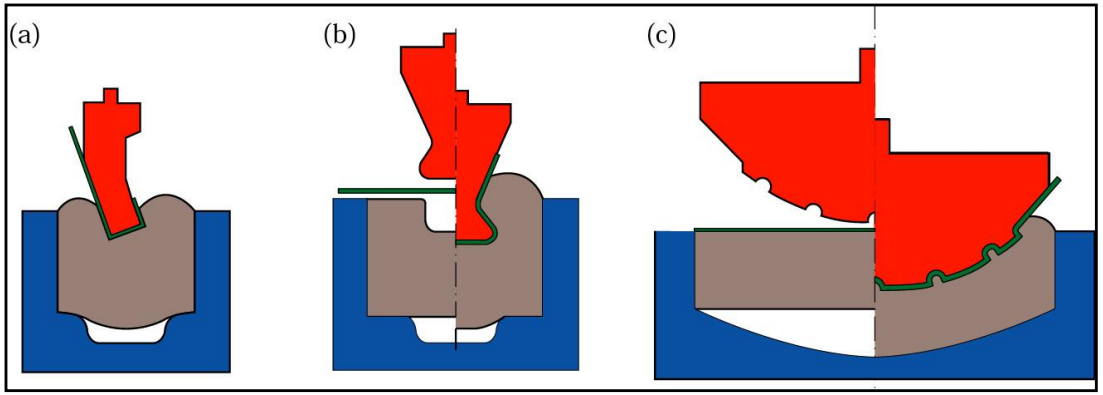

(a) deep-drawing process on a circular sheet-metal blank. The stripper ring facilitates the removal of the formed cup from the punch. (b) Process variables in deep drawing. Except for the punch force, *F*, all the parameters indicated in the figure are independent variables.

# Drawing Operations

**Deep Drawability:** Deep drawability or drawing ratio of a metal is defined as the ratio of the maximum blank diameter (D) to the diameter of the cup (d) drawn from the blank (usually taken to be equal to the punch diameter), i.e. D/d. For a given material there is a limiting drawing ratio (LDR), after which punch will pierce a hole in the blank instead of drawing the blank. This ratio depends upon many factors, such as type of material, amount of friction present, etc. The usual range of the maximum drawing ratio is 1.6 to 2.3.

## Rubber Forming

- Large flexible rubber base acts as a die
  - The rubber acts like a semi fluid medium pushing the sheet against the die shape
- Advantages
  - Only one side of the die needs to be made
- Disadvantages
  - Shapes are limited

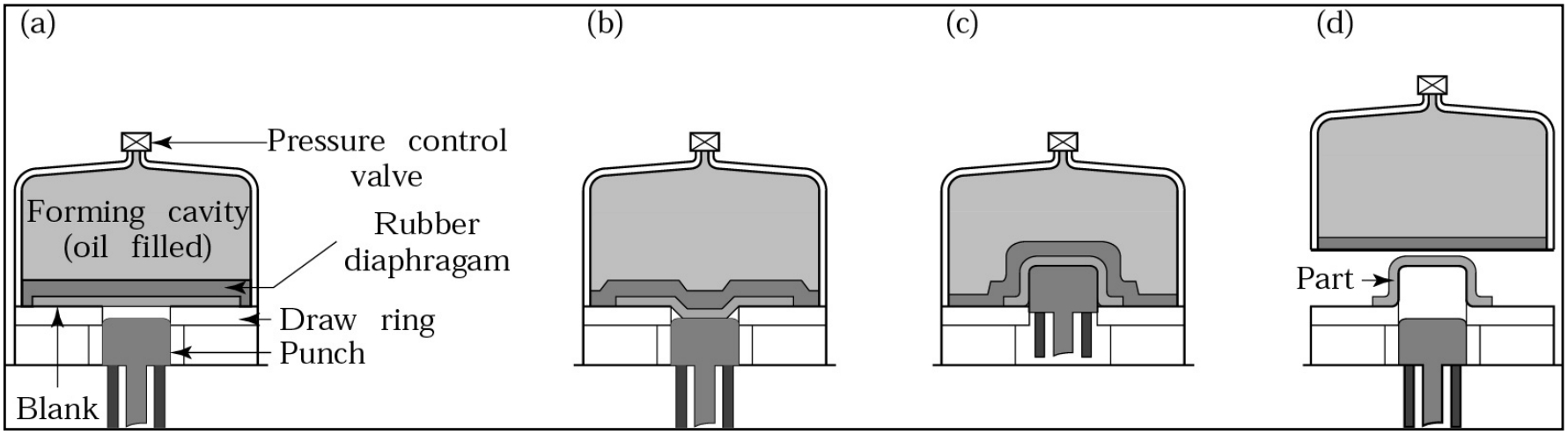



Examples of the bending and the embossing of sheet metal with a metal punch and with a flexible pad serving as the female die.

# Hydro-Form (or) Fluid Forming Process

## Hydro-form (or) Fluid Forming Process:

- The pressure over rubber membrane is controlled through out the forming cycle, with max pressure up to 100 Mpi
- As a result the friction at the punch-cup interface increases ,this increase reduces the longitudinal tensile stresses in the cup and delays fracture

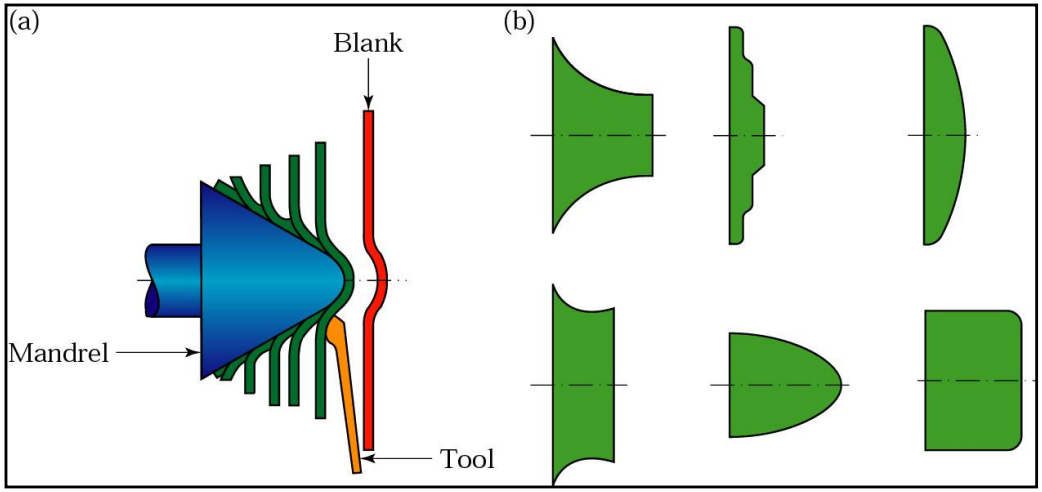



The hydroform (or fluid forming) process. Note that, in contrast to the ordinary deep-drawing process, the pressure in the dome forces the cup walls against the punch. The cup travels with the punch; in this way, deep drawability is improved.

**Spinning:** Shaping thin sheets by pressing them against a form with a blunt tool to force the material into a desired form . There are different types of spinning like, conventional spinning, shear spinning and tube spinning.

# Spinning

**Conventional Spinning:** A circular blank if flat or performed sheet metal hold against a mandrel and rotated ,while a rigid metal is held against a mandrel and rotated ,wile a rigid tool deforms and shapes the material over the mandrel.

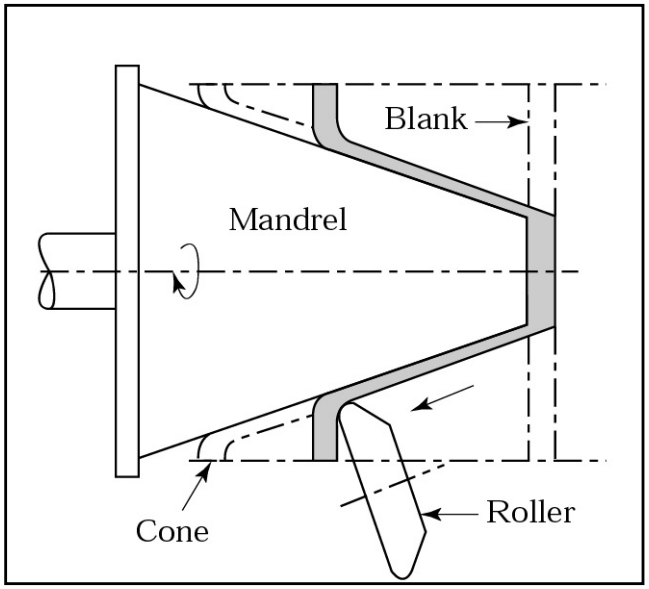



(a) Schematic illustration of the conventional spinning process.
(b) Types of parts conventionally spun. All parts are axisymmetric.

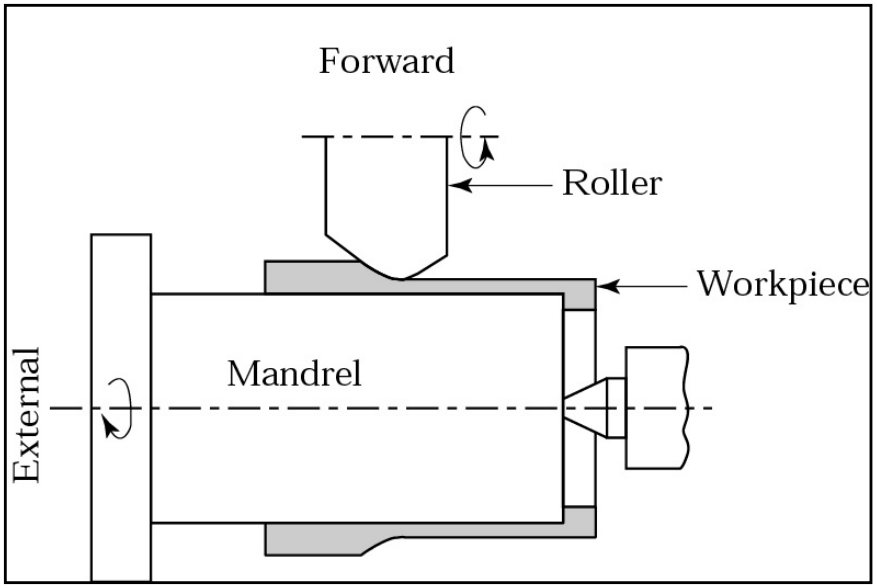
## Shear Spinning:

- Known as power spinning, flow turning, hydro-spinning, and spin forging
- Produces axisymmetric conical or curvilinear shape
- Single rollers and two rollers can be used
- It has less wastage of material
- Typical products are rocket- motor casing and missile nose cones.

# Spinning




Shear spinning




Tube spinning

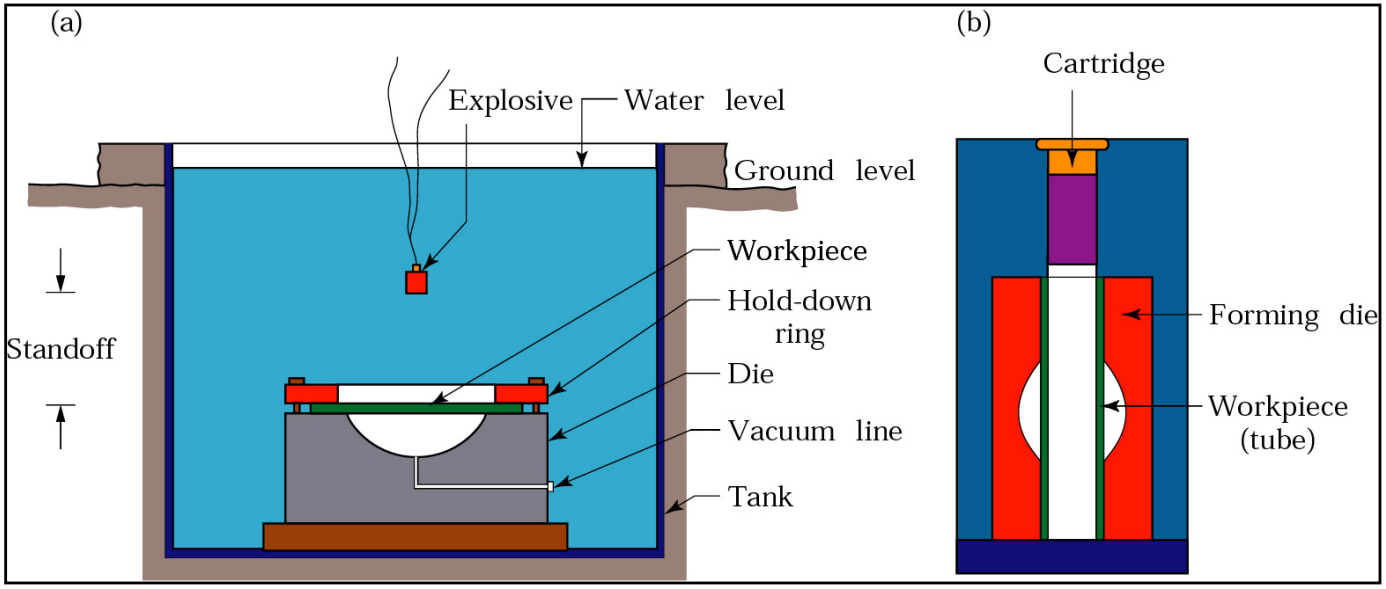
## Tube Spinning:

- Thickness of cylindrical parts are reduced by spinning them on a cylindrical mandrel rollers
- Parts can be spun in either direction
- Large tensile elongation up to 2000 % are obtained within certain temperature ranges and at low strain rates.

# Explosive Forming

## Explosive Forming:

- Explosive energy used s metal forming
- Sheet-metal blank is clamped over a die
- Assembly is immersed in a tank with water
- Rapid conversion of explosive charge into gas generates a shock wave. The pressure of this wave is sufficient to form sheet metals




(a) explosive forming process. (b) confined method of explosive bulging of tubes.

# Diffusion Bonding and Superplastic Forming

## Diffusion Bonding and Superplastic Forming:

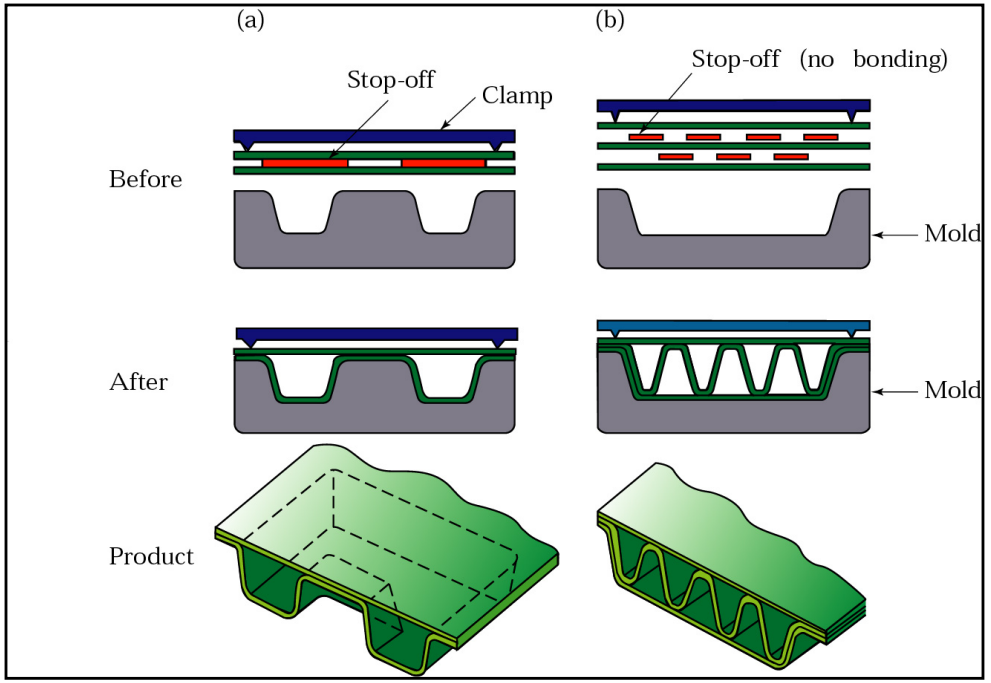
Advantages :

- Lower strength is required and less tooling costs
- Complex shapes with close tolerances can be made
- Weight and material savings
- Little or no residual stress occurs in the formed parts

Disadvantages :

- Materials must not be super elastic at service temperatures
- Longer cycle times

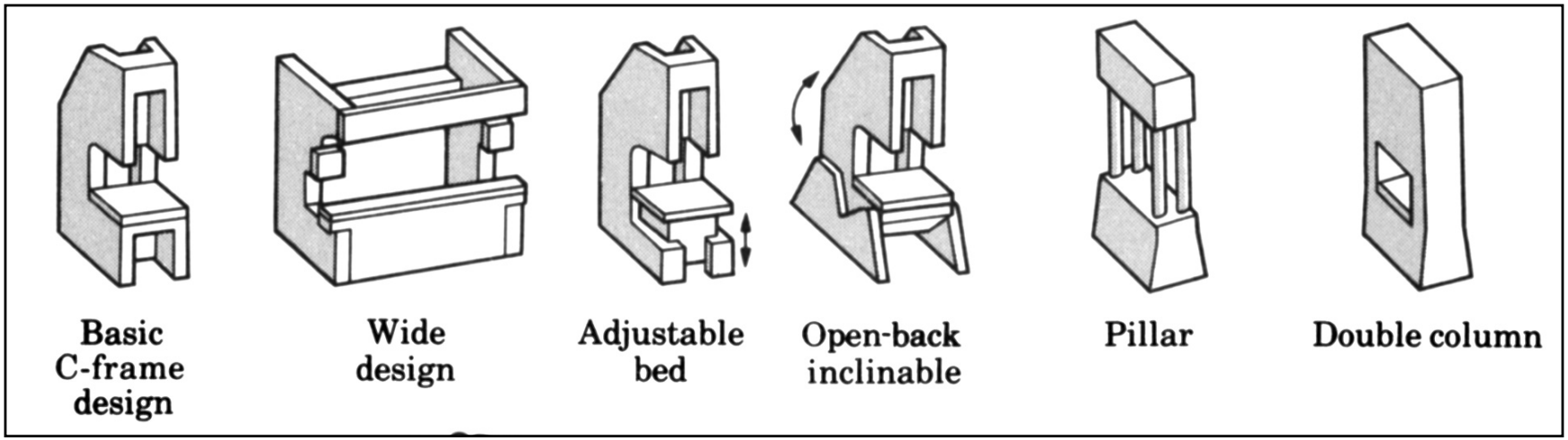
Types of structures made by diffusion bonding and superplastic forming of sheet metal. Such structures have a high stiffness-to-weight ratio.



# Press for Sheet Metal

Press selection for sheet metal forming operations depends on several factors:

- Type of forming operation, and dies and tooling required
- Size and shape of workpieces
- Length of stroke of the slide, stroke per minute, speed and shut height (distance from the top of the bed to the bottom of the slide, with the stroke down)
- Number of slides (single action, double action and triple action)
- Maximum force required (press capacity, tonnage rating)
- Type of controls
- Die changing features
- Safety features




Schematic illustration of types of press frames for sheet- forming operations. Each type has its own characteristics of stiffness, capacity, and accessibility.

***THE END***