

LECTURE-14

SHEET METAL FORMING PROCESSES



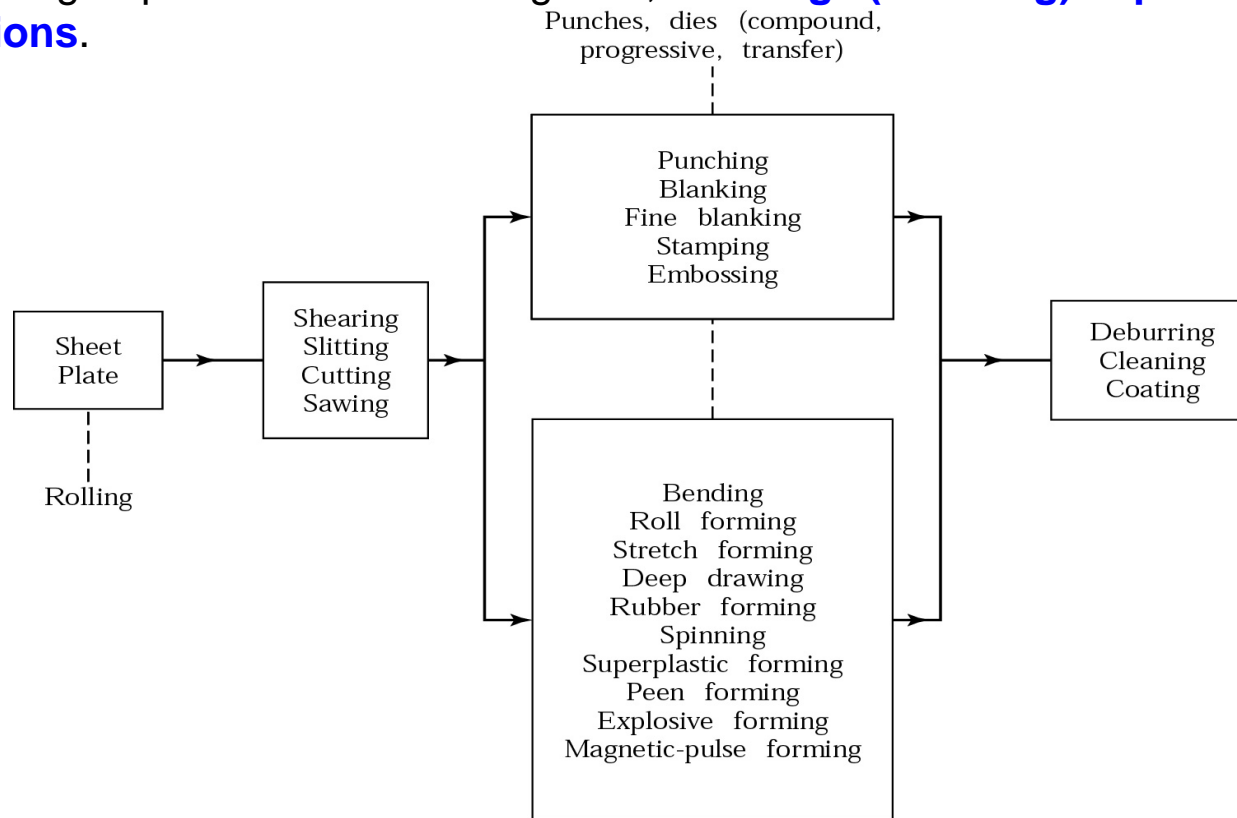
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BUET

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 processes, one should determine whether a particular sheet metal can be formed into the desired shape without failure. The sheet metal operations done on a press may be grouped into two categories, **cutting (shearing) operations** and **forming operations**.

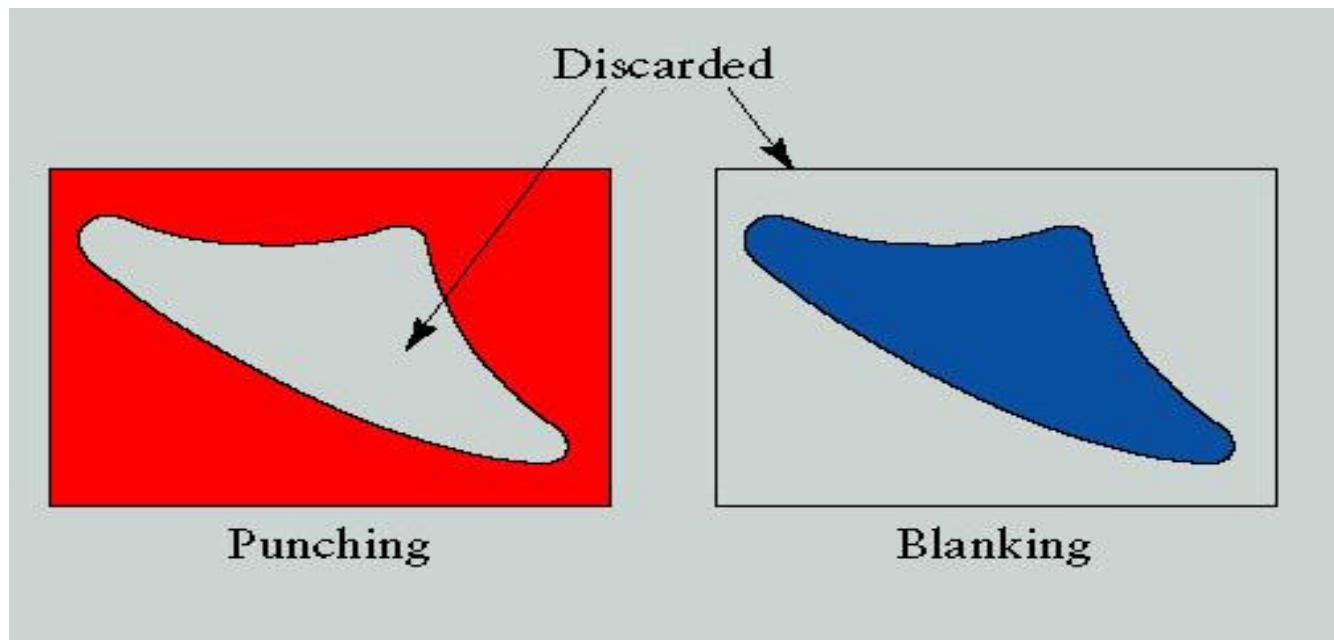


Cutting (Shearing) Operations

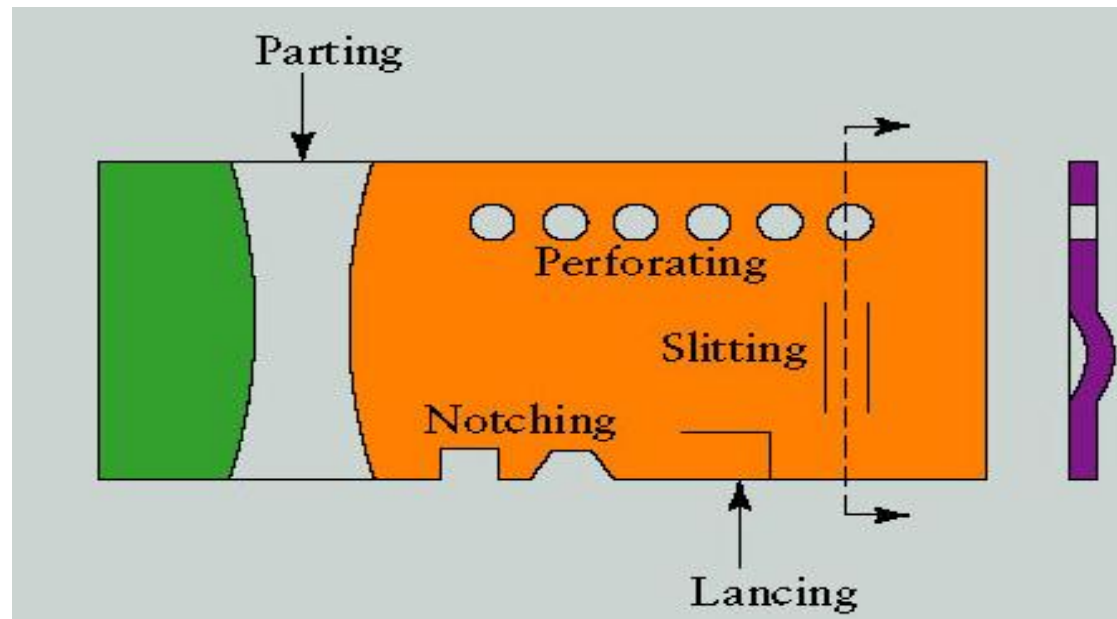
- In this operation, the workpiece is stressed beyond its ultimate strength. The stresses caused in the metal by the applied forces will be shearing stresses. The cutting operations include:
 - Punching (Piercing)
 - Blanking
 - Notching
 - Perforating
 - Slitting
 - Lancing
 - Parting
 - Shaving
 - Trimming
 - Fine blanking

Shearing Operations

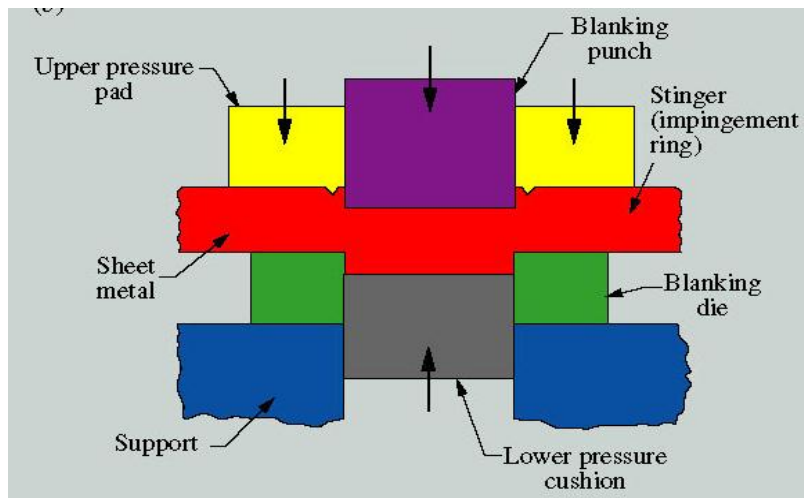
- **Punching (Piercing):** It is a cutting operation by which various shaped holes are made in sheet metal. Punching is similar to blanking except that in punching, the hole is the desired product, the material punched out to form the hole being waste.
- **Blanking:** Blanking is the operation of cutting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



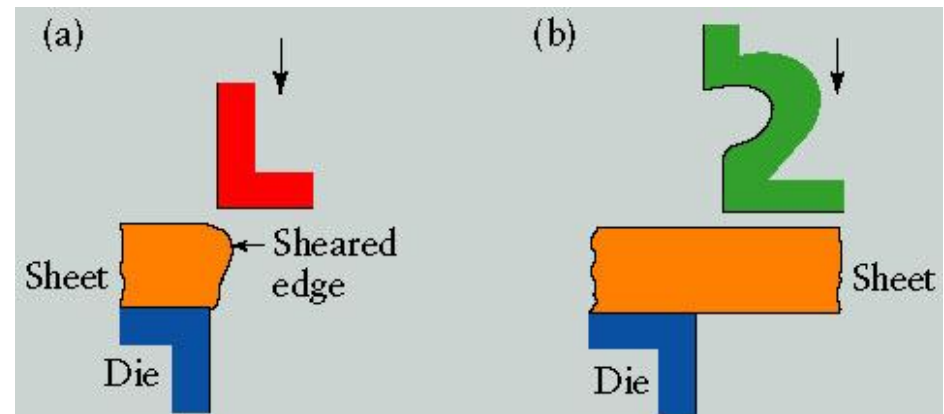
- **Notching:** This is cutting operation by which metal pieces are cut from the edge of a sheet, strip or blank.
- **Perforating:** This is a process by which multiple holes which are very small and close together are cut in flat work material.
- **Slitting:** It refers to the operation of making incomplete 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.
- **Parting:** Parting involves cutting a sheet metal strip by a punch with two cutting edges that match the opposite sides of the blank.



- **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.
- **Fine blanking:** Fine blanking is a operation used to blank sheet metal parts with close tolerances and smooth, straight edges in one step.



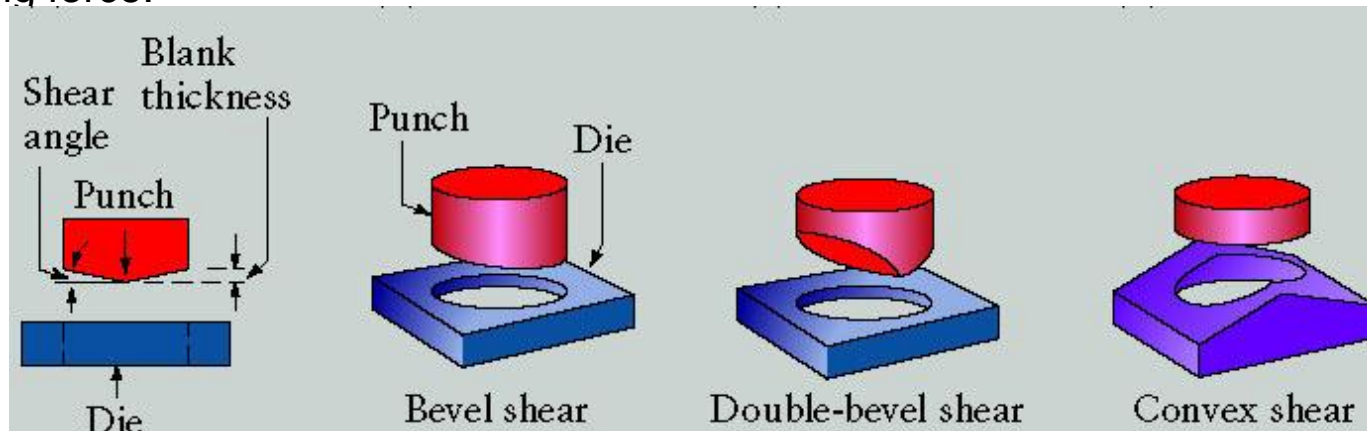
Fine blanking



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

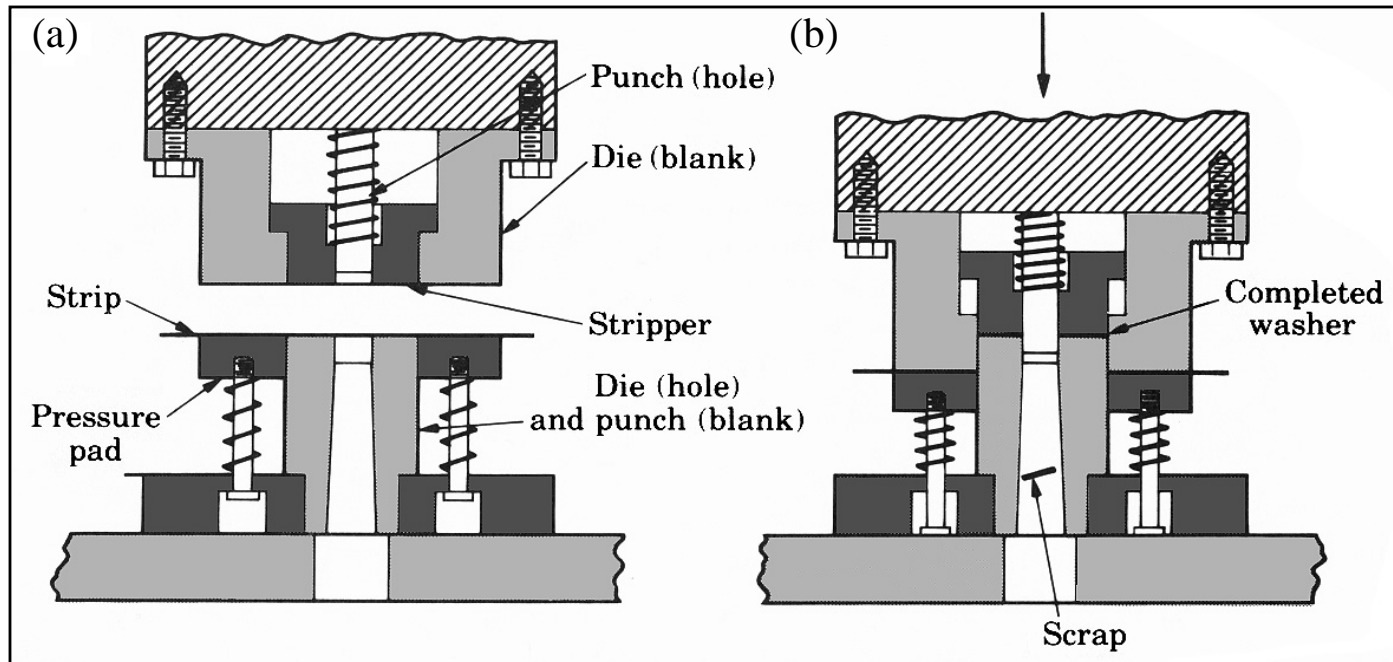
Shearing Dies

- Because the formability of a sheared part can be influenced by the quality of its sheared edges, clearance control is important. In practice, clearances usually range between 2% and 8% of the sheet's thickness; generally, the thicker the sheet, the larger is the clearance (as much as 10%). However, the smaller the clearance, the better is the quality of the edge. Some common shearing dies are describe below:
 - **Punch and Die Shapes:** As the surfaces of the punch and die are flat; thus, the punch force builds up rapidly during shearing, because the entire thickness of the sheet is sheared at the same time. However, the area being sheared at any moment can be controlled by beveling the punch and die surfaces, as shown in the following Figure. This geometry is particularly suitable for shearing thick blanks, because it reduces the total shearing force.



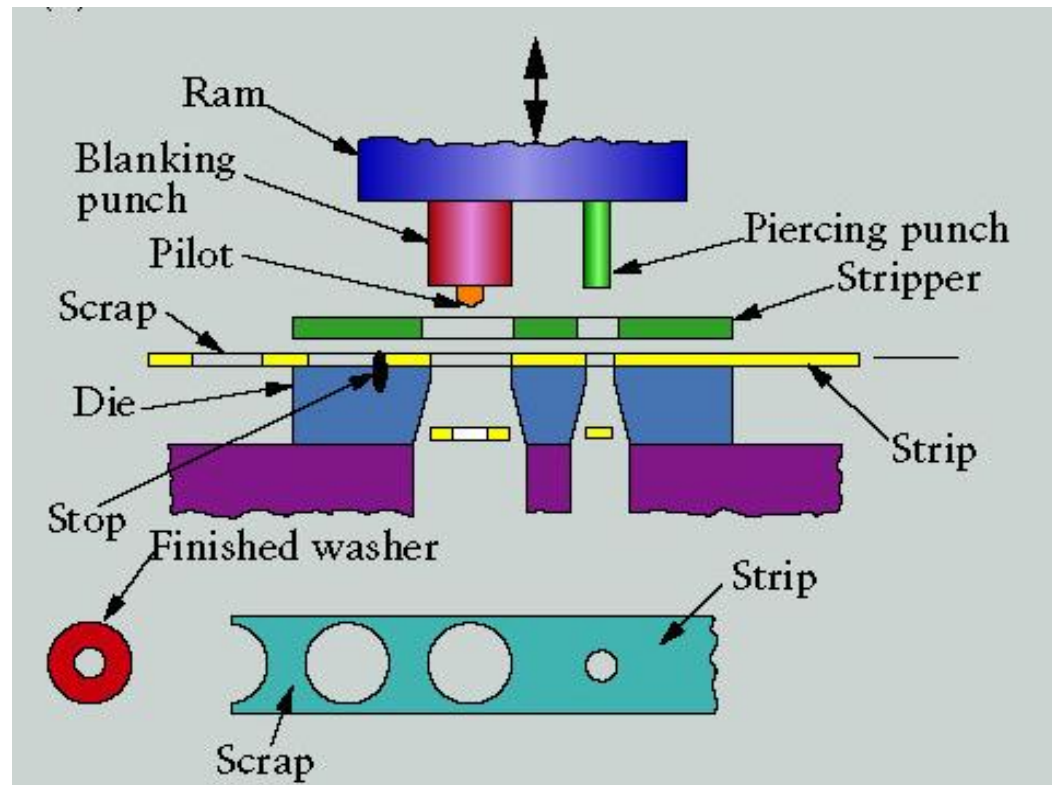
Examples of the use of shear angles on punches and dies.

- 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.



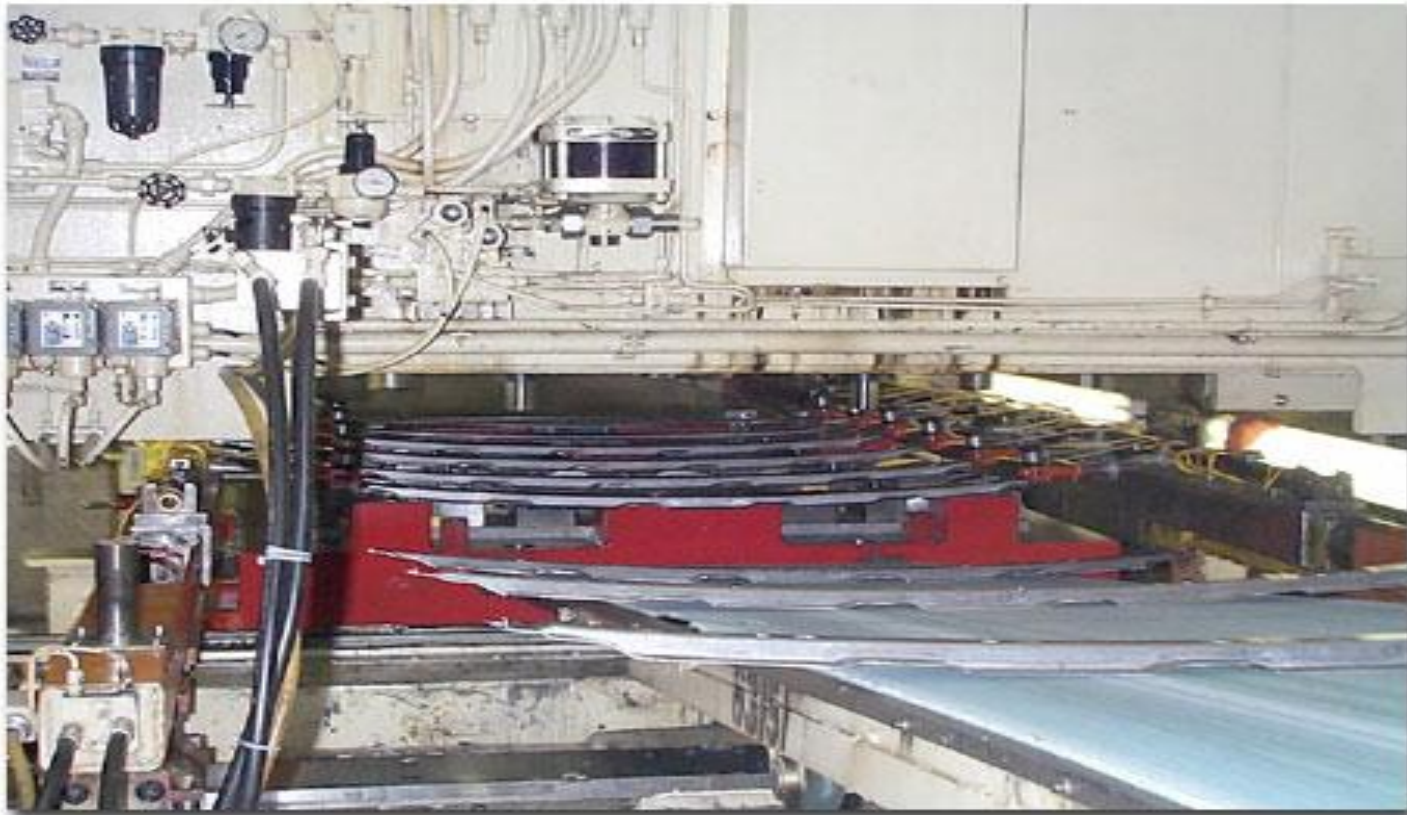
Schematic illustrations: (a) before and (b) after blanking a common washer in a compound die. Note the separate movements of the die (for blanking) and the punch (for punching the hole in the washer).

- **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) 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.

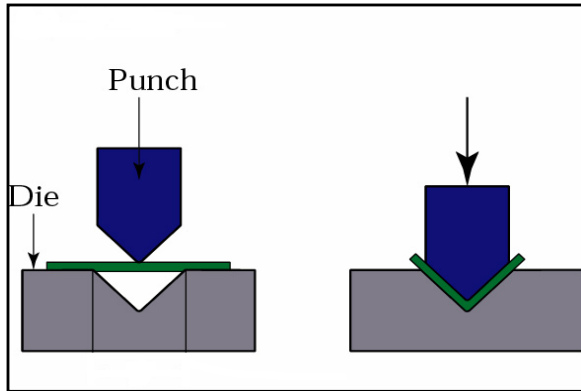
- **Transfer Dies:** In a transfer die setup, the sheet metal undergoes different operations at different stations, which are arranged along a straight line or a circular path. After each operation, the part is transfer to the next operation for additional operations.



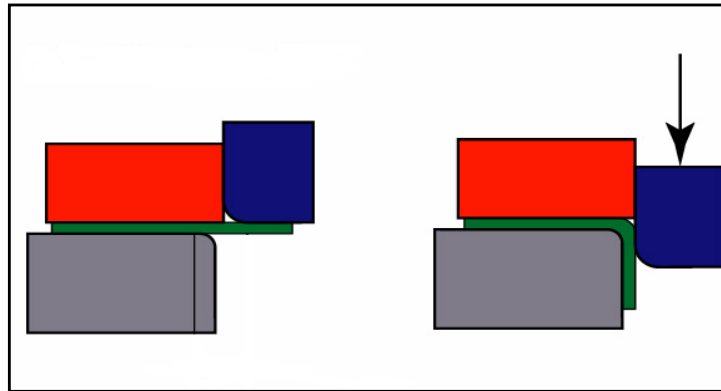
Forming Operations

- 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:** 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. The bending operations include:
 - ▶ V-bending
 - ▶ Edge bending
 - ▶ Roll bending
 - ▶ Air bending
 - ▶ Flanging
 - ▶ Dimpling
 - ▶ Press break forming
 - ▶ Beading
 - ▶ Roll forming
 - ▶ Tube forming
 - ▶ Bulging
 - ▶ Stretch forming
 - **Drawing:** This is a process of 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.

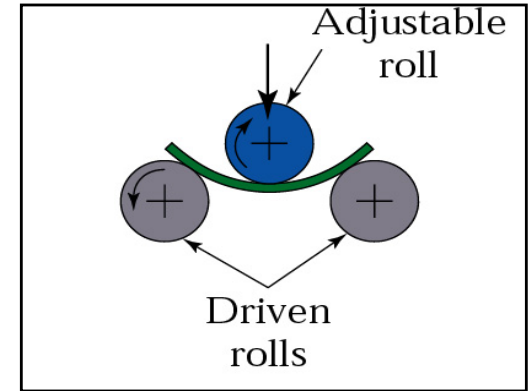
Bending of Flat Sheet and Plate



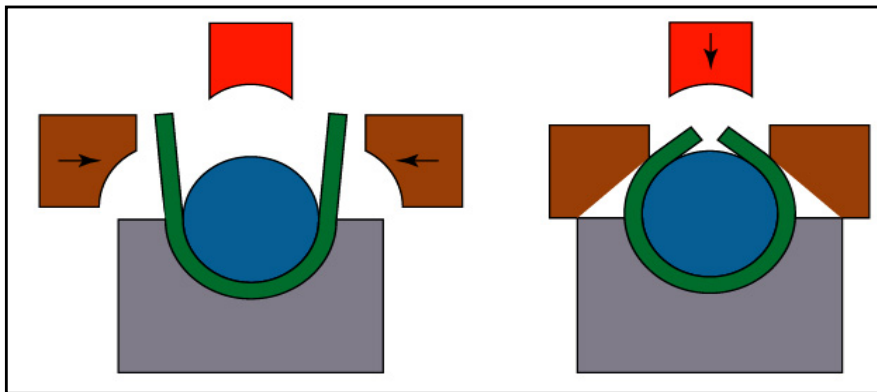
V-bending



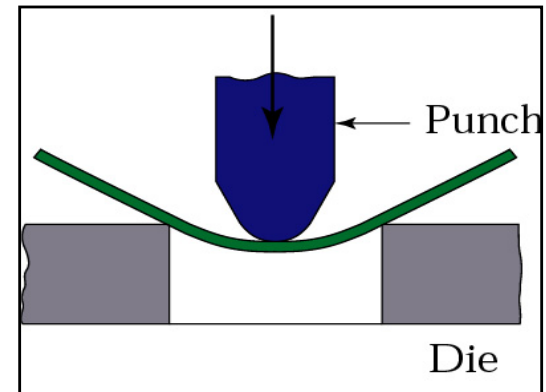
Edge bending



Roll bending

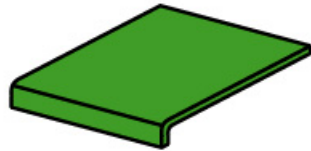


Bending in 4-slide machine

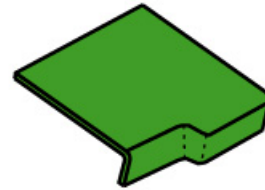


Air bending

- **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



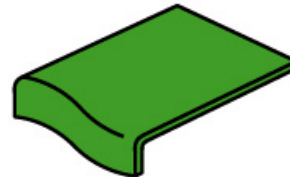
Straight flange



Joggled flange



Stretch flange



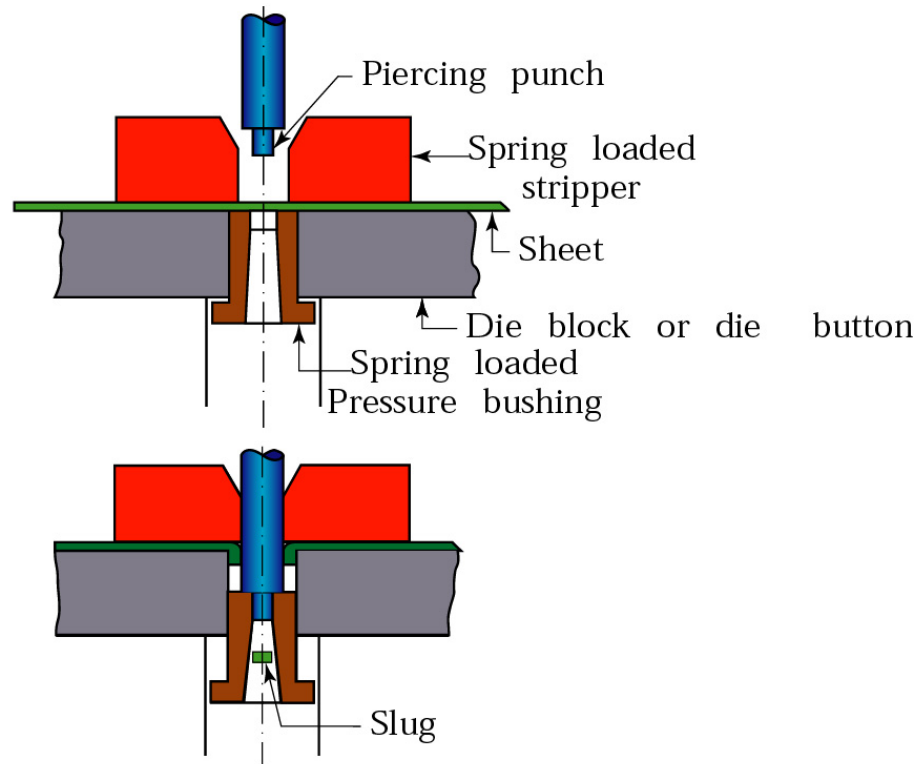
Reverse flange



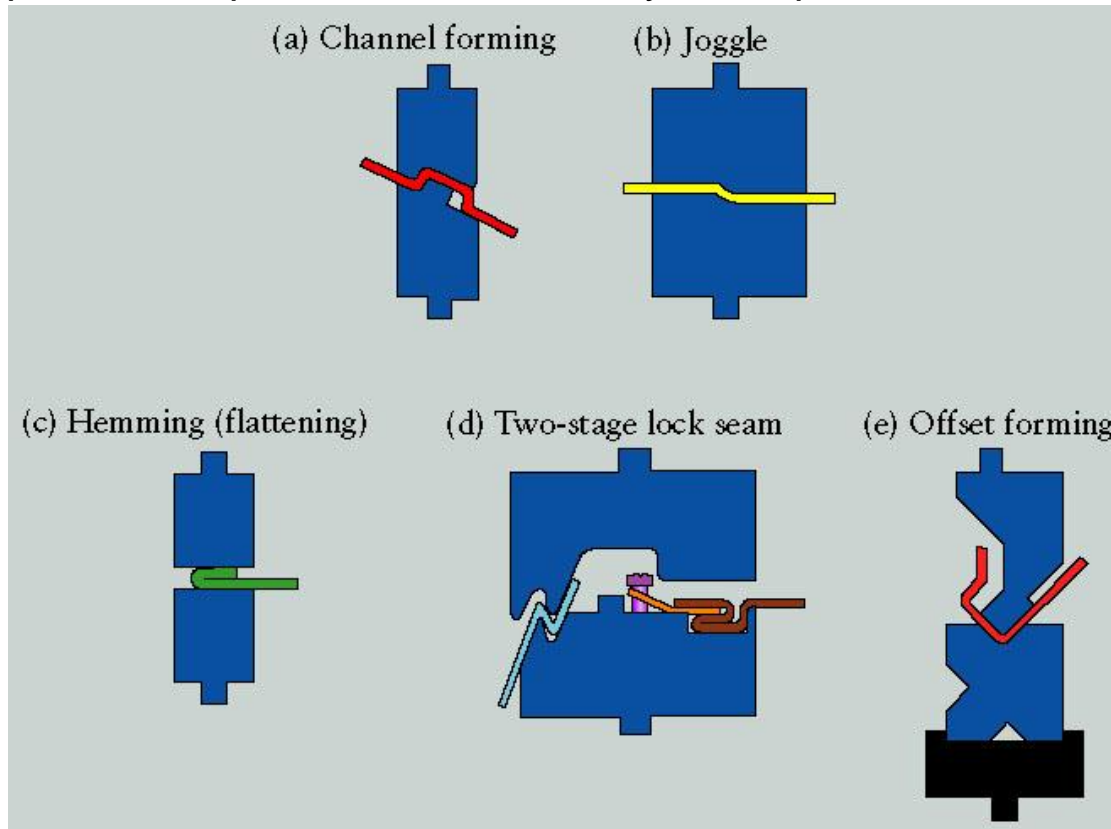
Shrink flange

● 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

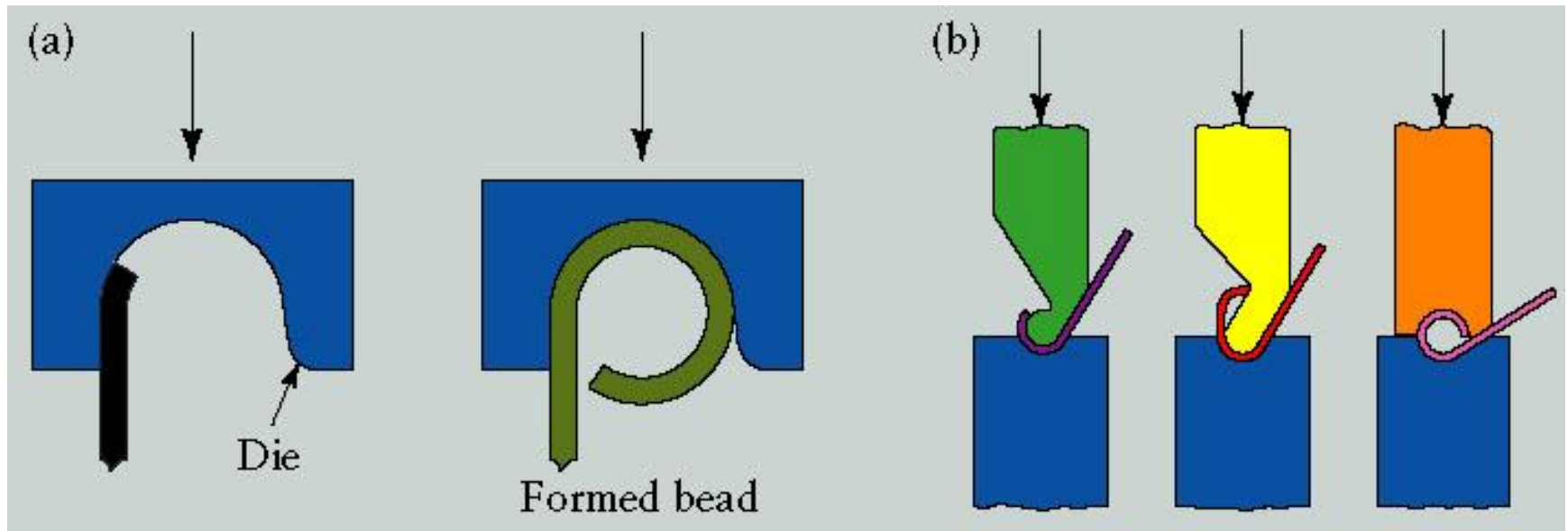


- **Press break forming:** Sheet metal or plate can be bent easily with simple fixtures using a press. Long and relatively narrow pieces are usually bent in a press break. This machine utilizes long dies in a mechanical or hydraulic press and is suitable for small production runs. The tooling is simple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



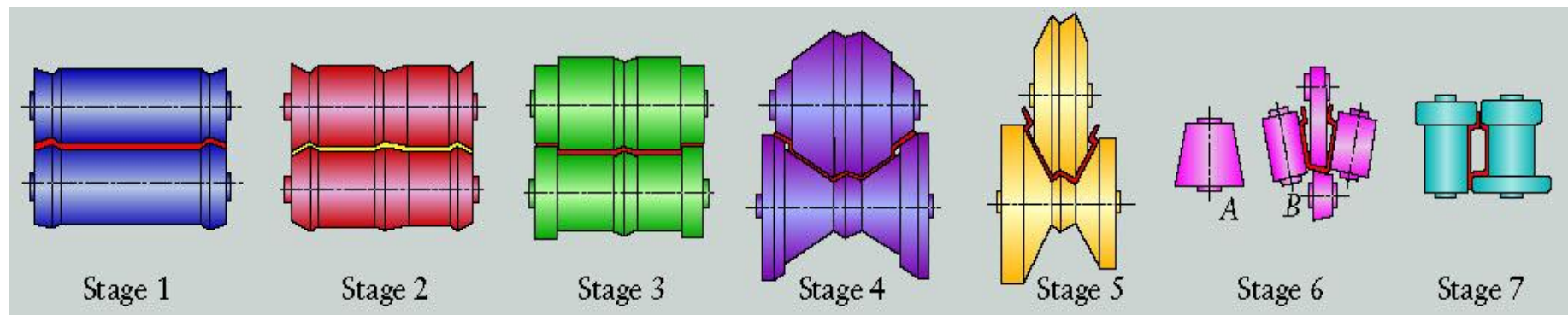
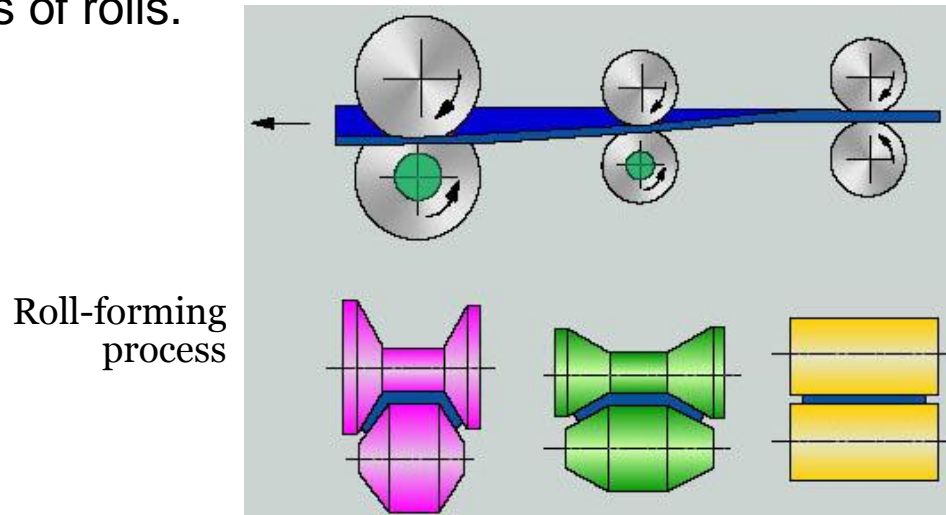
Schematic illustrations of various bending operations in a press brake

- **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.

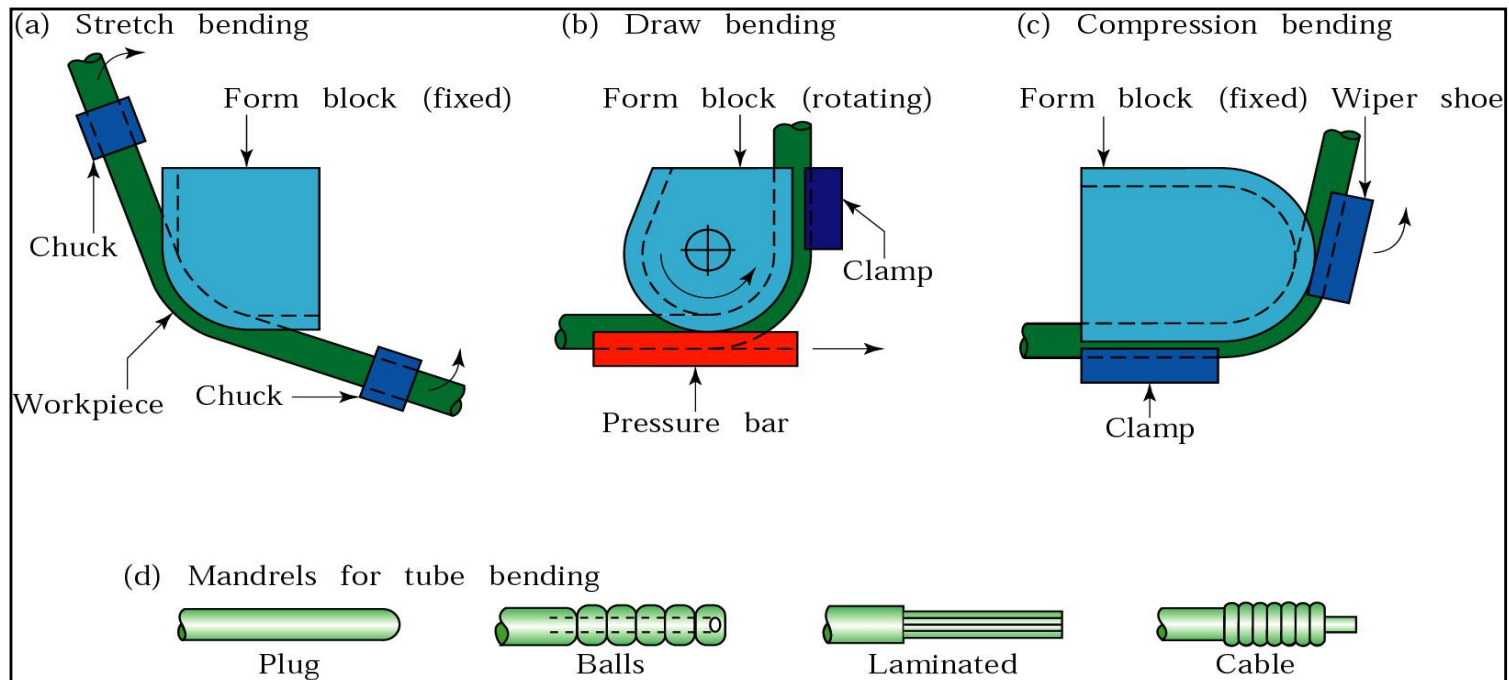
- **Roll forming:** For bending continuous lengths of sheet metal and for large production runs, roll forming is used. The metal strip is bent in stages by passing it through a series of rolls.



Stages in roll forming of a sheet-metal door frame. In Stage 6, the rolls may be shaped as in A or B.

Tube Bending

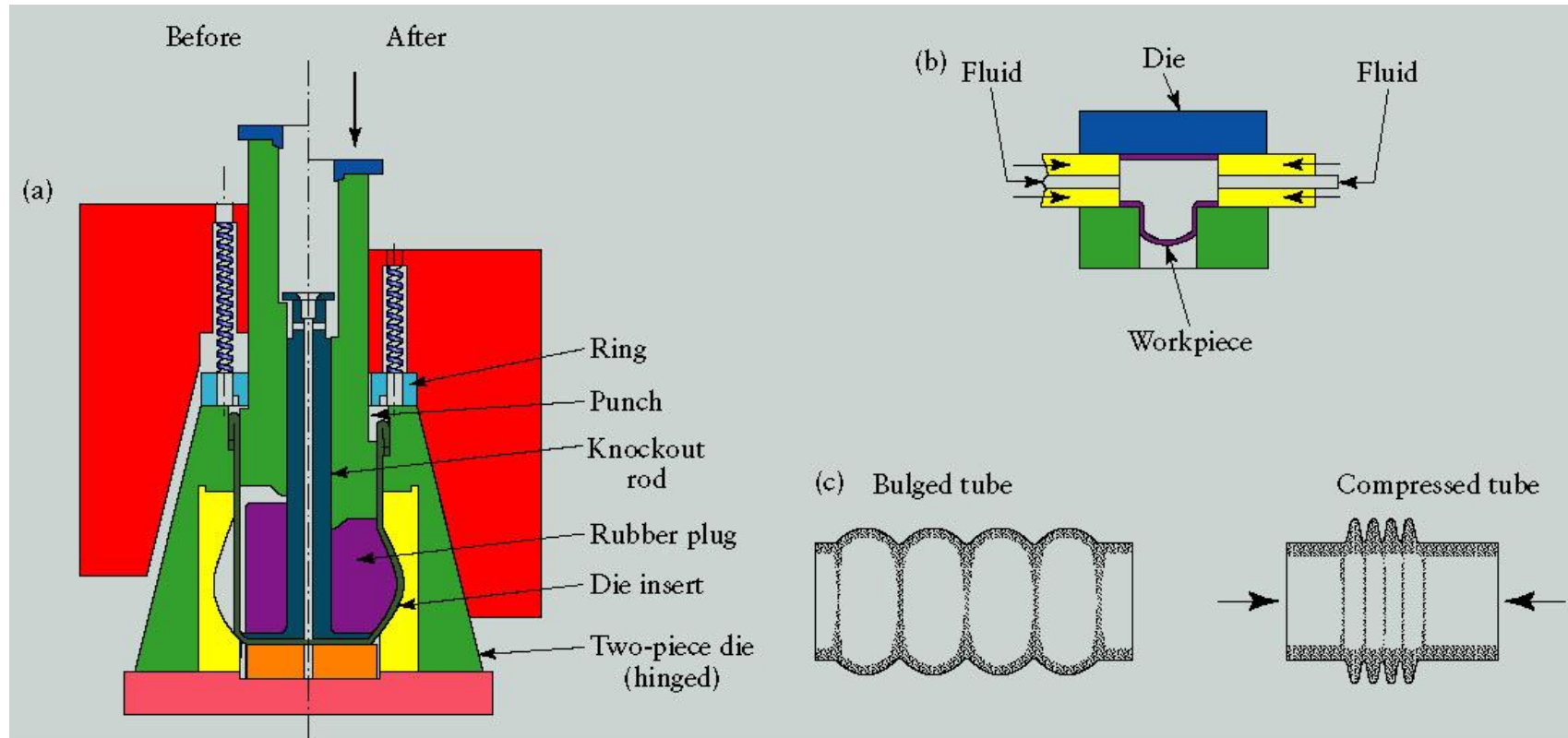
- Bending and forming tubes and other hollow sections require special tooling to avoid buckling and folding. The oldest method of bending a tube or pipe is to pack the inside with loose particles, commonly used sand and bend the part in a suitable fixture. This technique prevents the tube from buckling. 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.

Bulging

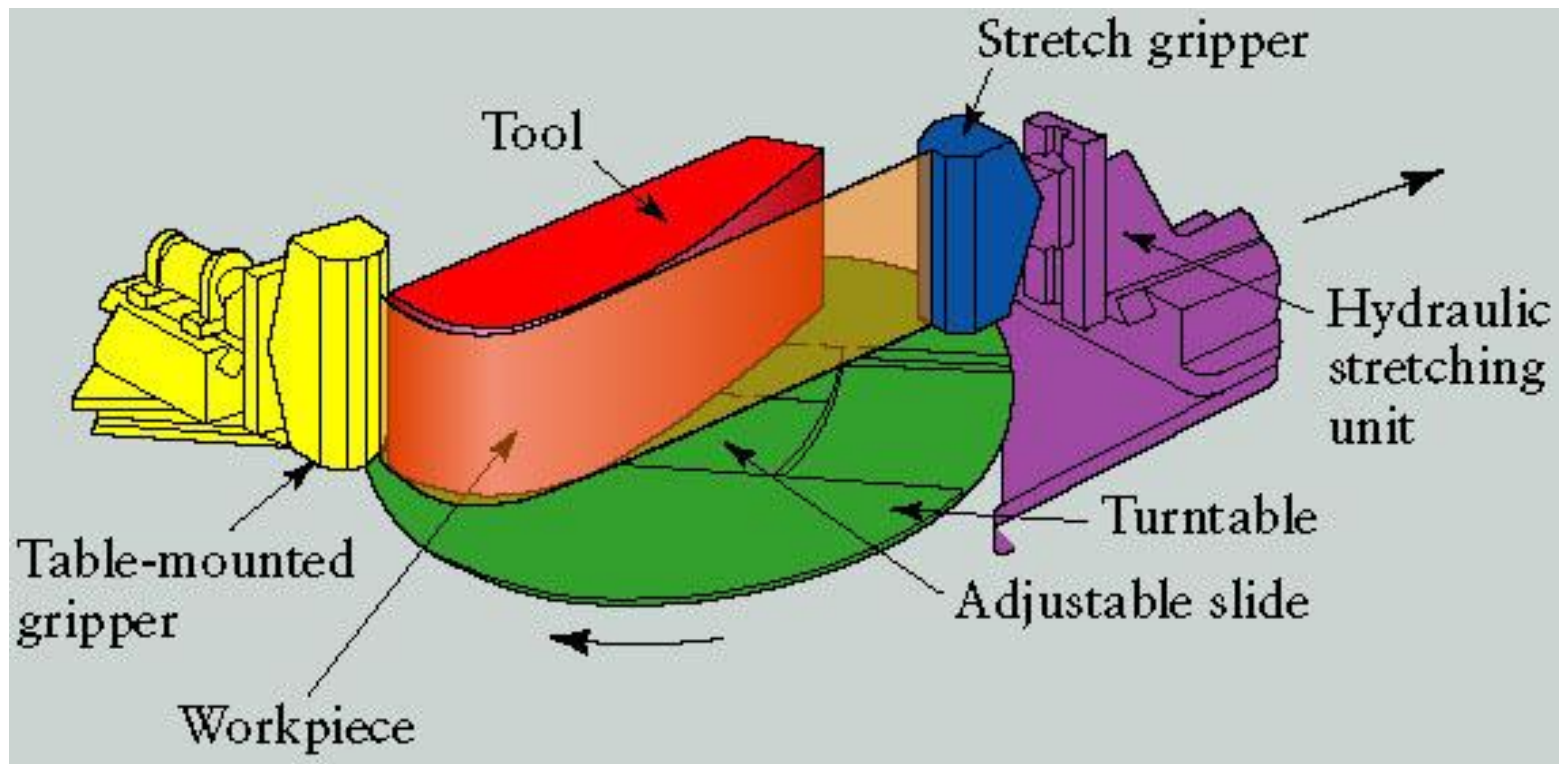
- The basic forming process of bulging involves placing tabular, conical or curvilinear part into a split-female die and expanding it with, say, a polyurethane plug. The punch is then retracted, the plug returns to its original shape and the part is removed by opening the dies.



(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 with internal pressure. The bottom of the piece is then punched out to produce a "T." (c) Manufacturing of Bellows.

Stretch Forming

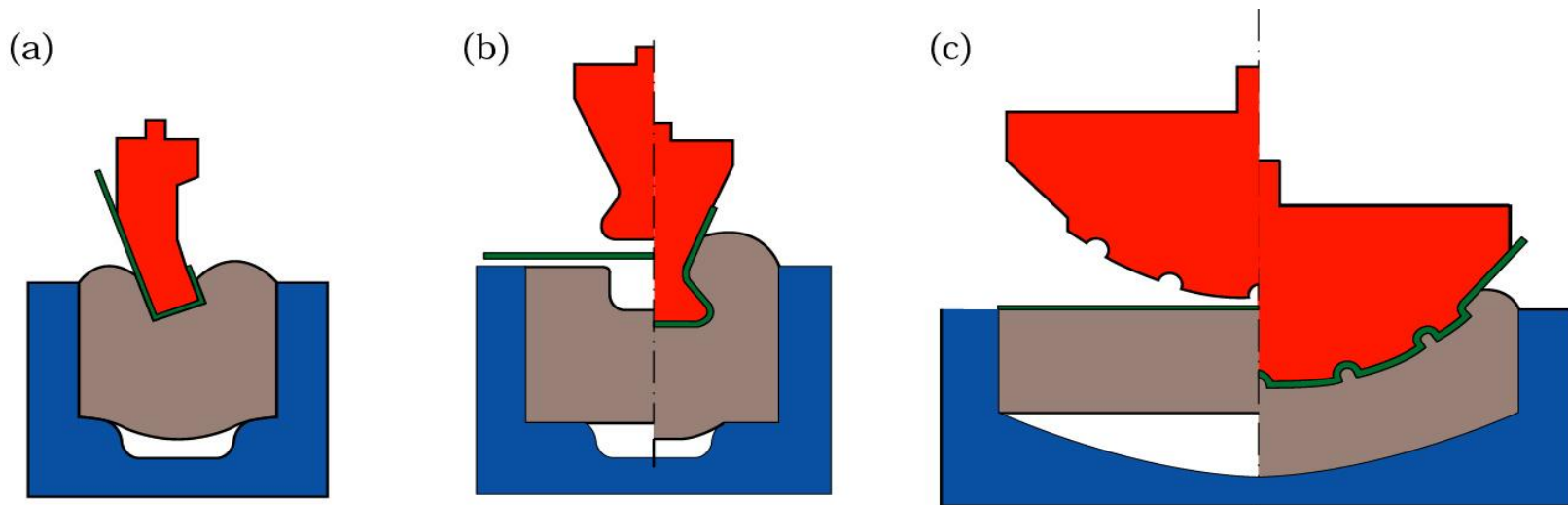
- In stretch forming, the sheet metal is clamped around its edges and stretched over a die or form block, which moves upward, downward or sideways, depending on the particular machine. Stretch forming is used primarily to make aircraft-wing skin panel, automobile door panels and window frames.



Schematic illustration of a stretch-forming process. Aluminum skins for aircraft can be made by this process.

Rubber Forming

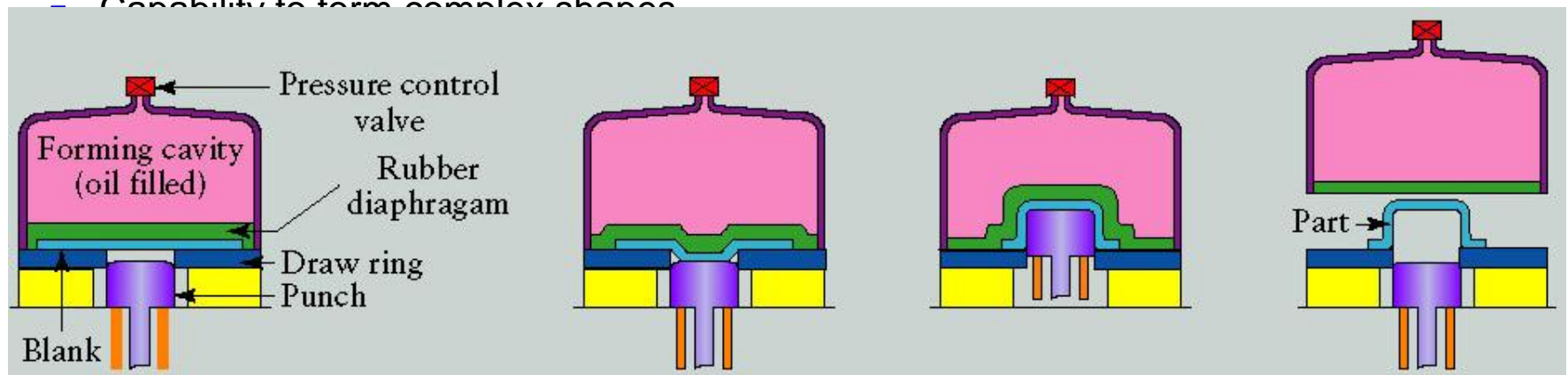
- In rubber forming, one of the dies in a set is made of flexible material, such as a rubber or polyurethane membrane. Polyurethanes are used widely because of their resistance to abrasion, long fatigue life and resistance to damage by burrs or sharp edges of the sheet blank. In bending and embossing sheet metal by the rubber forming method, as shown in the following Figure, the female die is replaced with a rubber pad. Parts can also be formed with laminated sheets of various nonmetallic material or coatings.



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

Hydroform (or) Fluid Forming Process

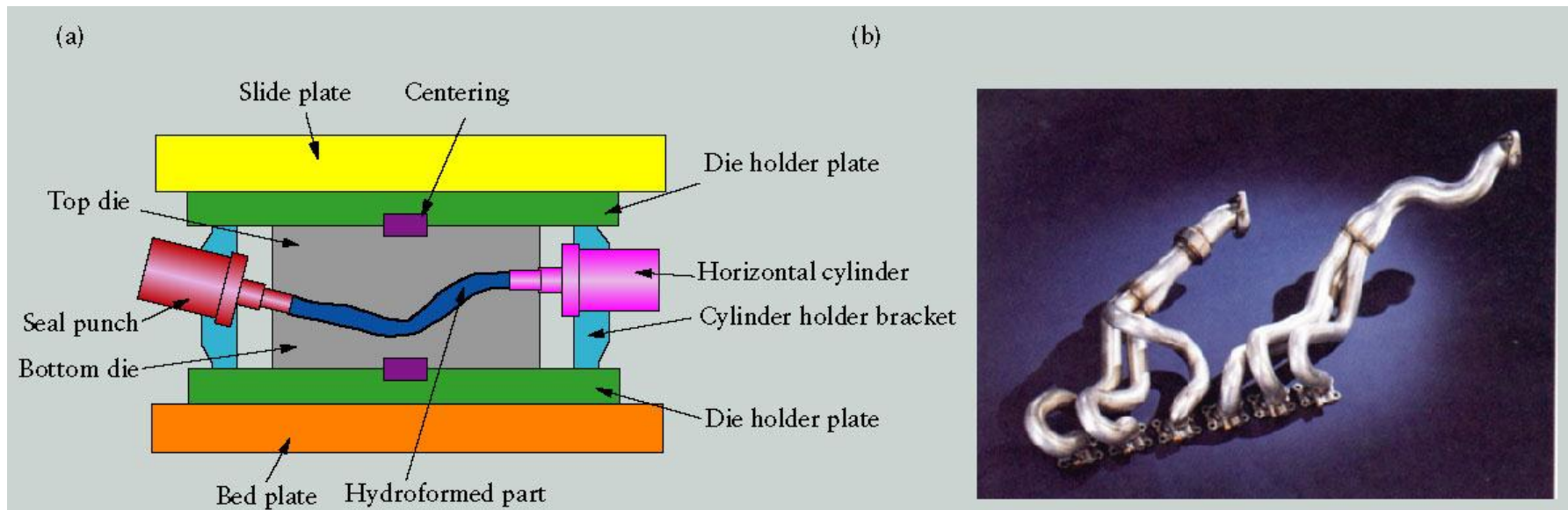
- In hydroforming or fluid forming process, the pressure over the rubber membrane is controlled throughout the forming cycle, with maximum pressure reaching 100 MPa (15000 psi). This procedure allows close control of the part during forming to prevent wrinkling or tearing. When selected properly, rubber forming and hydroforming processes have the following advantages:
 - Low tooling cost
 - Flexibility and ease of operation
 - Low die wear
 - No damage to the surface of the sheet and
 - Capability to form complex shapes



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.

Tube-Hydroforming Process

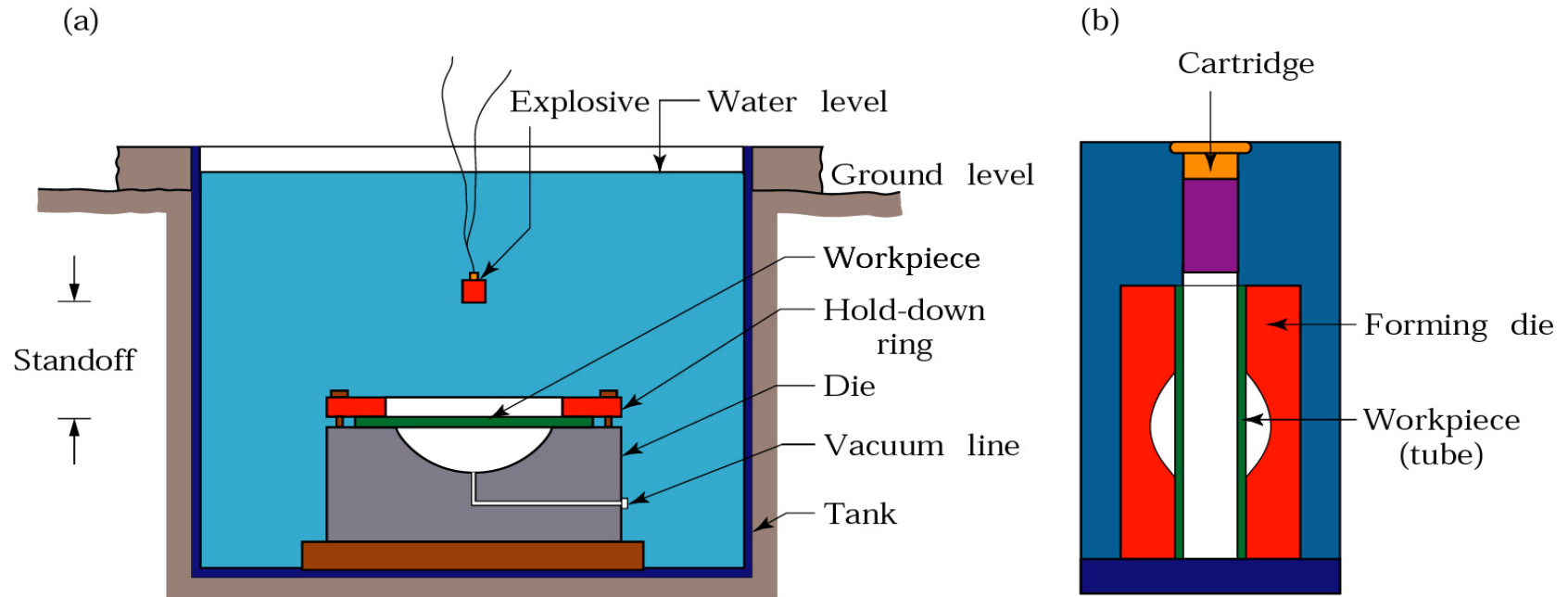
- In tube hydroforming, steel or other metal tubing is formed in a die and pressurized by a fluid. This procedure can form simple tubes or it can form intricate hollow tubes as shown in the following Figure. Applications of tube-hydroformed parts include automotive exhaust and structural components.



(a) Schematic illustration of the tube-hydroforming process. (b) Example of tube-hydroformed parts. Automotive exhaust and structural components, bicycle frames, and hydraulic and pneumatic fittings are produced through tube hydroforming.

Explosive Forming Process

- Explosive energy used as 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.

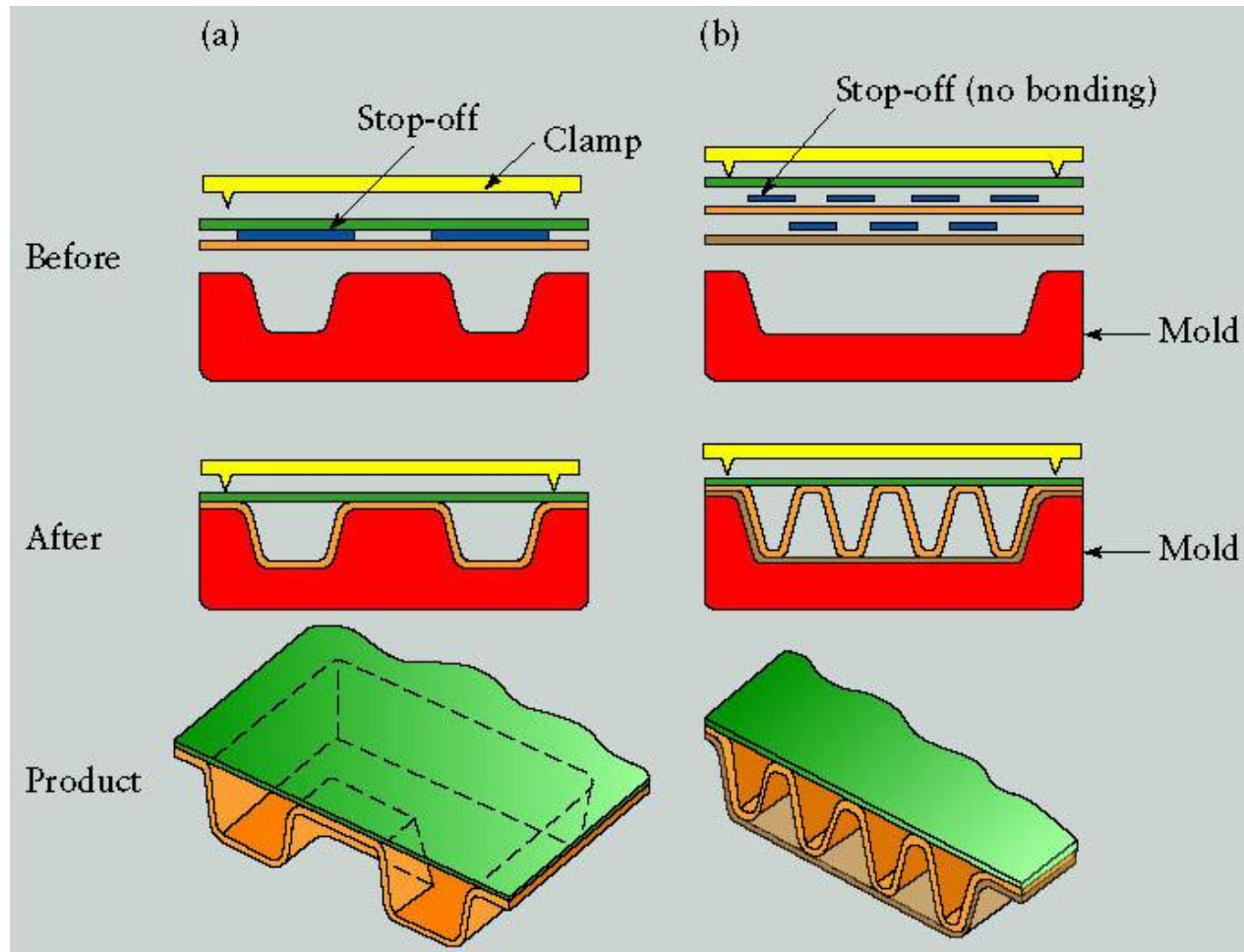
Diffusion Bonding and Superplastic Forming:

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

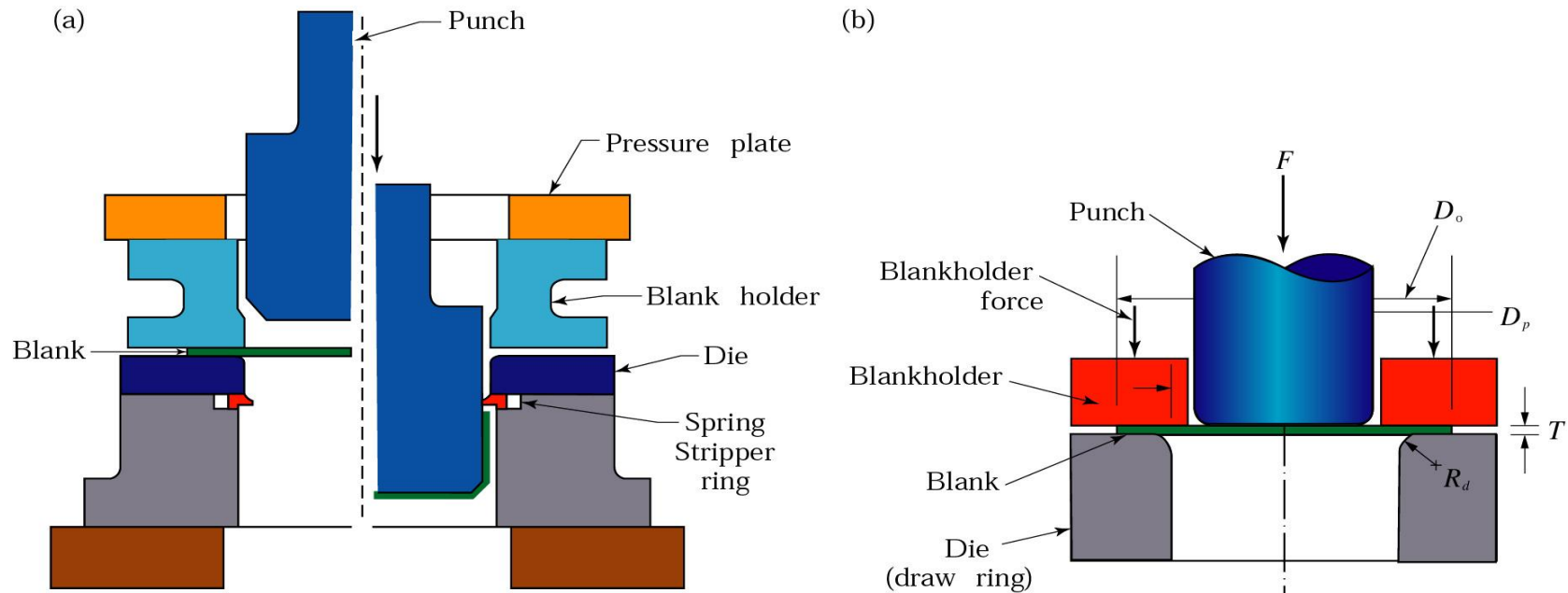
- Materials must not be super elastic at service temperatures
- Longer cycle times



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

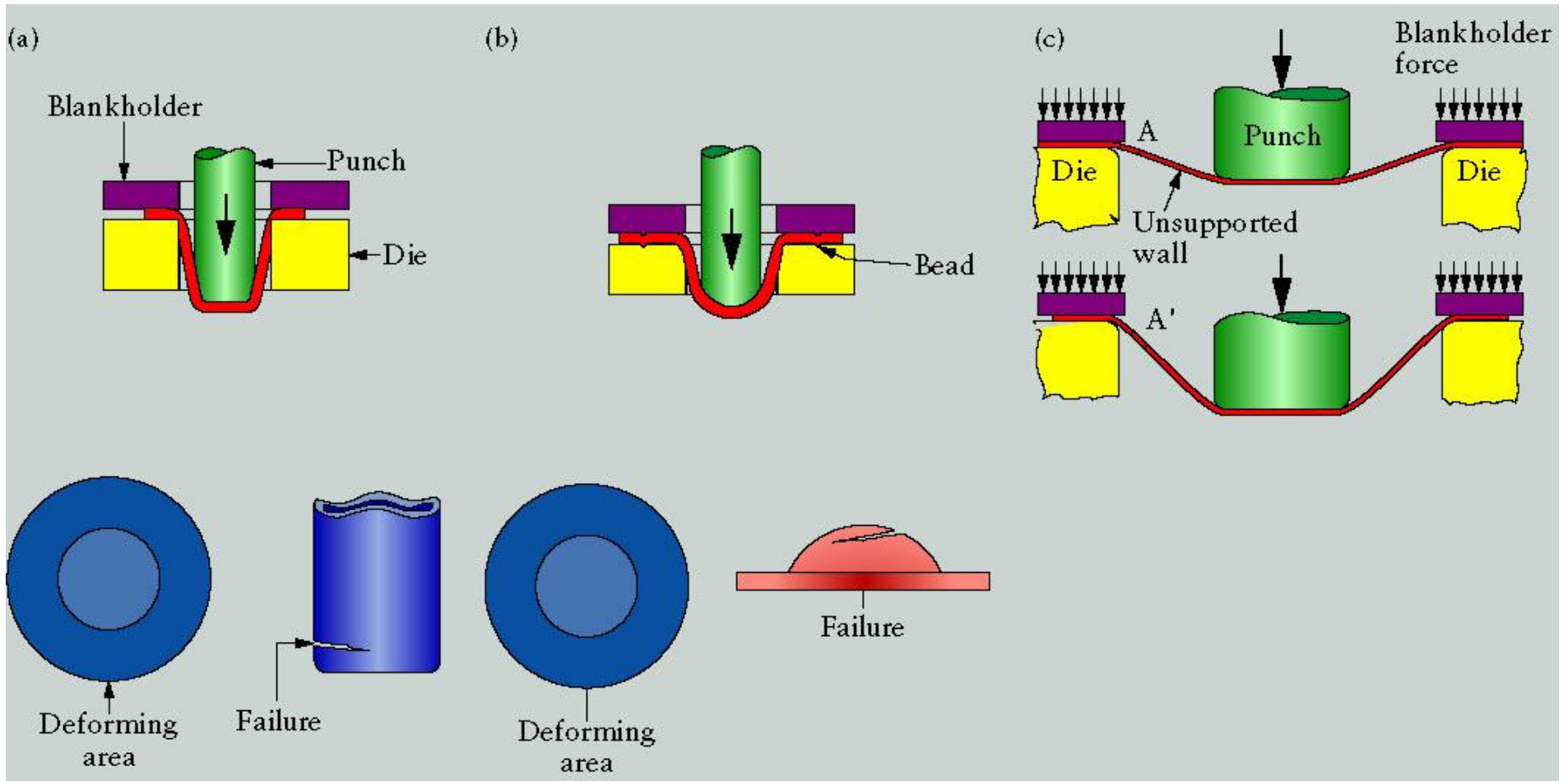
Deep Drawing Processes

- 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 blank 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 $\leq D/2$
 - 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.

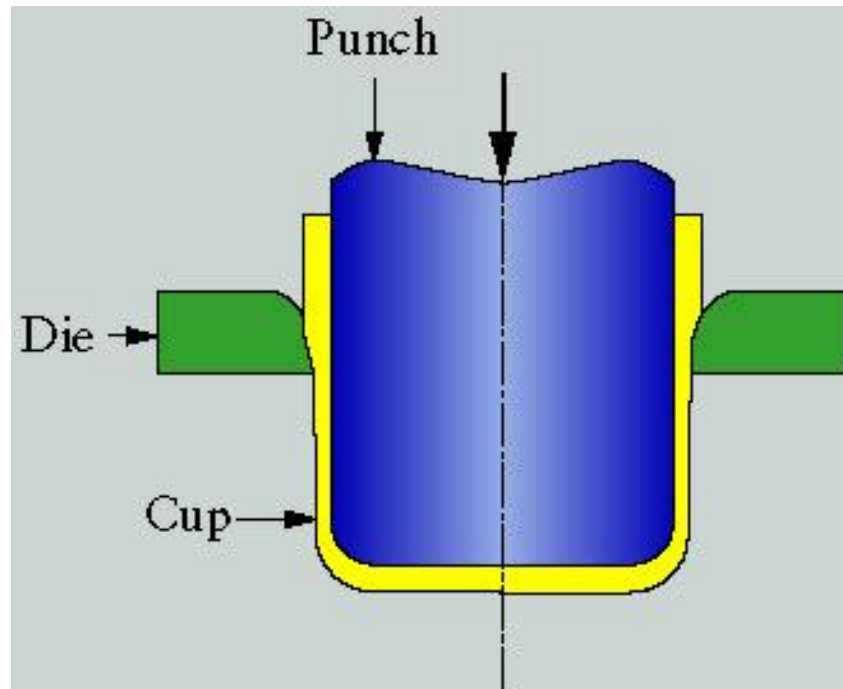
Drawing Operations



Examples of drawing operations: (a) pure drawing and (b) pure stretching. The bead prevents the sheet metal from flowing freely into the die cavity. (c) Possibility of wrinkling in the unsupported region of a sheet in drawing.

Ironing Process

- If the thickness of the sheet as it enters the die cavity is more than the clearance between the punch and the die, the thickness will have to be reduced; this effect is known as ironing. Ironing produces a cup with constant wall thickness thus, the smaller the clearance, the greater is the amount of ironing.

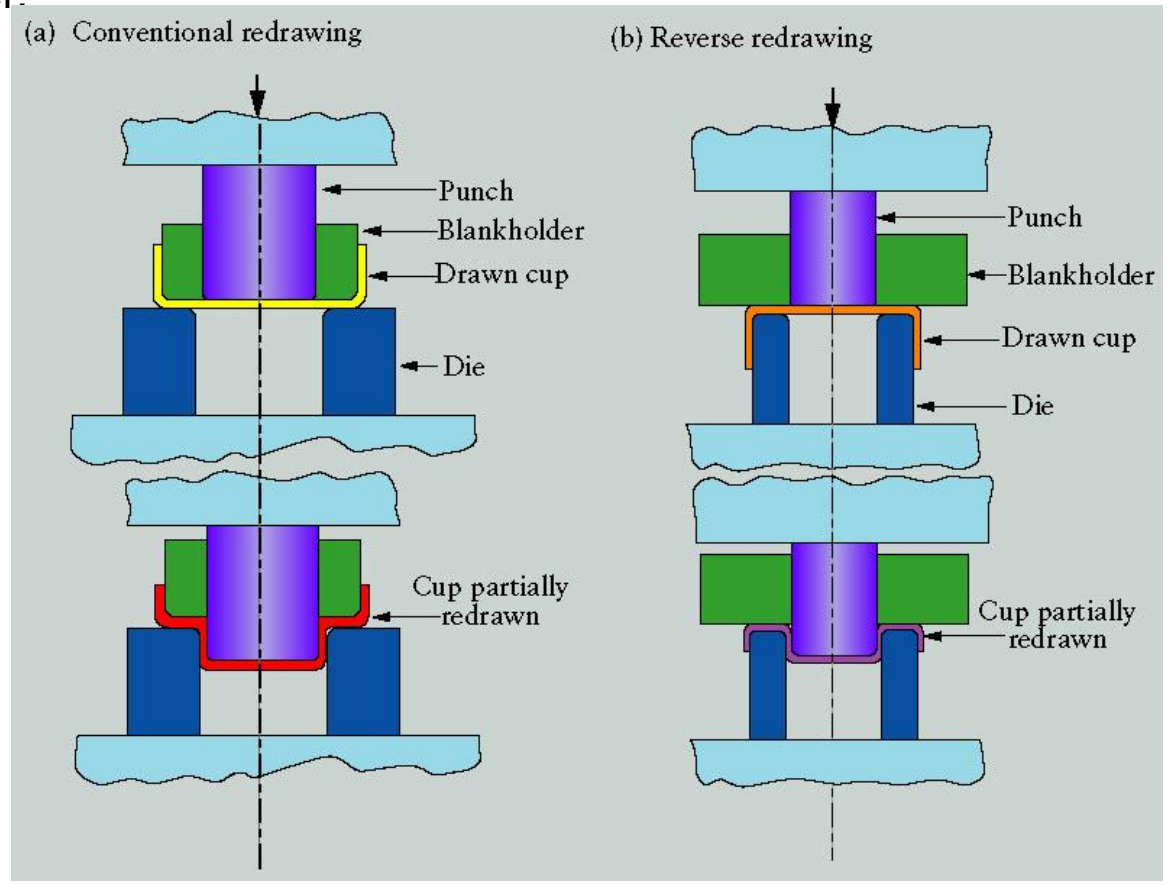


Schematic illustration of the ironing process. Note that the cup wall is thinner than its bottom. All beverage cans without seams (known as two-piece cans) are ironed, generally in three steps, after being deep drawn into a cup. (Cans with separate tops and bottoms are known as three-piece cans.)

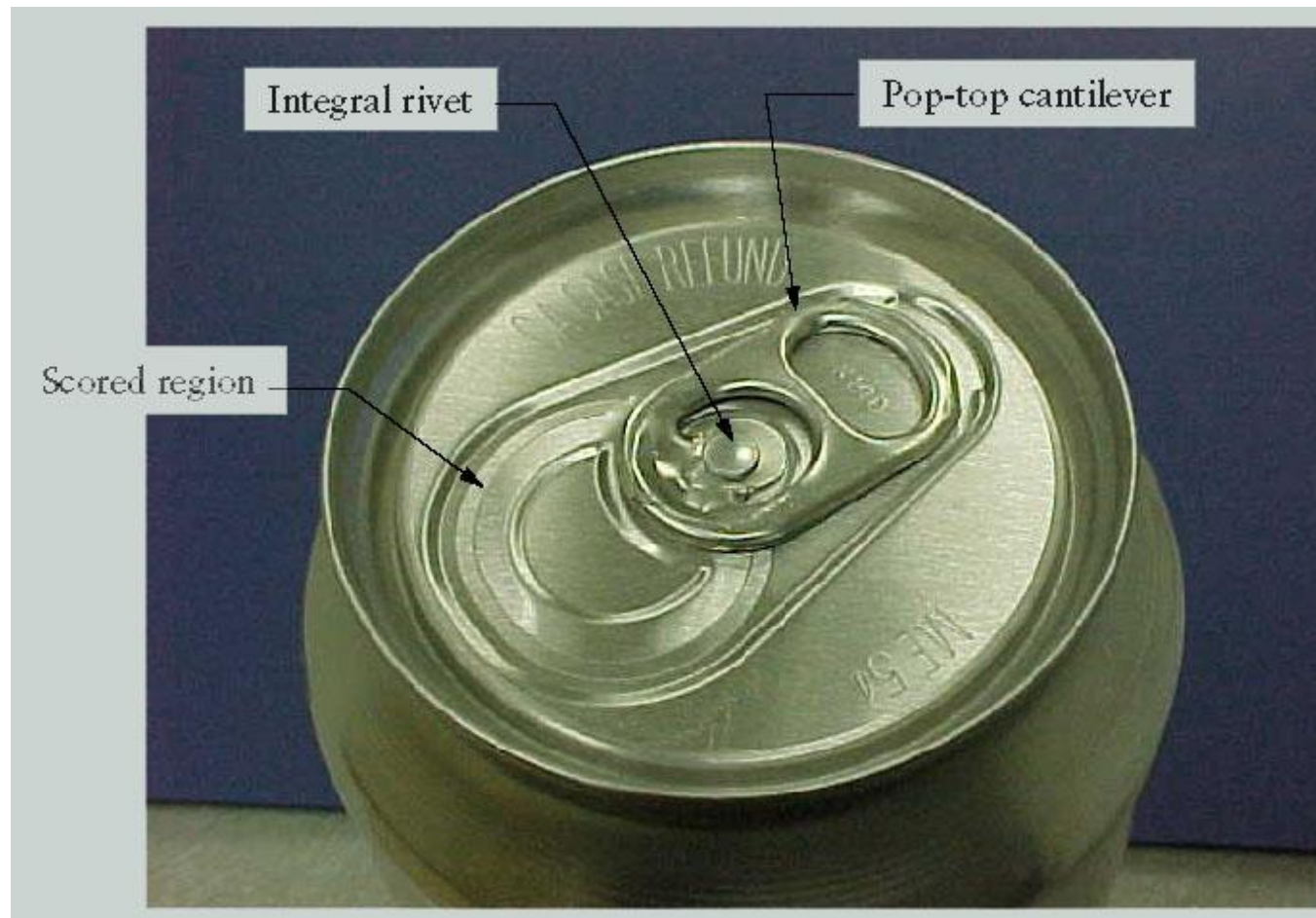
Redrawing Operations

- Containers or shells that are too difficult to draw in one operation are generally redrawn. In reverse redrawing, shown in following Figure, the metal is subjected to bending in the direction opposite to its original bending configuration. This reversal in bending results in strain softening. This operation requires lower forces than direct redrawing and the material behaves in a more ductile manner.

Reducing the diameter of drawn cups by redrawing operations: (a) conventional redrawing and (b) reverse redrawing. Small-diameter deep containers undergo many drawing and redrawing operations.



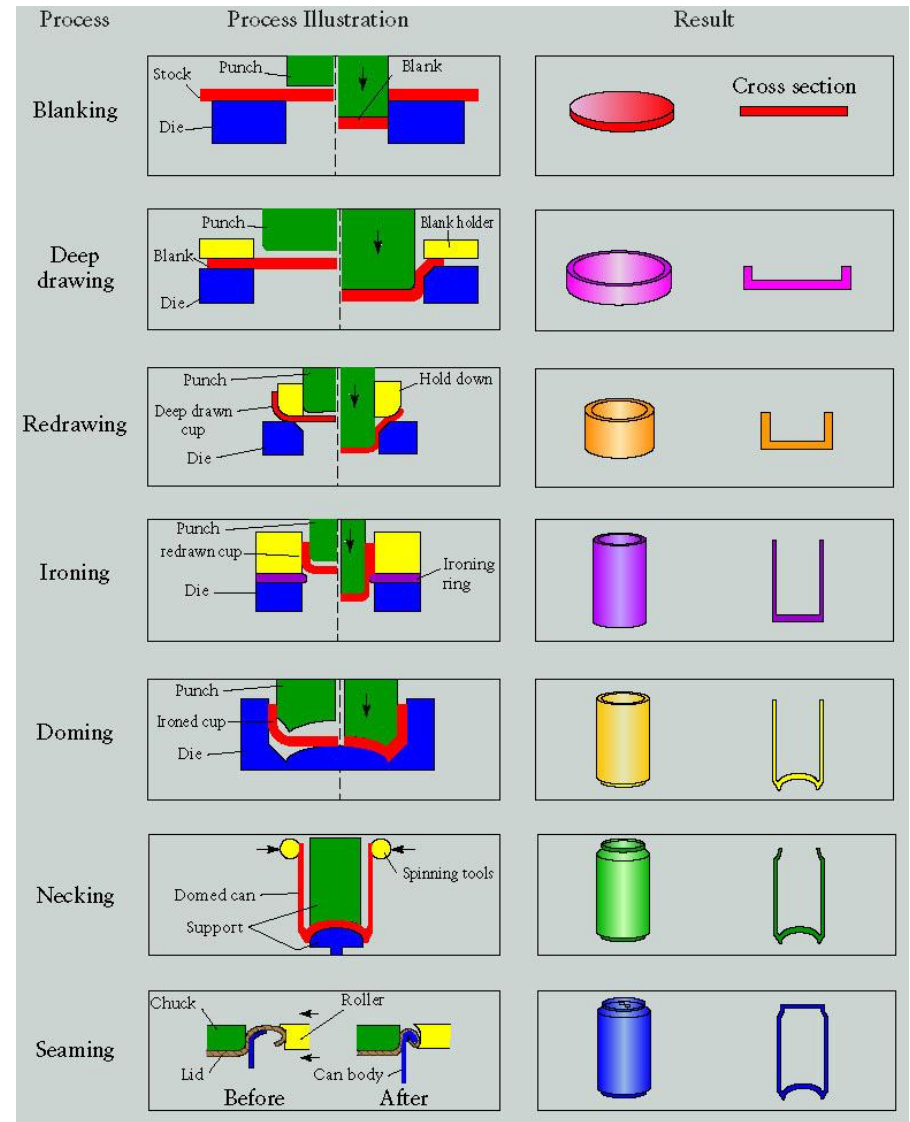
Top of Aluminum Can



Metal-Forming Process for Beverage Can

Steps in Manufacturing an Aluminum Can

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



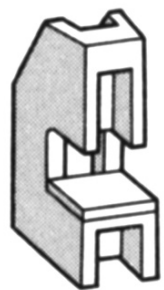
Aluminum Two-Piece Beverage Cans



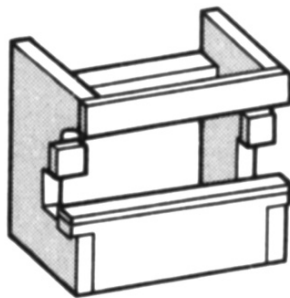
Aluminum two-piece beverage cans. Note the fine surface finish.

Press for Sheet Metal

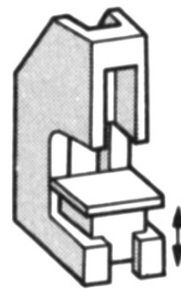
- Press selection for sheet metal forming operations depends on several factors:
 - Type of forming operation, and dies and tooling required
 - Size and shape of work pieces
 - Length of stroke of the slide, stroke per minute, speed and shut height (distance from the top of the bed to the bottom of the 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



**Basic
C-frame
design**



**Wide
design**



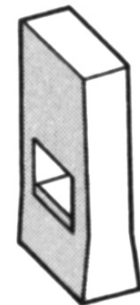
**Adjustable
bed**



**Open-back
inclinable**



Pillar



Double column

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



THANK YOU FOR YOUR ATTENTION

