Rao Badhur Y Mahabaleshwarappa Engineering College (RYMEC)

(Formerly , Vijayanagara Engineering College (VEC), Ballari)

Welcome to 4 Sem Mechanical Engineering, RYMEC Family.

Rao Badhur Y Mahabaleshwarappa Engineering College (RYMEC), BALLARI.

Dr. CHITRIKI THOTAPPA (MECH – 1987-1991)

PROFESSOR & M.Tech Co-Ordinator, Dept. of Mech.

SECRETARY - RYMEC, Alumni Association

QUALIFICATION:

BE (Mech) 1991 - (Gulbarga University)

ME (PM) 1994 - (Karnataka University)

Ph.D (SCM) 2012 - (Sree Venkateshwara University)

EXPERIENCE : 28 yrs Teaching, 1 yr Industry, 8 yrs Research.

PRESENTATION

Metal Cutting and Forming : (20ME45A)

By

Dr. Chitriki Thotappa

Email: thotappa@rymec.in

Contact No.: 9342612381

MODULE – 5
Sheet Metal forming (SMF)

CONTENT

Sheet metal operations: *Blanking, Punching, Piercing, drawing (Deep drawing / Cup drawing), Drawing ratio, Drawing force, variables in drawing Trimming and shearing.*

Bending *– Types of Bending dies, Bending force calculations. Embossing and Coining.*

Types of Dies*: Simple, Compound, Combination and Progressive dies.*

Difference between : Metal Slab, Metal Plate, Metal Sheet & Metal foil.

Module-3

Introduction to tool wear, tool wear mechanisms, tool life equations, effect of process parameters on tool life, machinability. Cutting fluid-types and applications, surface finish, effect of machining parameters on surface finish. Economics of machining process, choice of cutting speed and feed, tool life for minimum cost and production time. Numerical problems.

Module-4

MECHANICAL WORKING OF METALS Introduction to metal forming processes & classification of metal forming processes. Hot working & cold working of metals.

Forging: Smith forging, drop forging & press forging. Forging Equipment, Defects in forging.

Rolling: Rolling process, Angle of bite, Types of rolling mills, Variables of rolling process, Rolling defects.

Drawing & Extrusion: Drawing of wires, rods & pipes, Variables of drawing process. Difference between drawing & extrusion. Various types of extrusion processes.

Module-5

Sheet Metal Operations: Blanking, piercing, punching, drawing, draw ratio, drawing force, variables in drawing, Trimming, and Shearing.

Bending — types of bending dies, Bending force calculation, Embossing and coining.

Types of dies: Progressive, compound and combination dies.

2. NON-SHEARING OR FORMING SHEET METAL OPERATIONS.

1. Bending.
2. Spinning.
3. Stretching.
4. Embossing.
5. Coining.
6. Drawing.
7. Roll Forming.

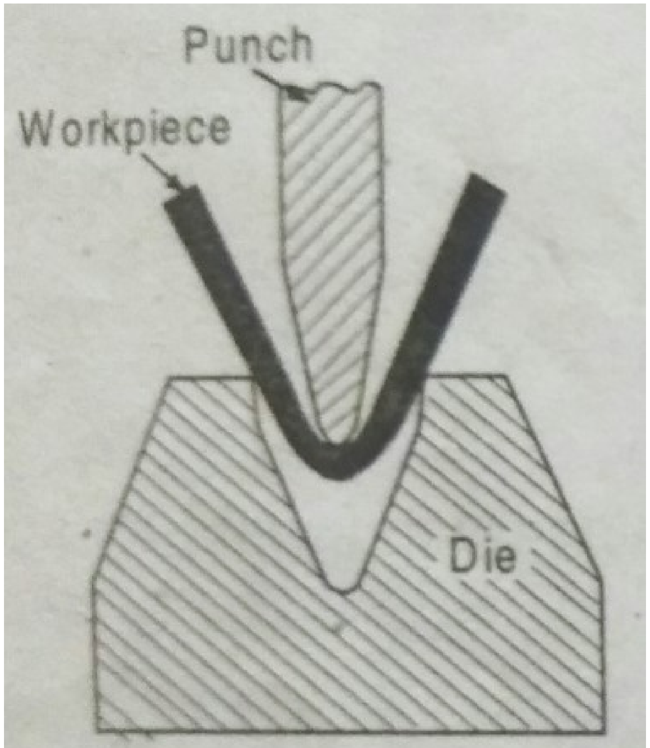
Bending : Bending is a Non-Shearing / forming sheet metal operation. In this operation, the material in the form of flat sheet or strip, is uniformly strained around a linear axis which lies in the neutral plane and perpendicular to the lengthwise direction of the sheet or metal.

BENDING : It Involves bending the sheet metal into a required angle or shape using punch and die.

Types of Bending Operations: There are various types of Bending operations, some Important bending operations are:

1. Air or Free bending.
2. Die bending (V or U-type etc.).
3. Wiper/Edge bending.
4. Contour roll forming or Cold roll forming.
5. Roll bending etc.

- **Air Bending : It** is widely used to obtain different angle V bends sections.
- In this required geometry is achieved by simple 3-point bending action.
- In this operation the entire length and surface area does not come in contact with the punch and the die.
- In fact the punch and die angles are less than the bend angle required on the work.

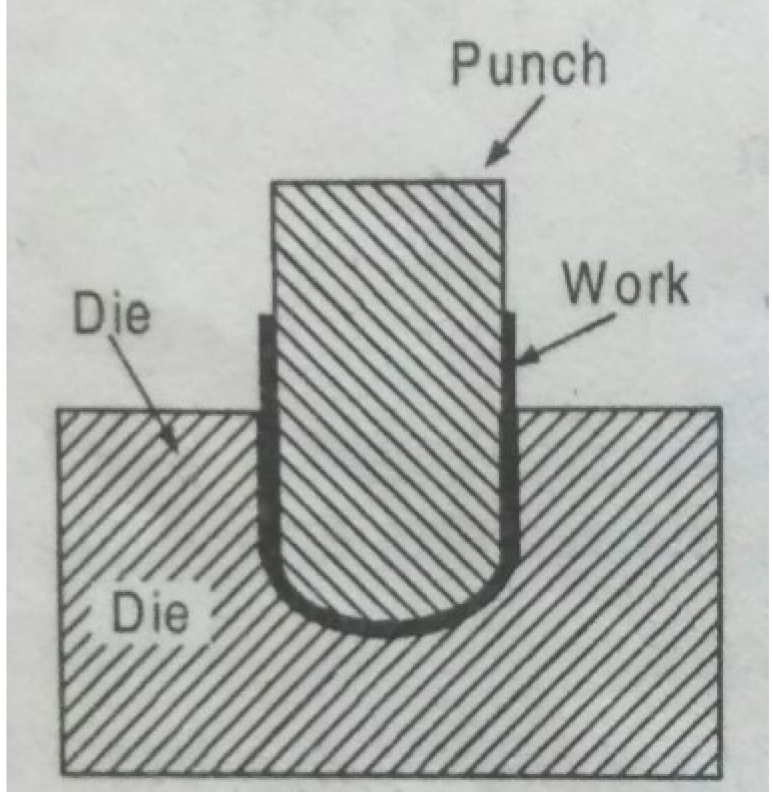


(a) Air or free bending

- The bend angle is simply controlled by changing the press ram position (height/up and down movement of the press ram) and spring-back action.
- With a given set of punch and die, different angle channels can be produced.

•Die Bending :

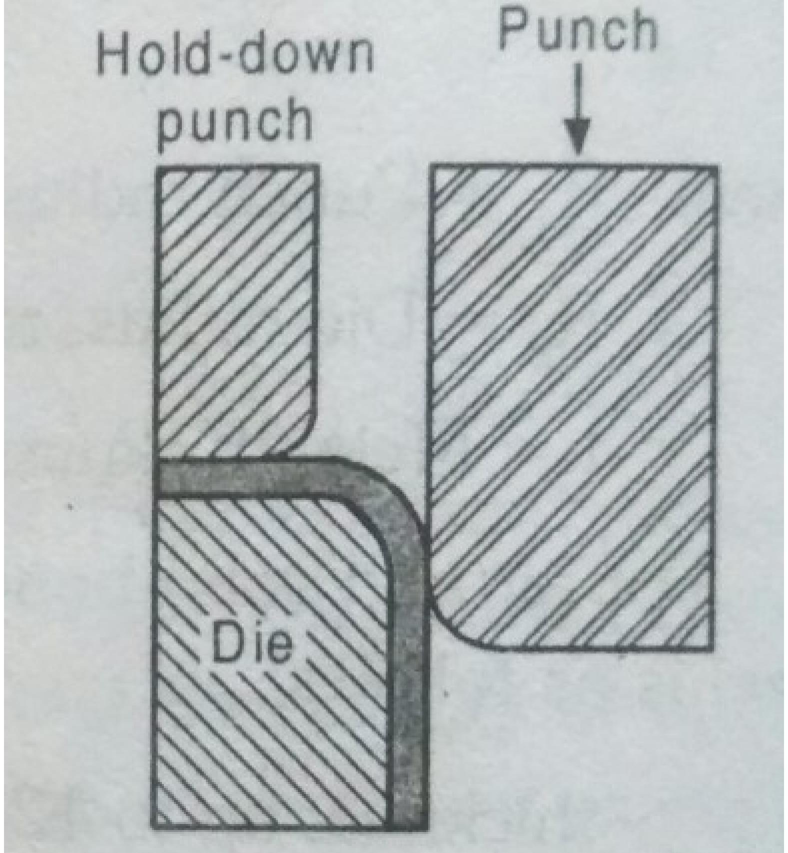
- **In this both Punch and die have the matching angles as required by the part/product.**
- **The sheet metal is hammered between the die and the punch.**
- **Thus, in this bending the sheet metal in the bending area is subjected to high localized compressive stresses/forces and in this bending spring-back action is less / negligible compared to Air bending.**



(b) Die or solid bending

•Edge / Wiper Bending:

- **In this operation the sheet metal is bent at the edge of the die using punch.**
- **The sheet metal is held down on the stationary die with a pressure pad (Hold down punch).**
- **As the punch descends (moves down) the sheet metal is bent to form a flange at the die edge.**

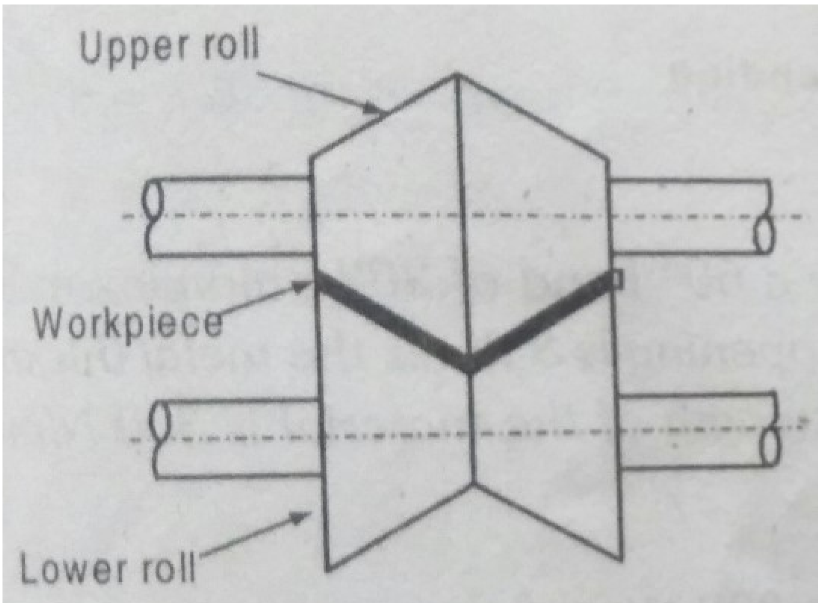


(c) Wiper or edge bending

Contour roll forming or Bending (Cold roll forming) : This type of sheet metal bending or forming is suitable for large scale production of continuous lengths of sheet metal sections.

The sheet metal is bent to get required contour or shape in stages by passing through a series of rolls of suitable shapes.

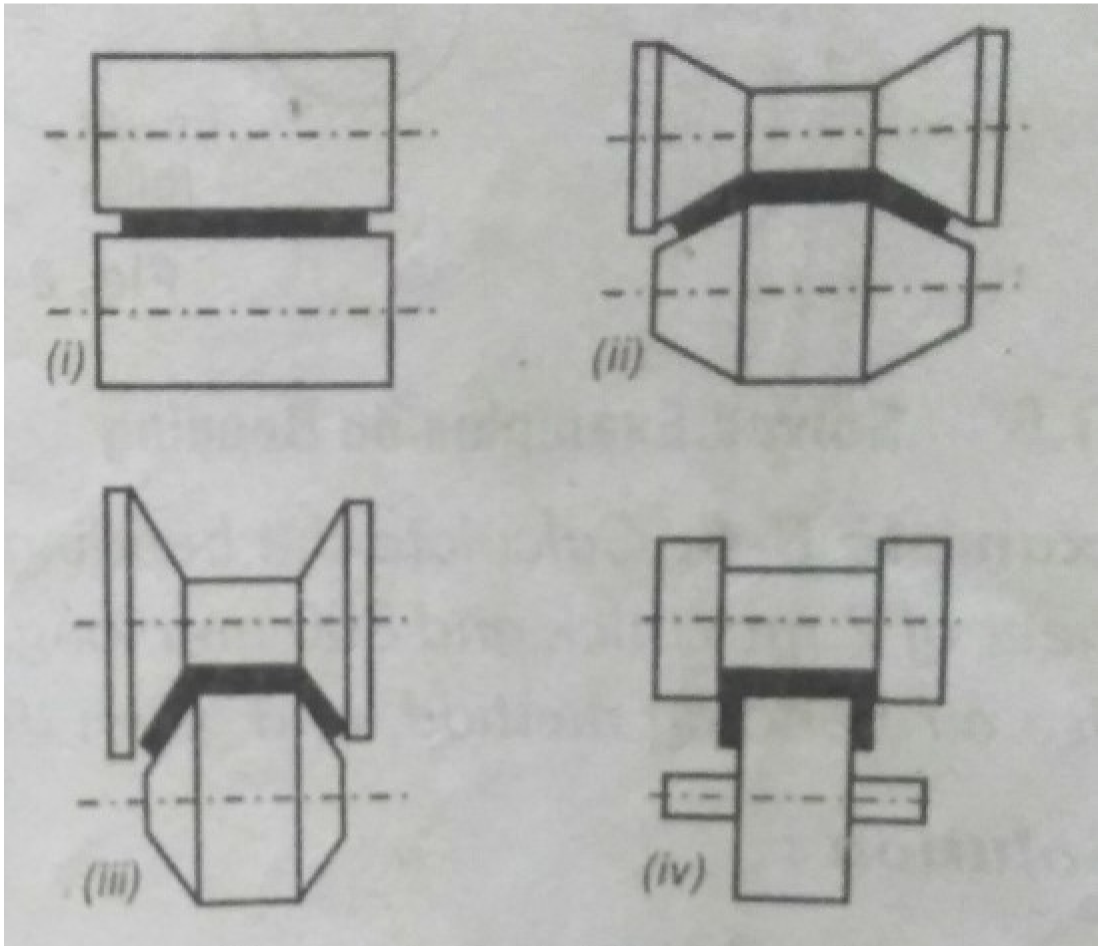
The Contour or Cold roll forming to obtain V shaped channel section is shown in Fig. (a).



(a) V-channel forming

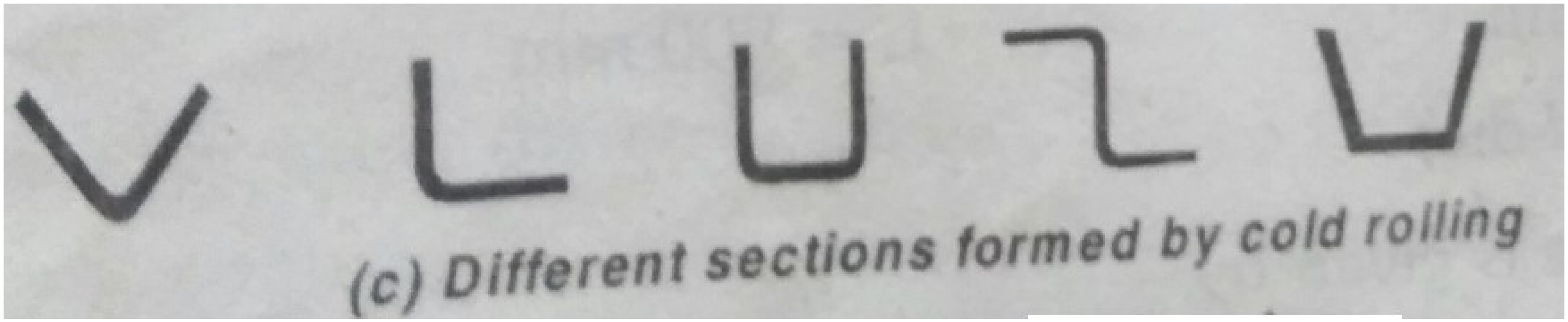
The different stages in the forming of U-channel is shown in Fig.(b)

Fig.(c) shows the different sections that can be formed by cold rolling.



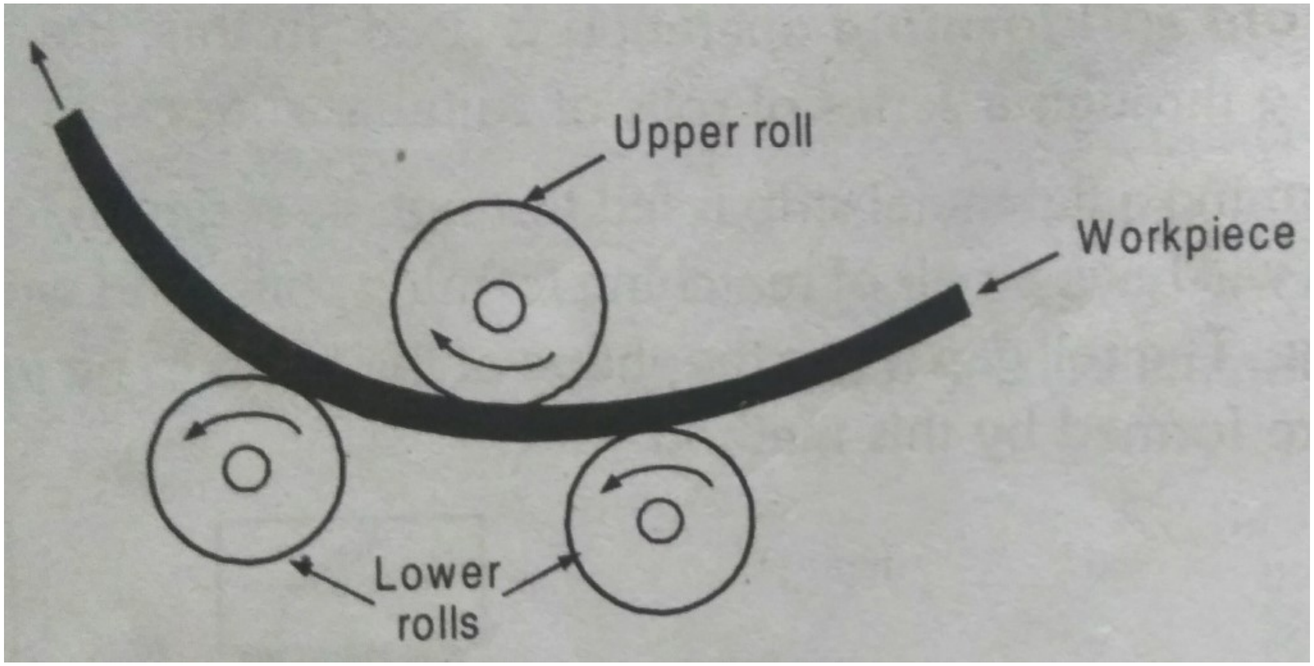
(b) Stages in U-channel forming

Fig.(c) shows the different sections that can be formed by cold rolling.

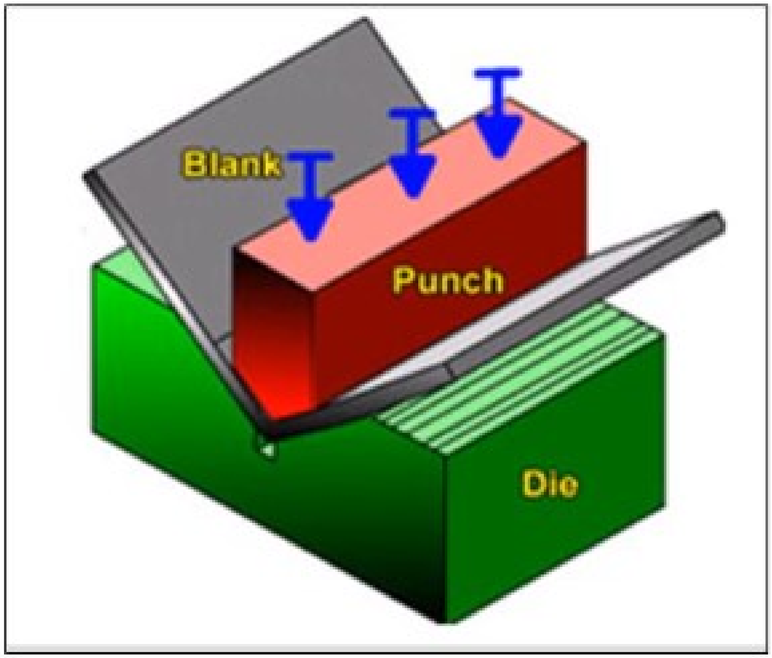


Roll bending : **Roll bending is a continuous form of 3-point bending.**

It uses 3- rolls to form the sheet metals as shown in the Fig. The upper and bottom rolls are adjustable, to accommodate different thickness of sheet metal and assist in bending the sheet metal to the required degree.



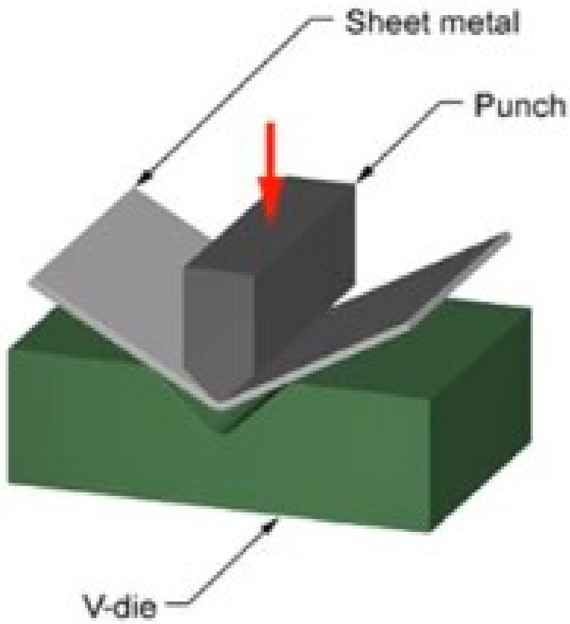
Bending types



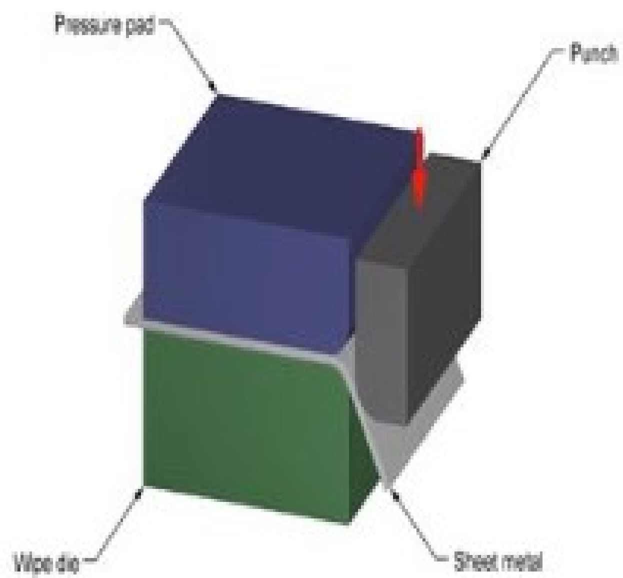
Two common bending methods are:

- **V-Bending**
- **Edge bending**

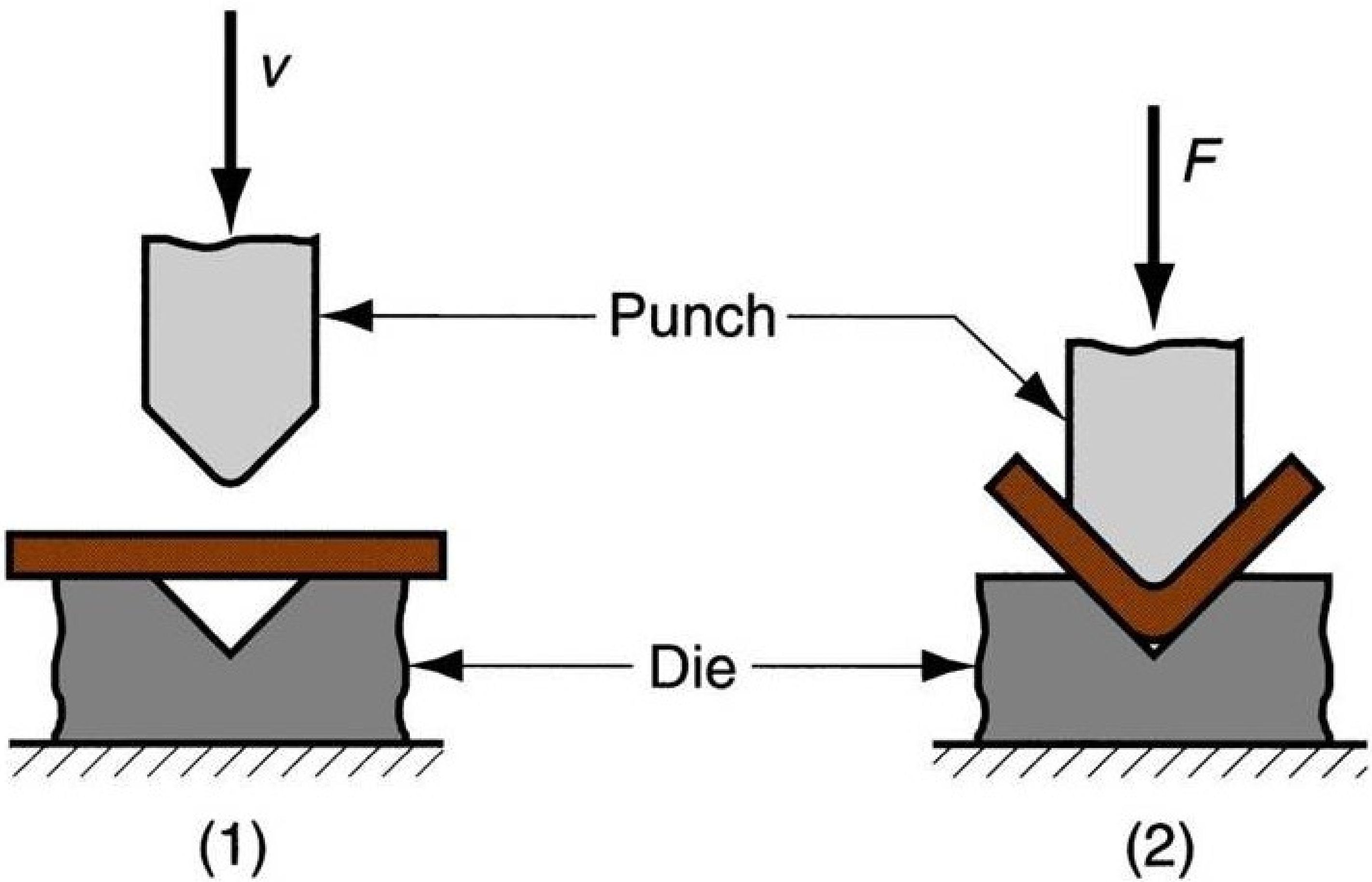
  - **V-Bending:** The sheet metal blank is bent between a V-shaped punch and die.
  - Air bending: If the punch does not force the sheet to the bottom of the die cavity, leaving space or air underneath, it is called "air bending“.



Air Bending



- **Edge or Wipe Bending:** Wipe bending requires the sheet to be held against the wipe die by a pressure pad. The punch then presses against the edge of the sheet that extends beyond the die and pad. The sheet will bend against the radius of the edge of the wipe die.



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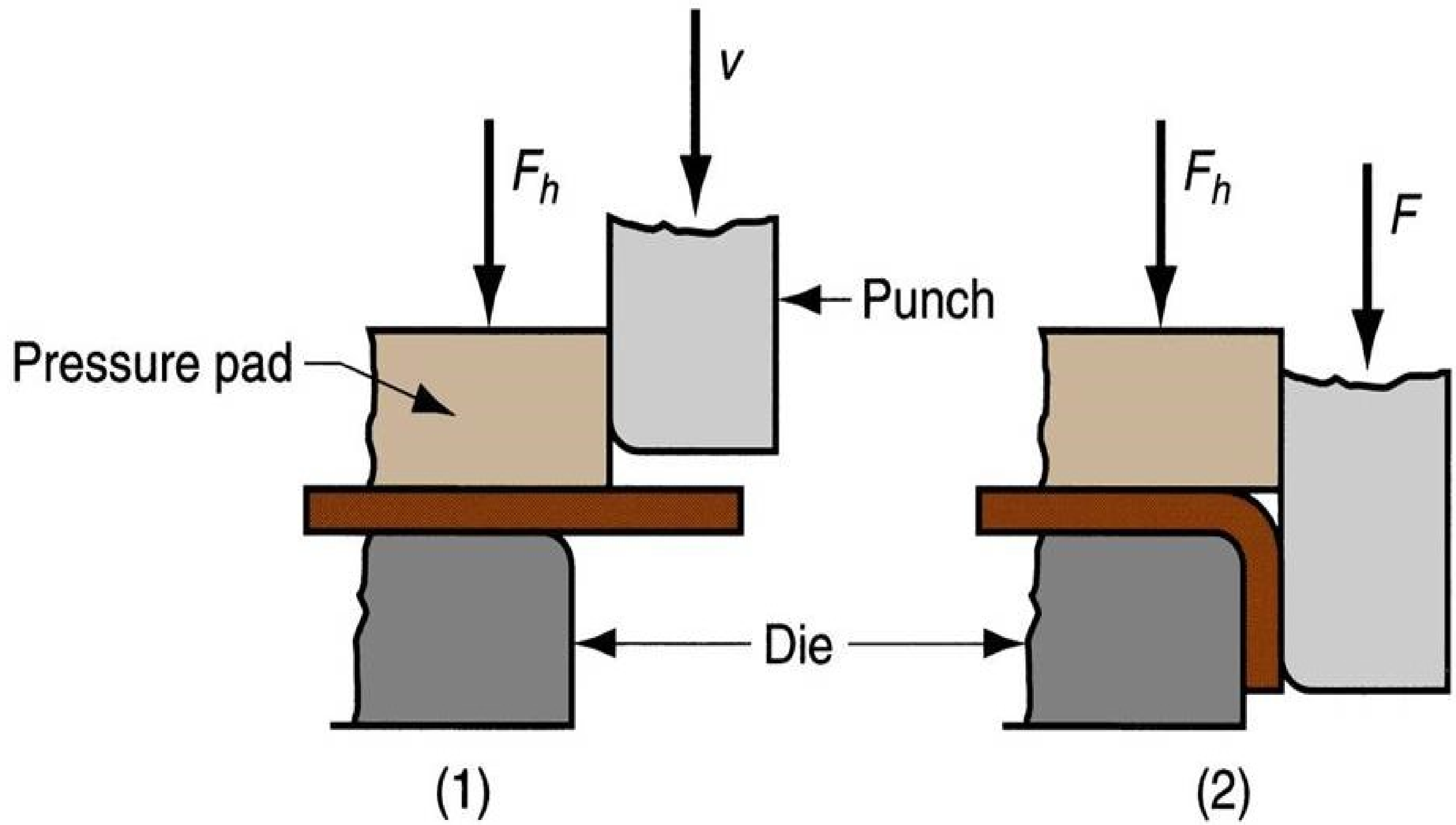

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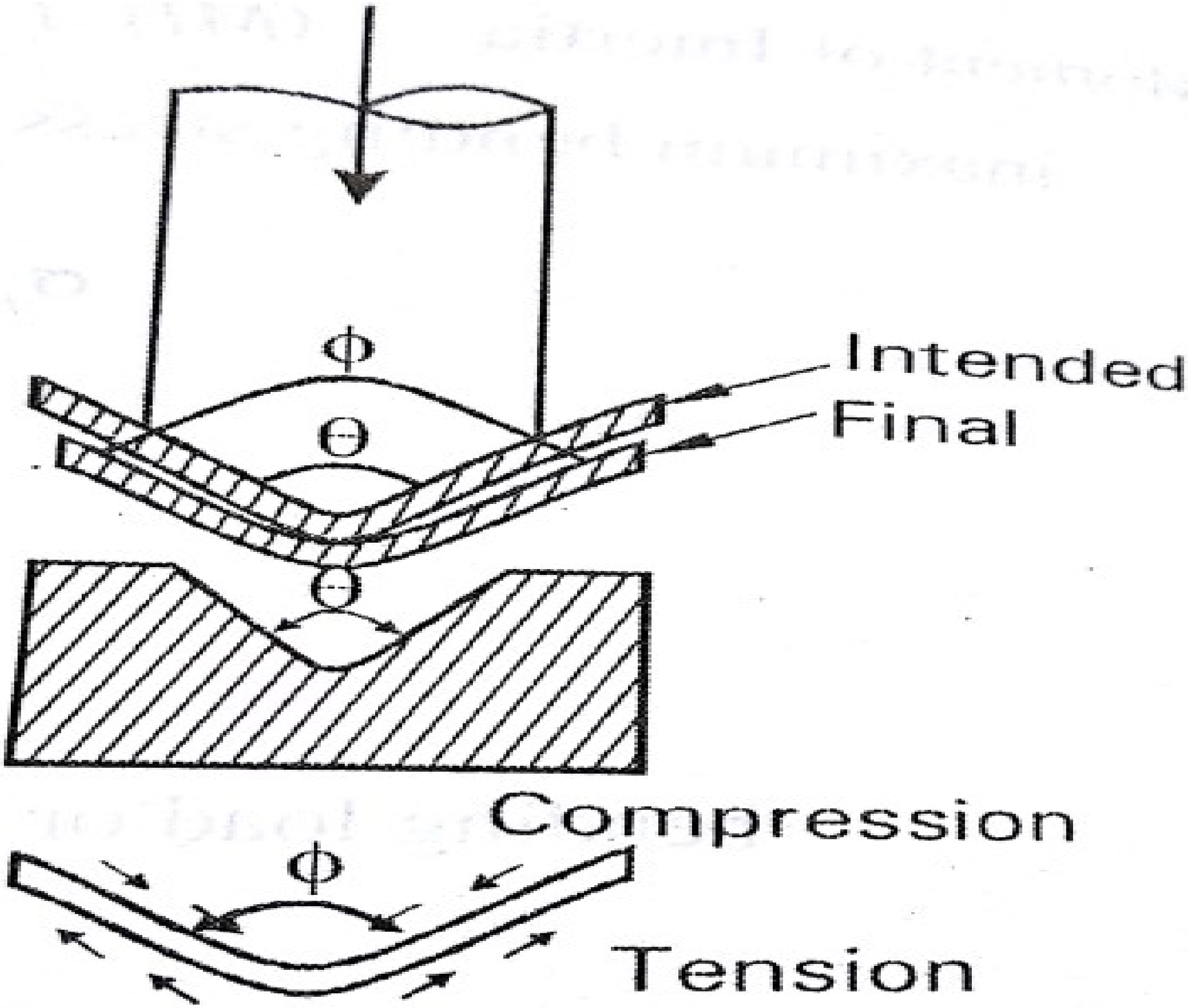
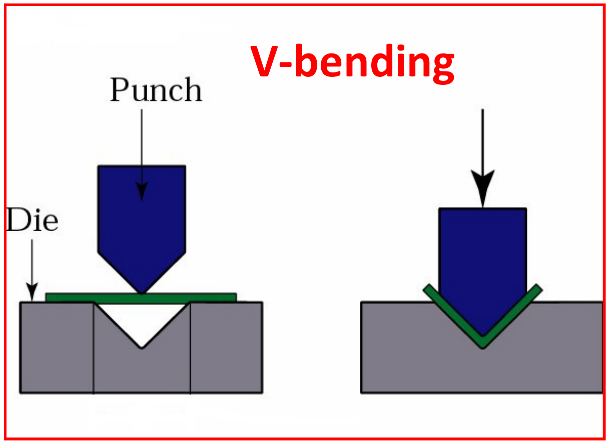
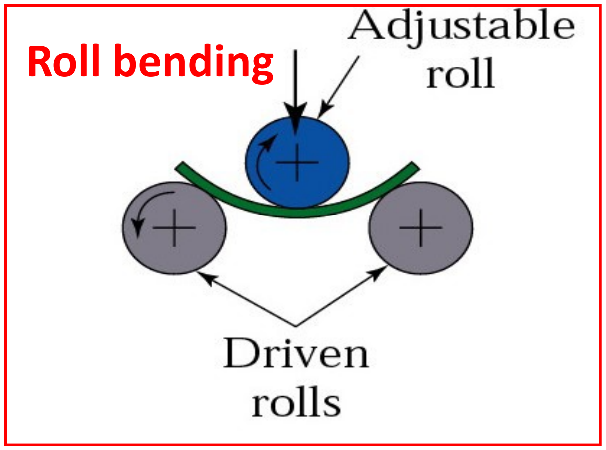
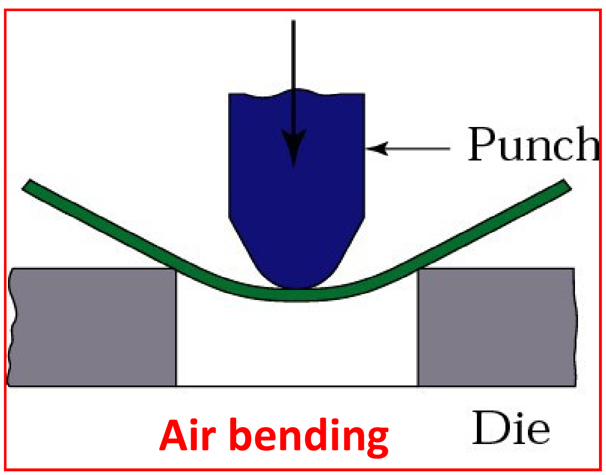


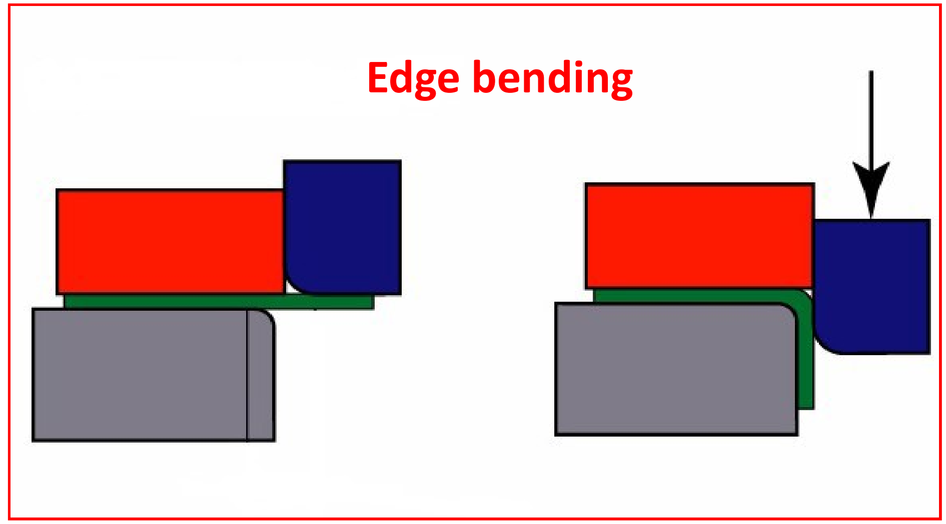
Fig. 7.46 Spring back in bending

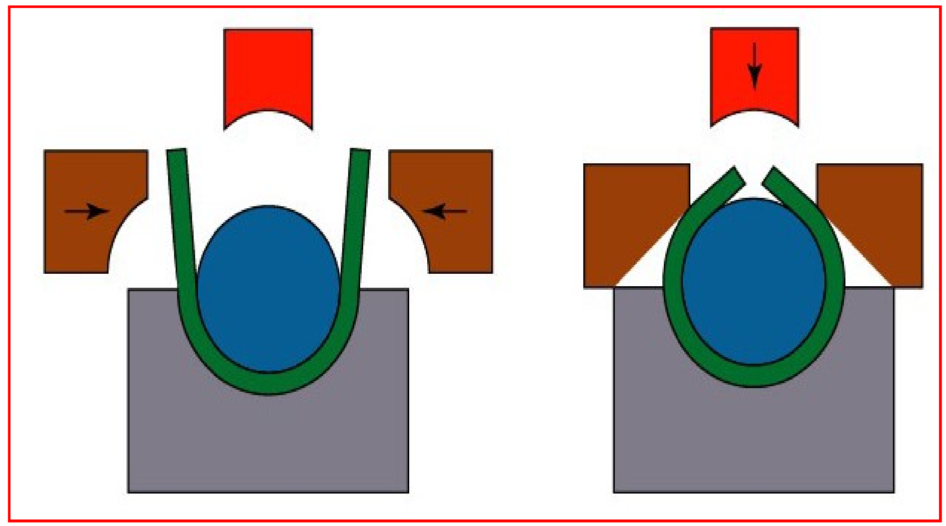
Types of Bending operations





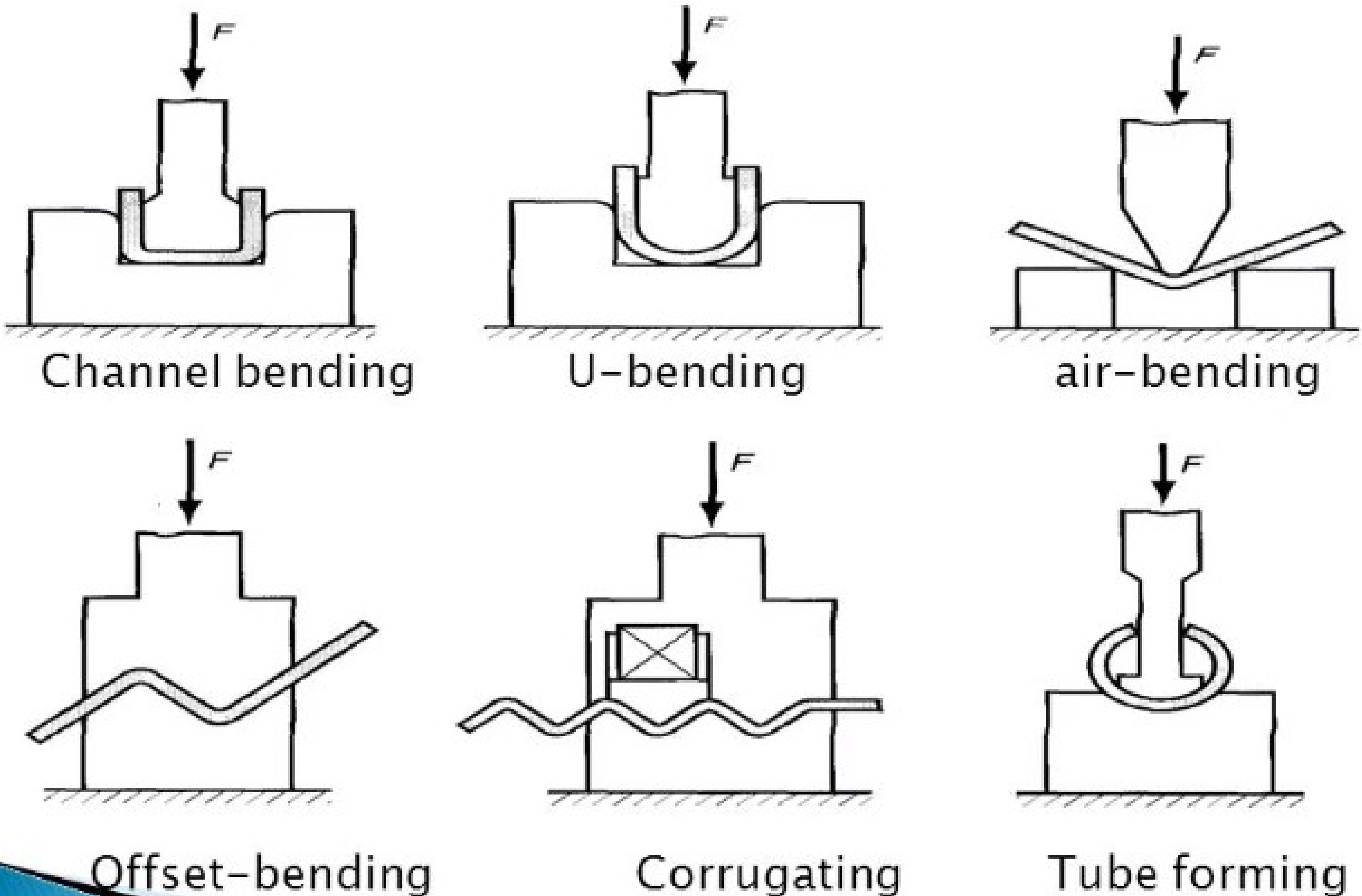






Bending in 4-slide machine

Bending Operations



Bending Force:

Bending force is the force required to bend or deform the sheet metal during bending operation.

Bending force (F_b) can be obtained using simple bending principle of a rectangular beam.

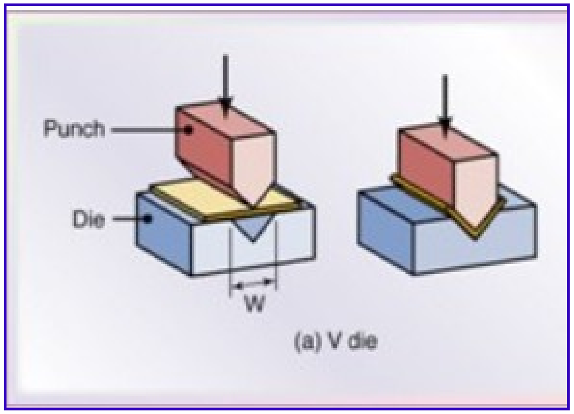
Bending force is a function or depends on the following factors or variables:

- **σ_y - Strength of the material (Sheet metal) (i.e. Yield strength of the material)**
- **L - Length of the bend.**
- **t - Thickness of the sheet metal.**
- **W - Beam span or Die opening.**
- **k - Bending factor which depends on type of bending die.**

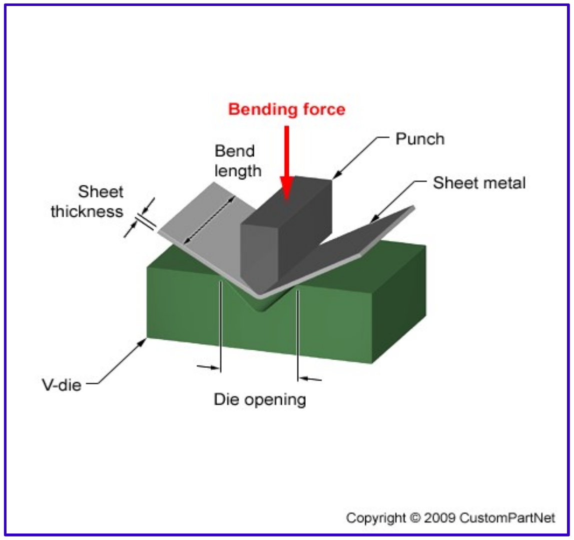
Bending Force = F_b is given by

$$F_b = \frac{\sigma_y \times k \times L \times t^2}{W}$$

- σ_y - Strength of the material (Sheet metal) (i.e. Yield strength of the material), MPa
- L - Length of the bend, mm
- t - Thickness of the sheet metal, mm
- W - Beam span or Die opening, mm
- k - Bending factor which depends on type of bending die.



Typical 'K' values are:



K = 0 for Wiping Die.

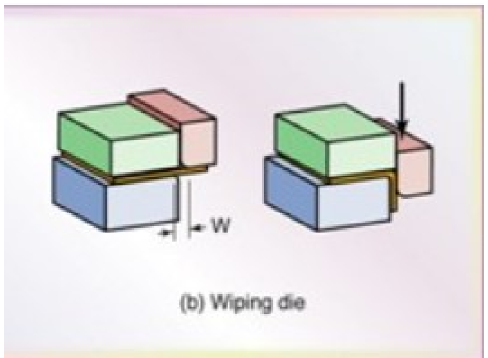
K = 0.7 for U-Die.

K = 1.33 for V-Die.

K = 2.66 for U-channel with flanges.

In case of Edge /Wiping die, the span length (W) is the sum of Punch (R1) and Die (R2) radii, and the metal thickness (t)

i.e. W = R1 + R2 + t



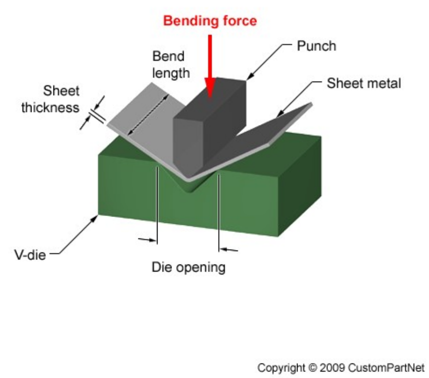
Where, R1 – Punch radius in mm
R2 – Die radius in mm
t – Sheet metal thickness in mm

For Air and Solid Die bending, the recommended Die opening (Span length – W)

For mild steel is as follows:

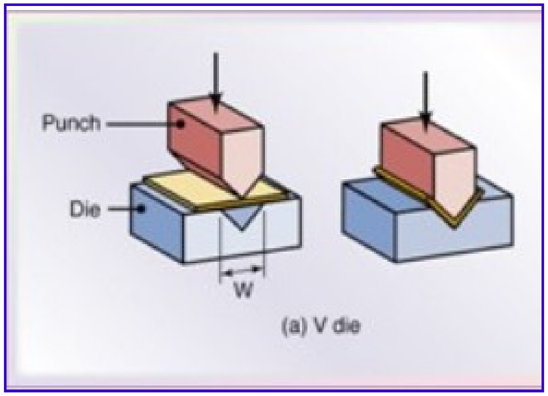
Thickness upto 12.5 mm, W = 8 t

Thickness > 12.5 mm, W = 10 t to 12 t



Problem on Bending Force:

P1: ***An L – angle is to be produced by bending operation. The material is a steel sheet of 4 mm thickness, 150 mm long and has an yield strength of 400 N/mm2. Now the choice is to be made between an Air-bending and Wiping die bending, considering the minimum bending force criteria. The Air bending die has beam span of 50 mm, while the Wiping die and punch have radii of 12 mm each.***

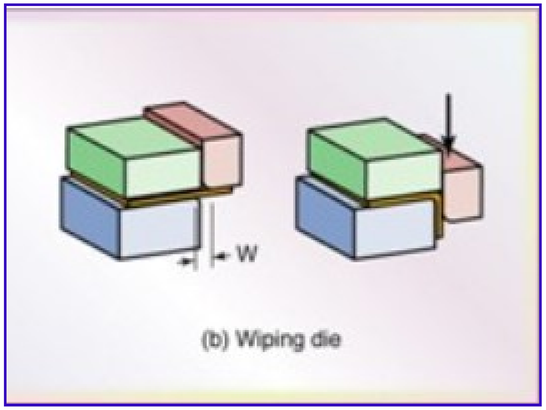


Solution: t = 4 mm, L = 150 mm, W = 50 mm (Air bend die),
R1 = R2 = 12 mm (Punch and Die radii)
W = R1 + R2 + t = 12 + 12 + 4 = 28 mm (for Wiper die)

Let us calculate the bending force for both the cases.

Bending force is given by

$$F_b = \frac{\sigma_y \times k \times L \times t^2}{W}$$



K = 1.33 for Air bending die.
K = 0.7 for Wiping die.

Bending force for Air bending operation is,

$$F_{ba} = \frac{400 \times 1.33 \times 150 \times 4^2}{50}$$

= 25536 N = 2.6 tonnes

Bending force for Wiper bending operation is,

$$F_{bW} = \frac{400 \times 0.7 \times 150 \times 4^2}{28}$$

= 24000 N = 2.45 tonnes

Since the bending force required for wiper die operation is lower than the Air die bending, the wiper die Bending is recommended.

EMBOSSING : It involves projection on one side of a sheet with a corresponding depression on the other side, Using die and punch. This produces relatively shallow indentations/impressions/projections with no change in sheet metal thickness. Embossing operation is a combination of bending and stretching operations, and there is no lateral flow of metal as in coining. It requires less force/pressure compared to coining operation. It is used for producing nameplates tags and many designs on the sheet metal.

Embossing

- Certain designs are embossed on the sheet metal.
- Punch and die are of the same contour but in opposite direction.

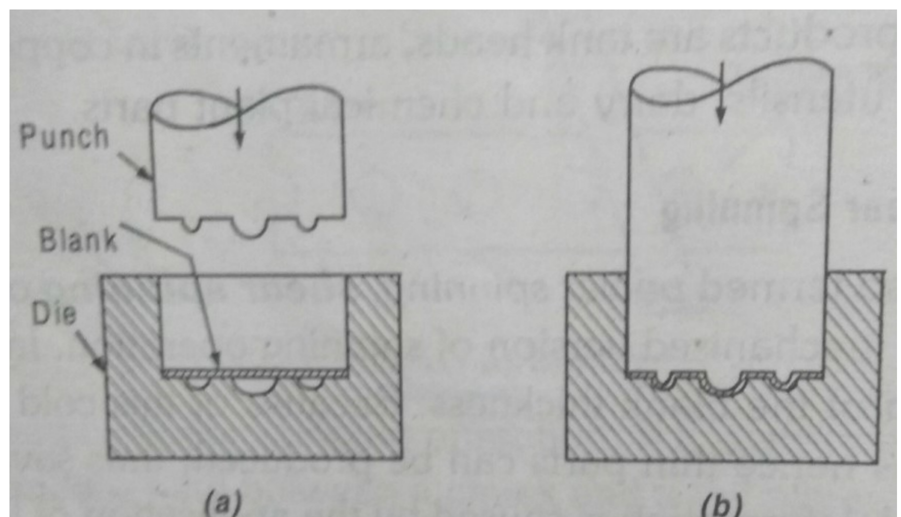


Fig. 8-49. Embossing

EMBOSSING :

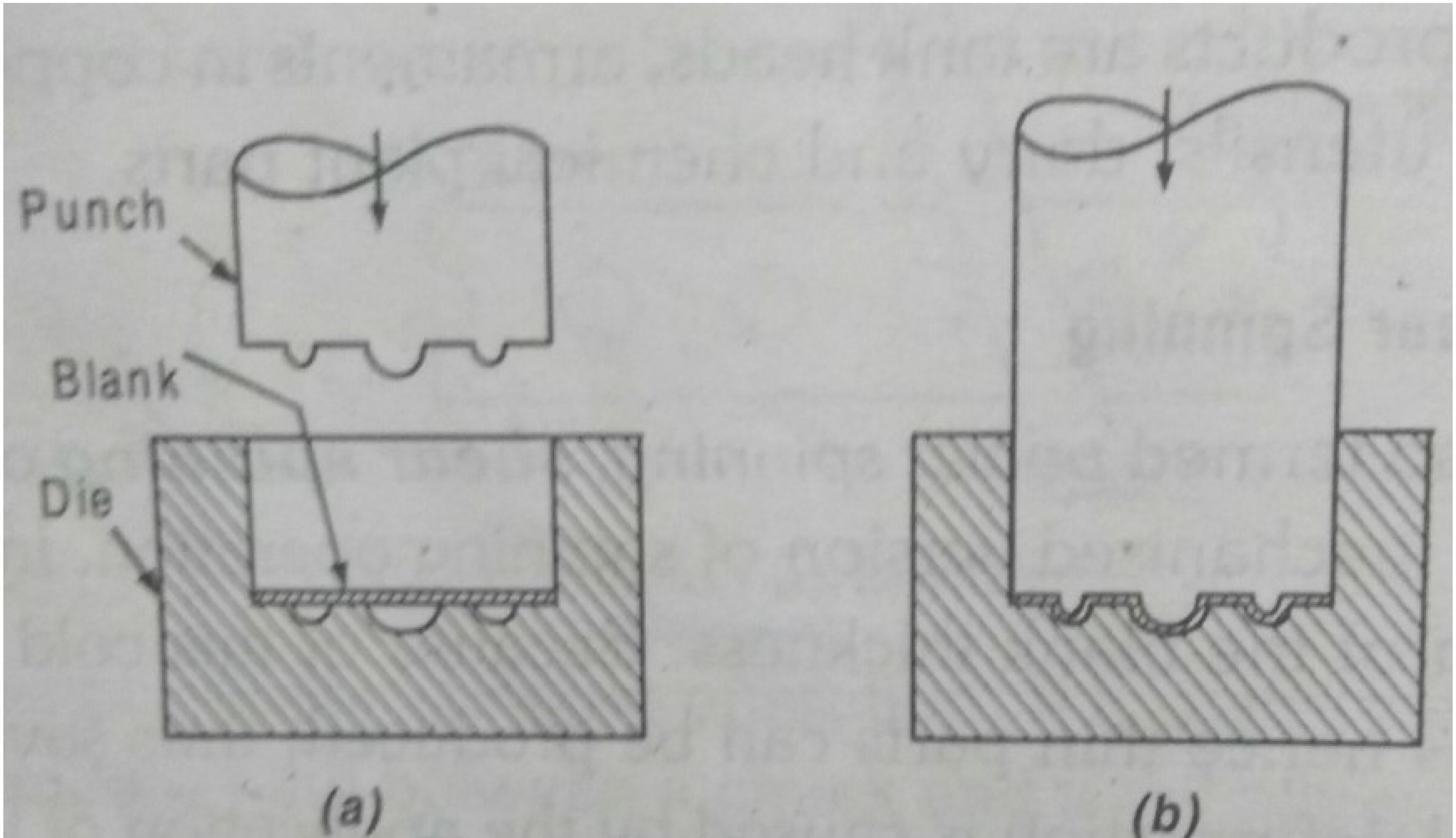
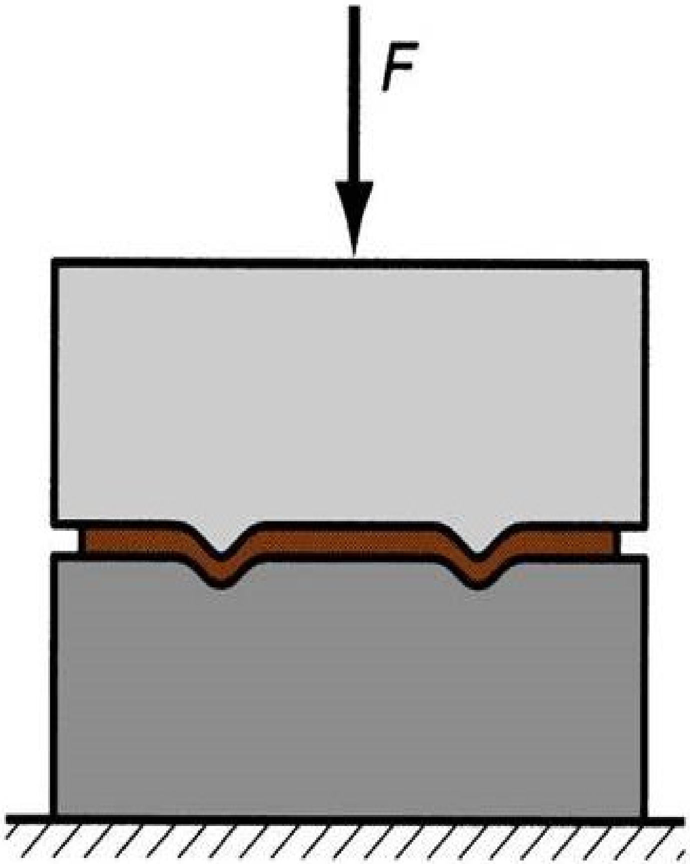


Fig. 8-49. Embossing

EMBOSSING



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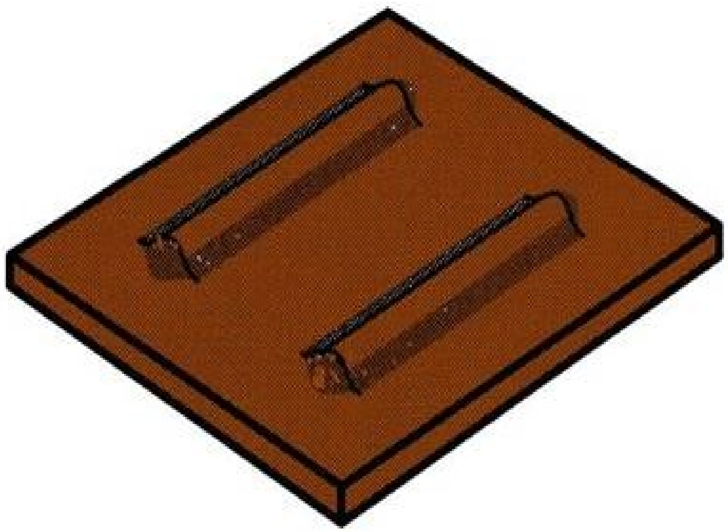


(b)

EMBOSSING

Sheet metal embossing is a stamping process for producing raised or sunken designs or relief in sheet metal.

EMBOSSING APPLICATION

NUMBER PLATE, NAME PLATE, LOGO, TRADEMARK, JEWELLERY ETC.

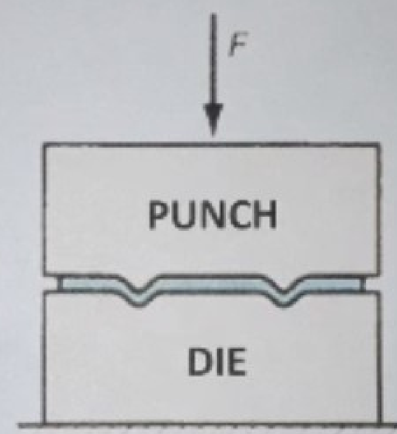
COLD WORKING PROCESS

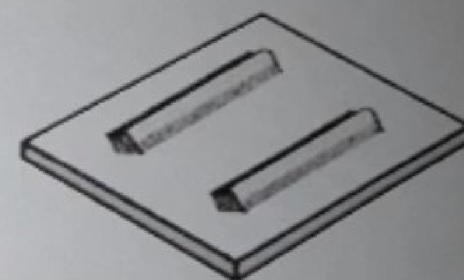
LESS FORCE REQUIRED COMPARED TO COINING PROCESS

SHEET METAL OPERATION

SHALLOW FORMING OPERATION

UNIFORM WORKPIECE THICKNESS





FINISHED PART WITH EMBOSSED RIBS

PUNCH AND DIE WITH SAME CONTOUR BUT IN OPPOSITE DIRECTION

EMBOSSING MATERIAL

ALUMINIUM,BRASS,COPPER, STEEL,ZINC,HOT ROLLED STEEL, COLD ROLLED STEEL, SILVER, GOLD ETC.

COINING : It involves creation of projection or impression on either side of the sheet not necessarily same Projections / impressions, using die and punch.

This process is used for manufacturing of coins, badges, medals, tokens etc.

Coining is a cold forging operation in which sheet metal flows plastically and squeezed to the shape between the punch and die.

The metal is caused to flow in the direction of perpendicular force. The type of impression is formed by compressive force.

Thus, there is change in the blank thickness after forming. Since there is considerable amount of metal flow, the coin thickness is more than that of the original blank thickness.

The process is carried out in a closed die, and the metal is not allowed to extrude out of the die. Care must be taken to see that the blank thickness is just enough to fill the die and punch cavity. If there is excess metal, then it may cause damage the punch and die.

Coining Operation:

By using the required shape punch and dies, the impression and images are created on both sides of the sheet metal. The type of impression obtained on both sides will be different.

Because of the metal flow in cold conditions, very high pressure about 1600Mpa is required for coining operation. For this purpose usually heavy duty hydraulic presses are used.

Coining

- Similar to embossing with the difference that similar or different impressions are obtained on both the sides of the sheet metal.

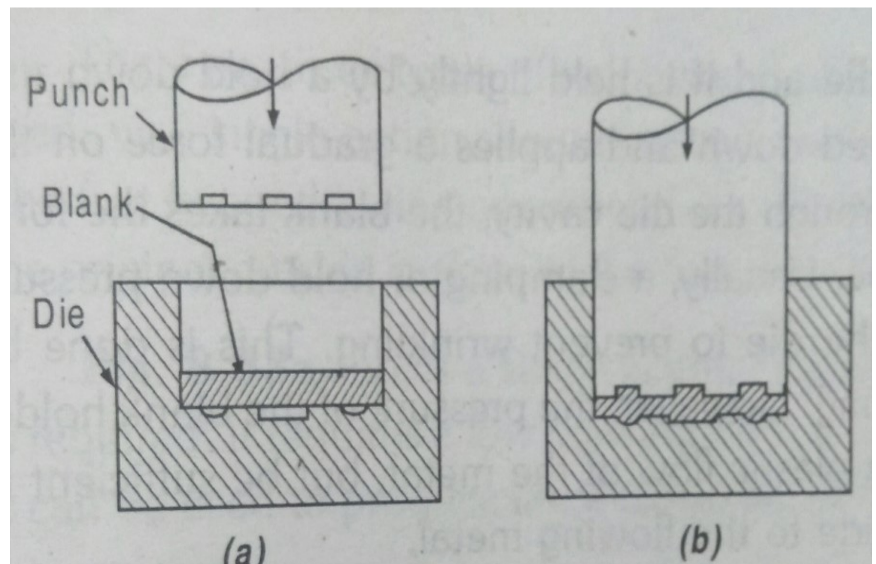


Fig. 8-50. Coining

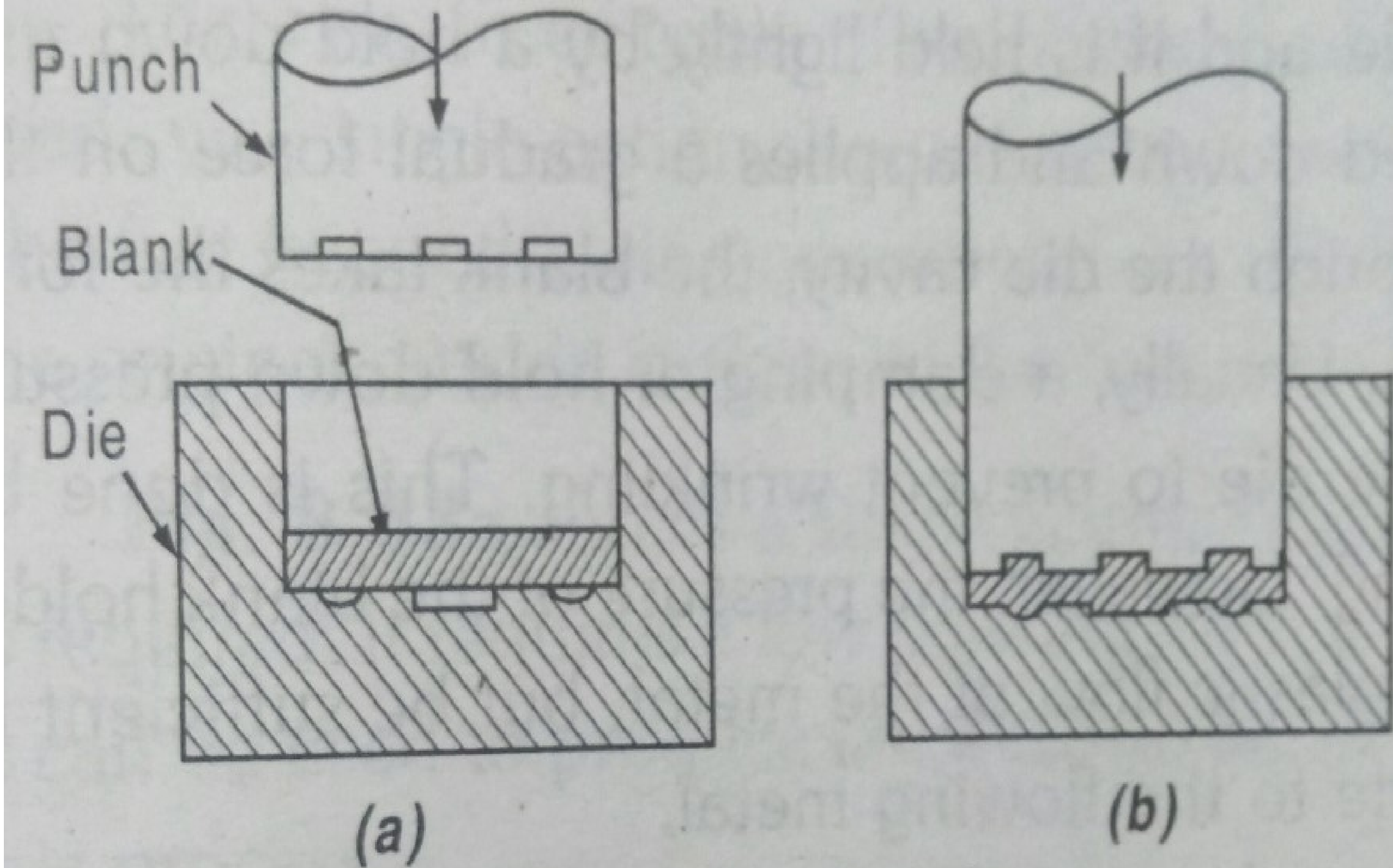


Fig. 8-50. Coining

COINING

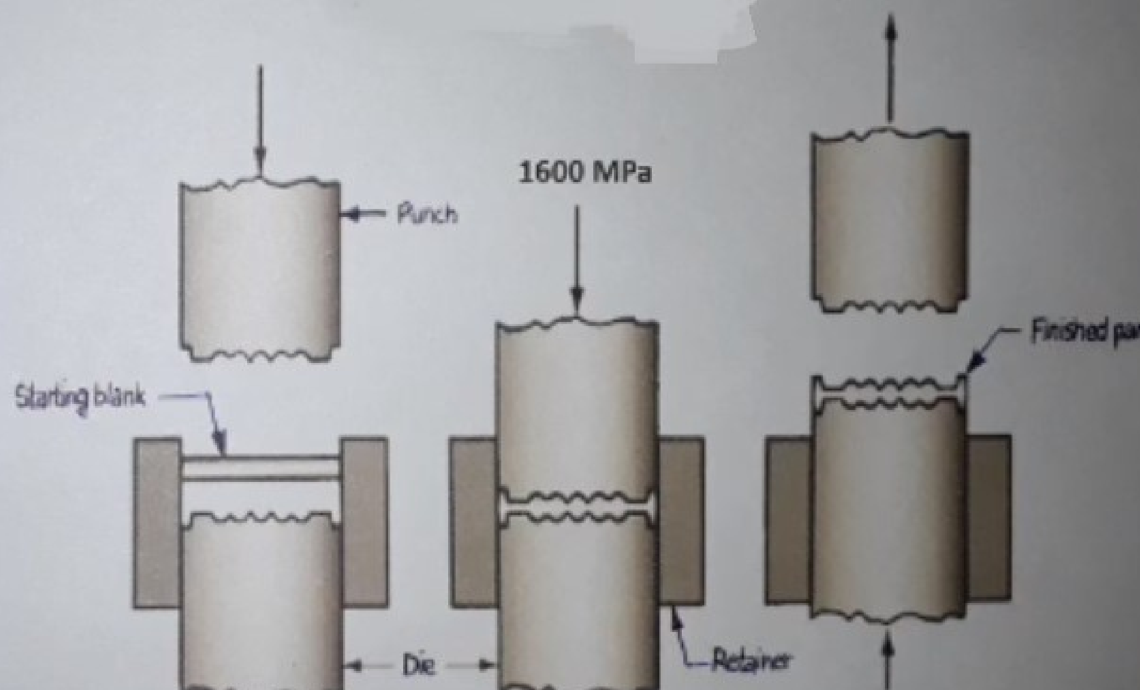
COLD WORKING PROCESS

CLOSED DIE FORGING PROCESS

HIGH PRESSURE REQUIRED ABOUT 1600 MPa

Similar to Embossing

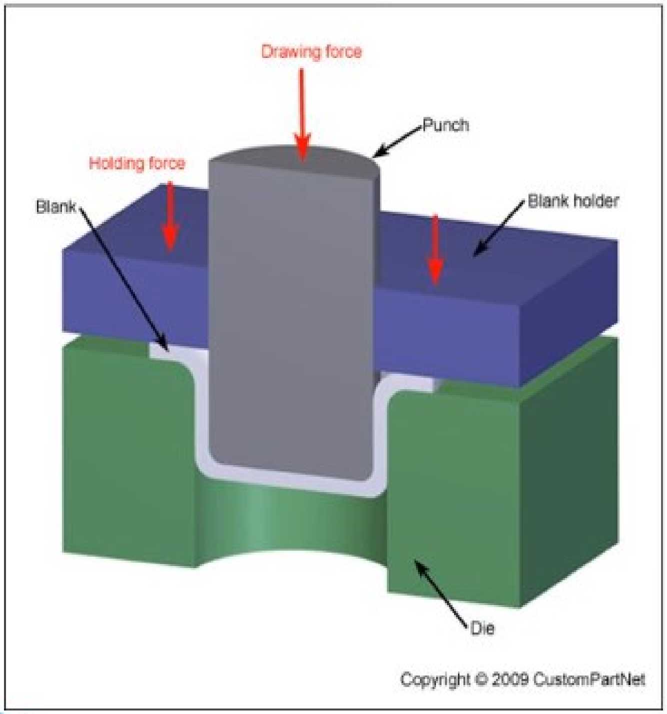
The term comes from the initial use of the process- Manufacturing of Coins



Drawing or Deep Drawing : Involves creating cup shaped sheet metal object, using punch and die. It is also called as Cup drawing.

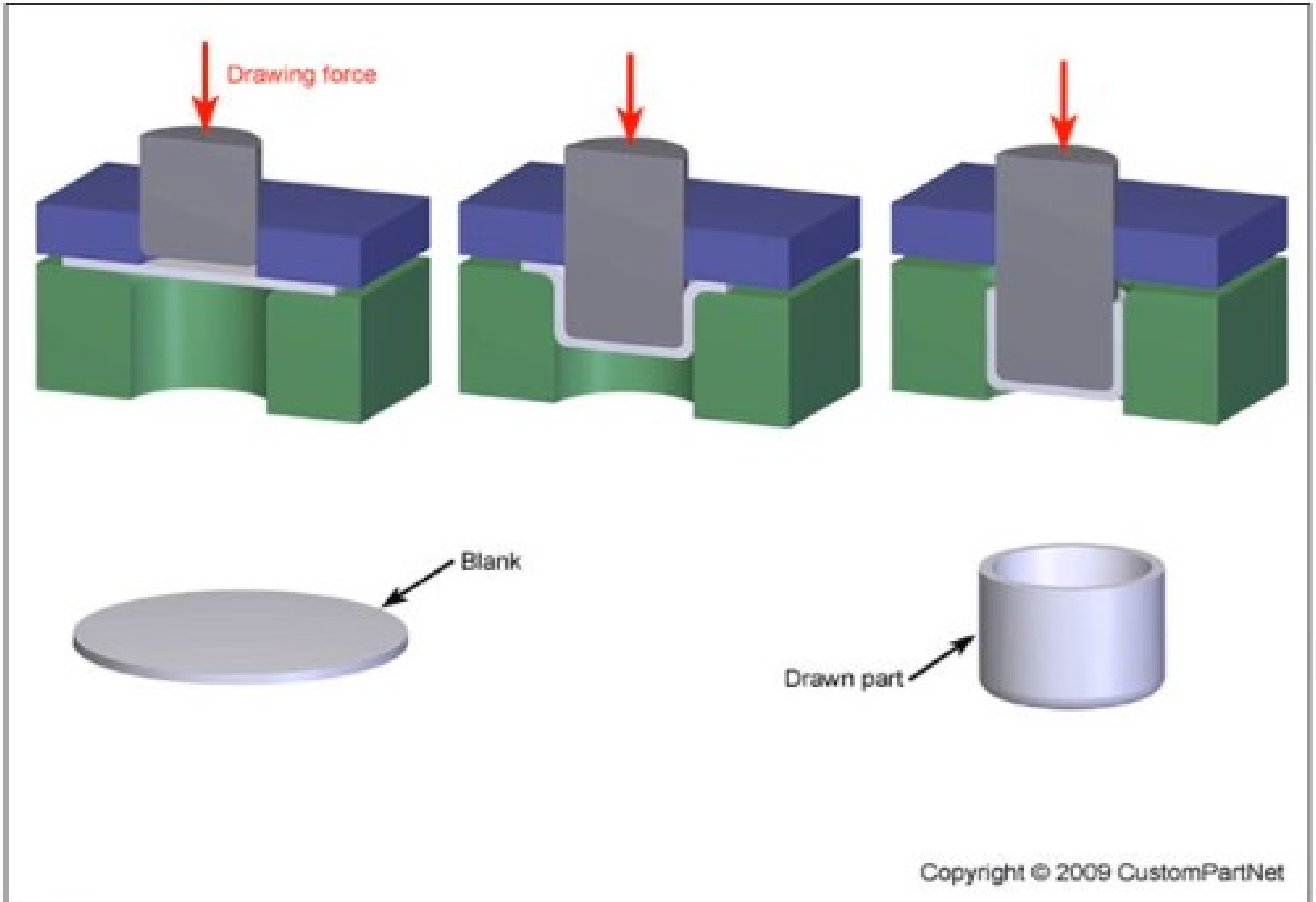
Drawing : This is a process of a forming a flat work piece (sheet metal) into a hollow cup shape part by means of a punch, which causes the blank to flow into die cavity.

Deep Drawing

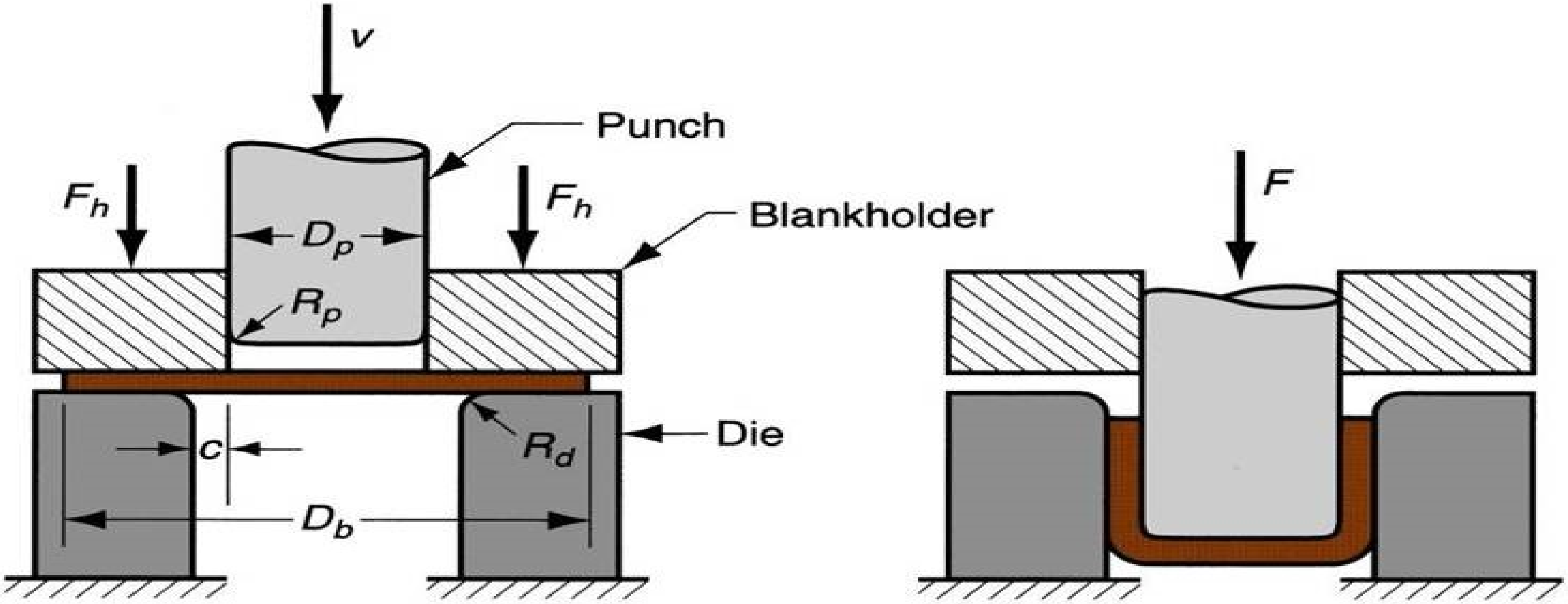


- Deep drawing is a metal forming process in which sheet metal is stretched into the desired shape.
- A tool pushes downward on the sheet metal, forcing it into a die cavity in the shape of the desired part.

Deep Drawing Sequence



Drawing or Deep Drawing



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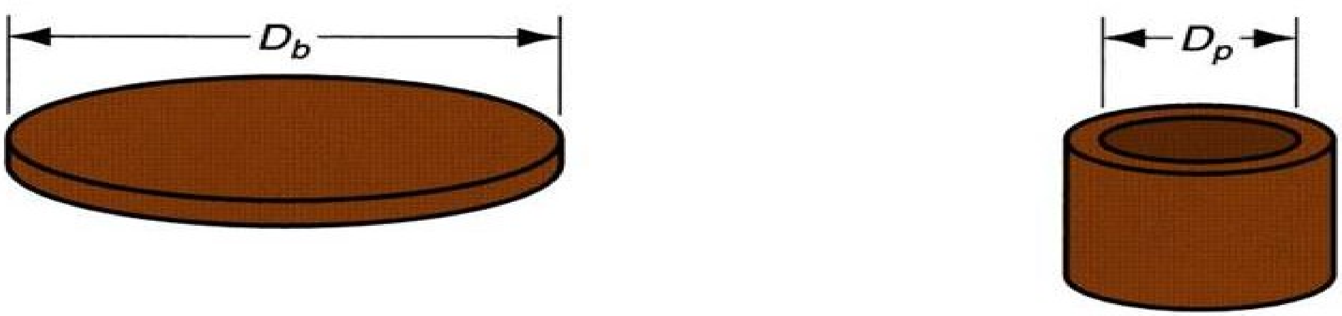


(1)

(2)

(b)

Drawability & Draw Ratio (Limiting Draw Ratio – LDR)

Drawability: **It is the ability of the sheet metal to draw / deform into cup to the Max. without causing any crack or failure.**

It is measured by the ratio know as Draw Ratio (Limiting Draw Ratio).

It depends on (is a function of) type of material (mechanical prosperities (ductility) of the sheet metal) and the thickness of the sheet metal.

It is a measure of how much Max. a given sheet metal can be drawn into cup shaped objects, without causing any cracks / damages or failures .

Draw Ratio (Limited Draw Ratio) : It is defined as a ratio of Initial **Blank diameter** (**Do or Db**) to the **Punch diameter** or Final **diameter of the Cup** drawn (**Dp or Dc**).

LDR = Dia. of blank / Dia. of Cup (Punch).

= Do or Db / Dp or Dc

This gives an idea of the largest diameter of the blank that can be drawn using a punch without tearing / failure.

Larger the blank diameter, larger is the punch force required.

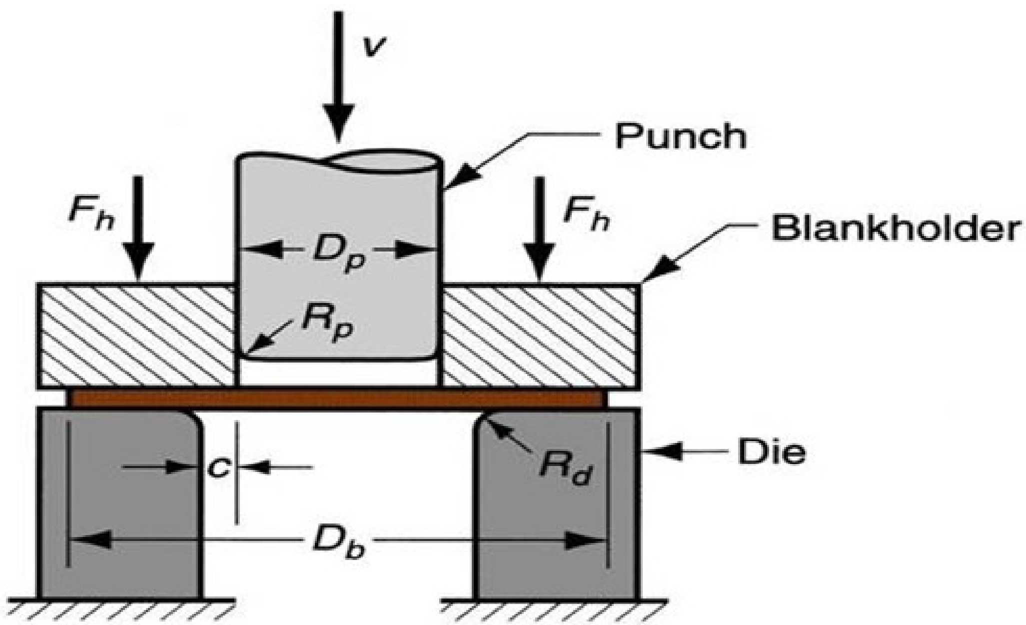
Higher the LDR , higher is the Drawability.

Drawing variables

- A Process in which a punch forces a flat sheet metal blank into a die cavity.
- Drawing variables:
  1. Properties of sheet metal.
  2. Ratio of blank diameter (D_o) to punch diameter (D_p).
  3. Clearance © between punch & die.
  4. Punch radius R_p.
  5. Die corner radius (R_d).
  6. Blank holder force.
  7. Friction and lubrication.
- The punch force increases with increasing in strength, diameter, and thickness of sheet metal blank.

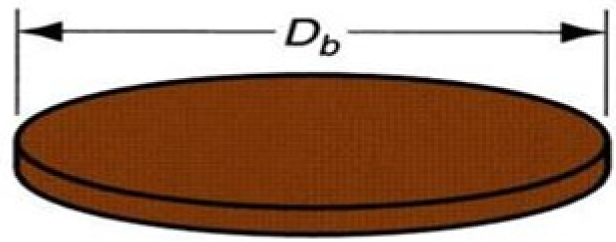
Variables in Drawing: **The important variables or parameters in deep drawing are:**

1. Corner Die radius.
2. Corner Punch radius.
3. Clearance between the Punch and Die.
4. Blank diameter.
5. Punch diameter.
6. Total Punch load or Force.
7. Speed of the punch.
8. Blank Hold down Pressure or Force.
9. Limiting Drawing Ratio.
10. Friction and Lubrication.
11. Properties of sheet metal.
12. Thickness of the Sheet metal.

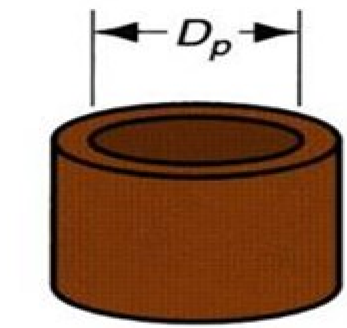


Blank Diameter calculation: For calculating the blank diameter Db, to produce a cup of diameter Dc or Dp, it is necessary to equate the surface areas of both on the Assumption that there is no change in the metal thickness and no corner radius at the bottom of the drawn cup.

Surface area of Blank = $\frac{\pi D_b^2}{4}$ ---------------- (1)



Surface area of cup = $\frac{\pi D_c^2}{4} + \pi D_c h$ ------------------ (2)



By Equating both eqn. (1) & (2)

$$D_b = \sqrt{D_c^2 + 4 D_c h}$$

Drawing Force (F): It is a force required to draw the sheet metal blank to cup.

It is given by.

$$F = \tau \times \Pi \times D_c \times t \left[\frac{D_b}{D_c} - 1 + C \right]$$

Where,

- **τ** - Max. shear stress
- **D_b** - Blank diameter
- **D_c** - Cup diameter
- **t** - Sheet metal thickness
- **C** – Constant to cover friction (Friction constant).

Problem: A cup of 50 mm Dia. and 50 mm height is to be drawn from 1 mm thick sheet. Calculate the blank Size and the drawing force required. Take Shear stress τ = 400 N/mm2 and frication constant C =0.6.

Soln.

Dc = 50 mm, h = 50 mm, t = 1 mm, Shear stress = 400 N/mm2, C = 0.6

Blank Size: $D_b = \sqrt{D_c^2 + 4 D_c h} = \sqrt{50^2 + 4 \times 50 \times 50}$ **Db = 111.8 mm**

Drawing Force: $F = \tau \times \pi \times D_c \times t \left[\frac{D_b}{D_c} - 1 + C \right]$

$= 400 \times \pi \times 50 \times 1 \ [\ 111.8 / 50 - 1 + 0.6$

$= 115359$ N = 115 KN

F = 115 KN

END