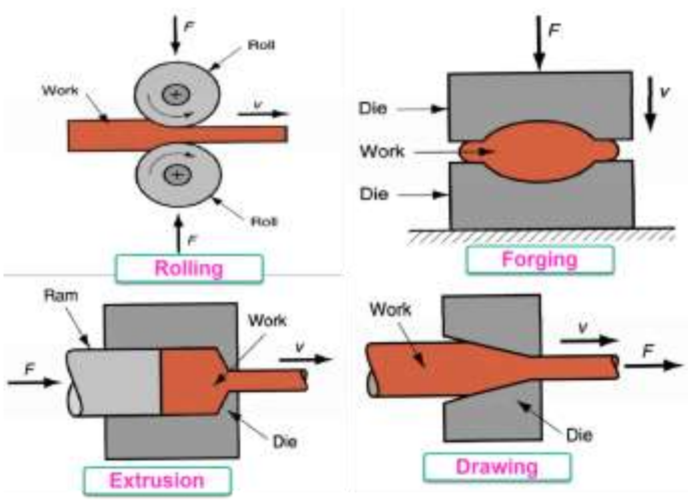
MANUFACTURING TECHNOLOGY

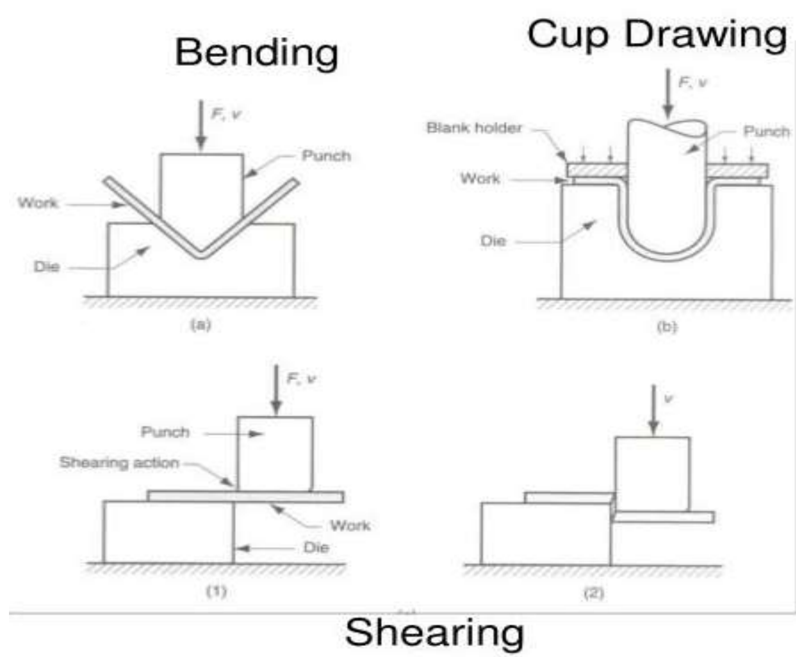
MECHANICAL WORKING OF METALS

Overview

- Metal Working Process
  - Hot Working
  - Cold Working
- Forging
  - Types/Defects
- Extrusion
  - Types/Defects
- Rolling
  - Types of Rolling
  - Rolling Mills
  - Rolling Defects
- Drawing/Types

- Sheet Metal Operations
- Shearing Operations
- Types of Shearing Dies
- Forming Operations
- Cutting Tools in Sheet metal process
- Striking Tools in Sheet Metals, Riveting





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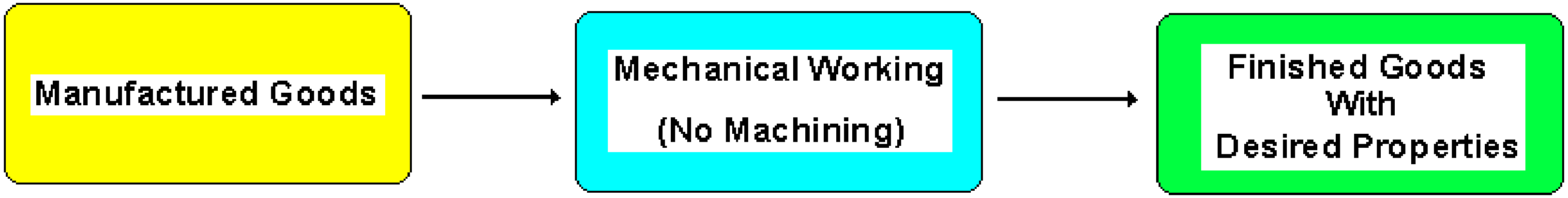
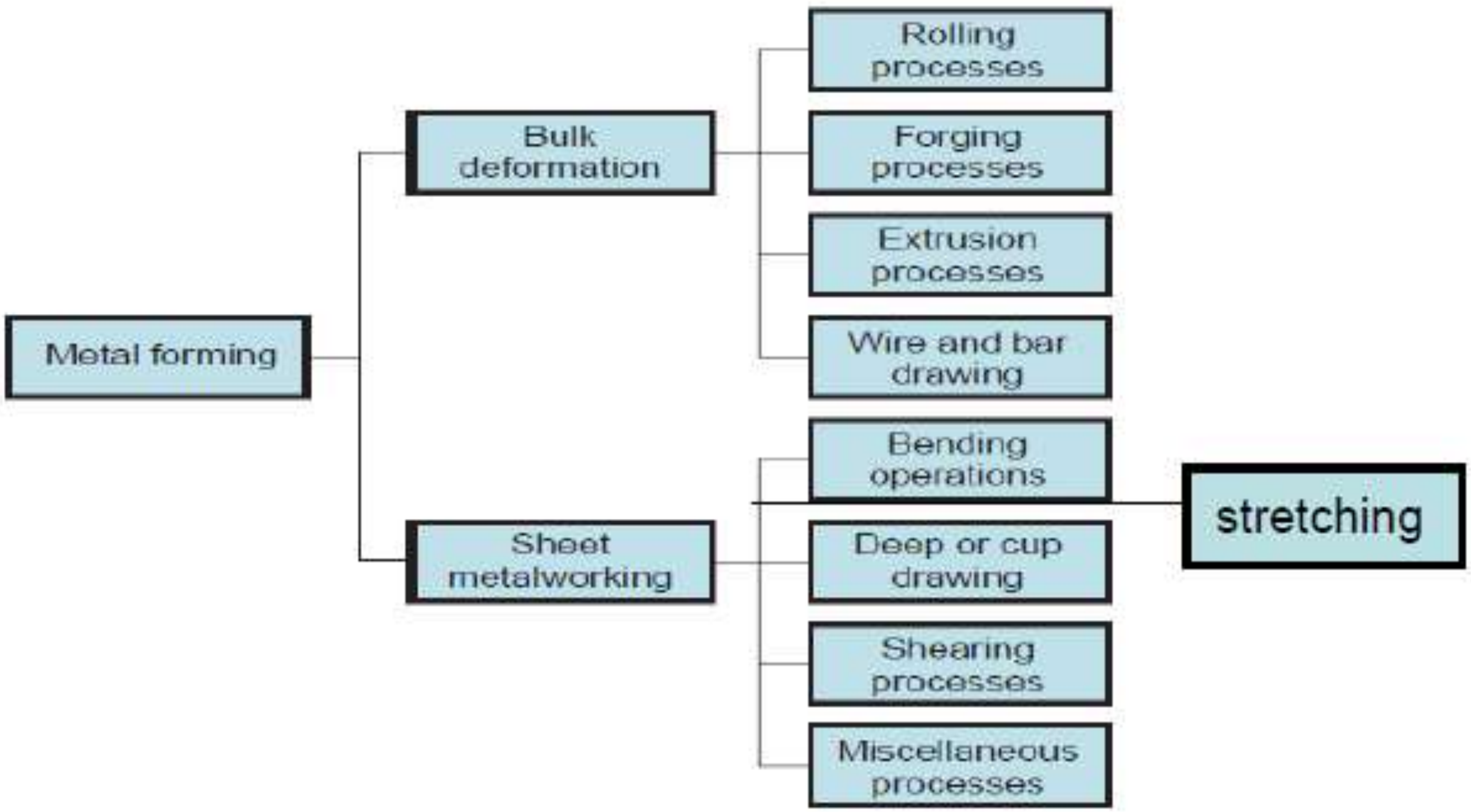
Mechanical Working of Metals

- In this method **no machining process** is carried out, but it is used to achieve **optimum mechanical properties** in the metal.
- The **wastage of material** in metal working process is **negligible** or very small. But the **production is very high** compared to other process.



METAL FORMING PROCESS

- Large set of manufacturing processes in which the **material is deformed plastically** to take the shape of the **die geometry**. The tools used for such deformation are called **die, punch** etc. depending on the type of process.

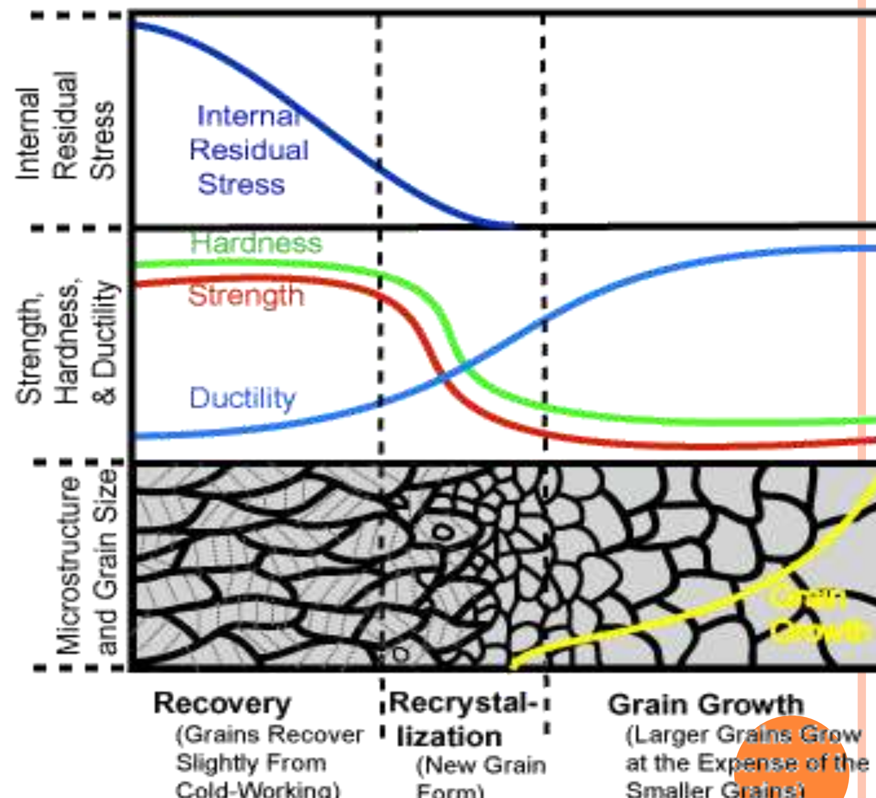


Types of Metal Working or Processing

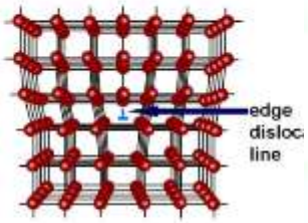
Methods

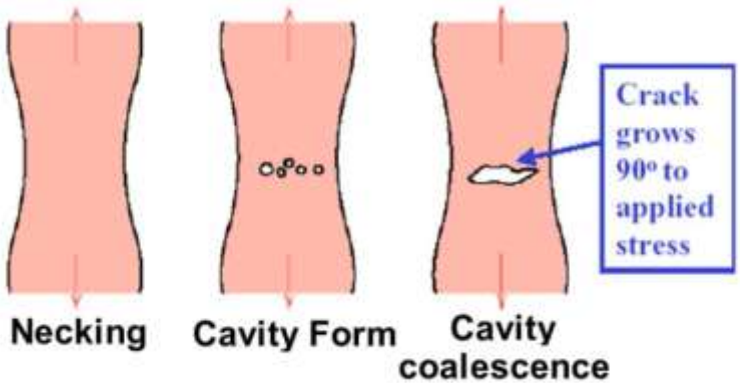
- Mechanical processing
  - Hot working
  - Cold working
- Thermal processing
  - Heat treatments
  - Annealing
    - Recovery, recrystallization and growth
- Both of these are used to control properties of the final product

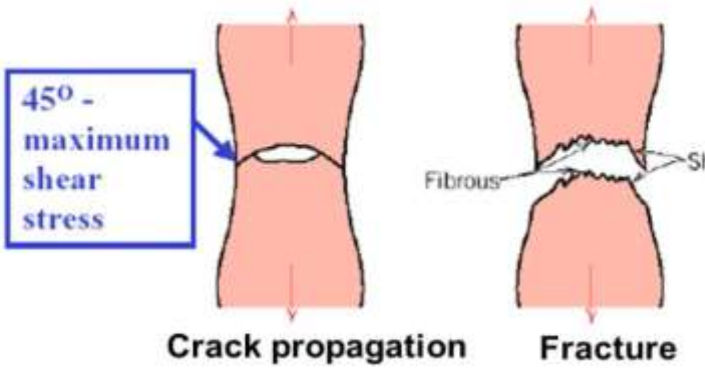
- **Mechanical working** is a **process of shaping** of **metals by plastic deformation**. When a **metal** is subjected to **external force beyond yield strength** but less than fracture strength of the **metal, metal** is deformed by **slip or twin formation**.

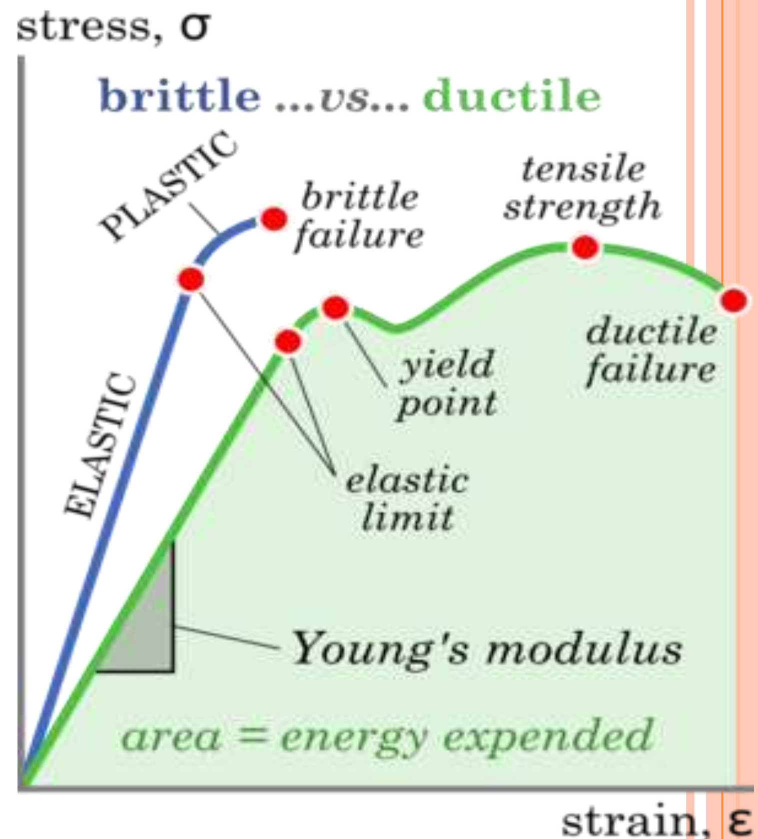


- **Ductile fracture** - most metals (not too cold):
  - Extensive plastic deformation ahead of crack
  - Crack is "stable": resists further extension unless applied stress is increased









- **Brittle fracture** - ceramics, ice, cold metals:
  - Relatively little plastic deformation
  - Crack is "unstable": propagates rapidly without increase in applied stress

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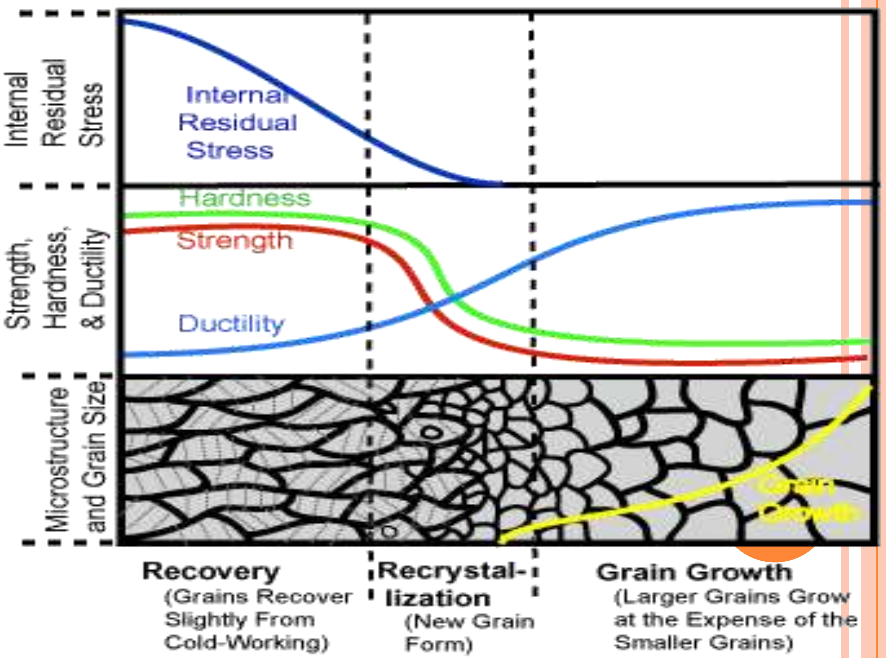
Hot Working: $T > 0.5T_m$

- Mechanical working of a metal **above the recrystallization temperature** but below the melting point is known as **hot working**.
- The temperature at which the **complete recrystallization** of a metal take place with in a specified time
- The **recrystallization temperature** of metal will be **about 30 to 40%** of its melting temperature.

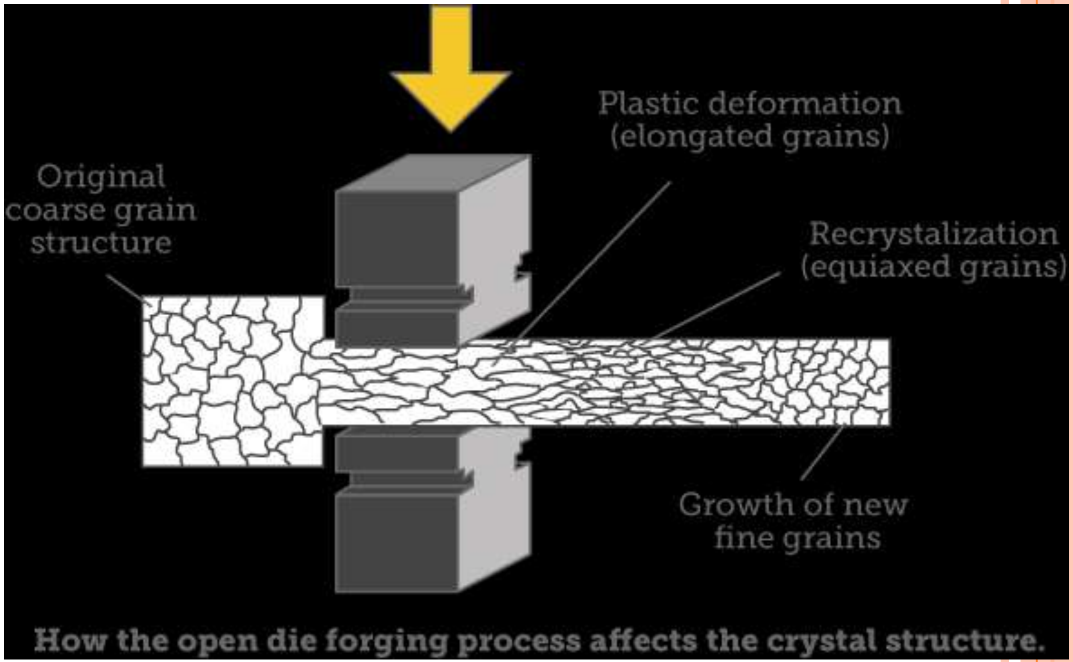
Types

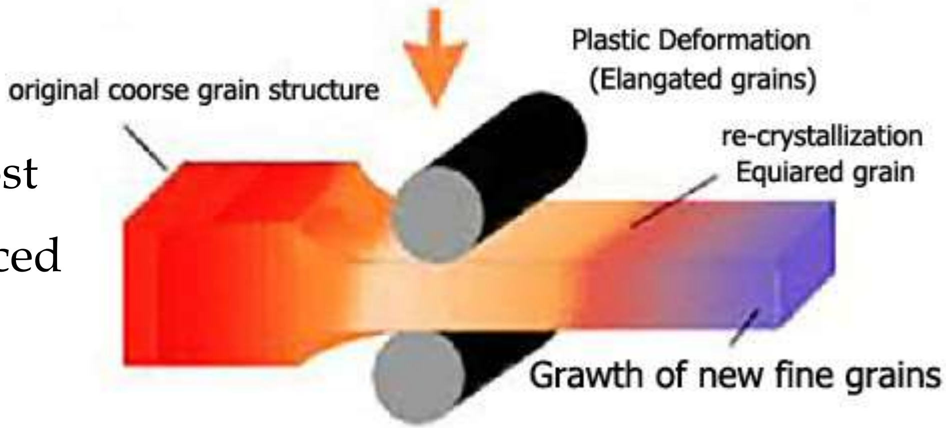
- Forging
- Rolling
- Extrusion
- Drawing



Hot Working

- **Advantages**
  - Force requirement is less
  - Refined grain structure
  - No stress formation
  - Quick and Economical
  - Suitable for all metals
- **Disadvantages**
  - Poor surface finish
  - Less accuracy
  - Very high tooling and handling cost
  - Sheets and wires cannot be produced





Hot Rolling Process

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Cold Working : $T < 0.3T_m$

- Mechanical working of a metal **below the recrystallization temperature** (Room Temperature) is known as **cold working**.
- **Reduces the amount of plastic deformation** that a material can undergo in subsequent processing and **requires more power** for further working

Types

- Drawing
- Squeezing
- Bending

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Cold Working

- Advantages
  - Better surface finish
  - High dimensional accuracy
  - Sheets and wires can be produced
  - Suitable for Mass production
- Disadvantages
  - Stress formation in metal very high
  - Close tolerances cannot be achieved
  - No Refined grain structure

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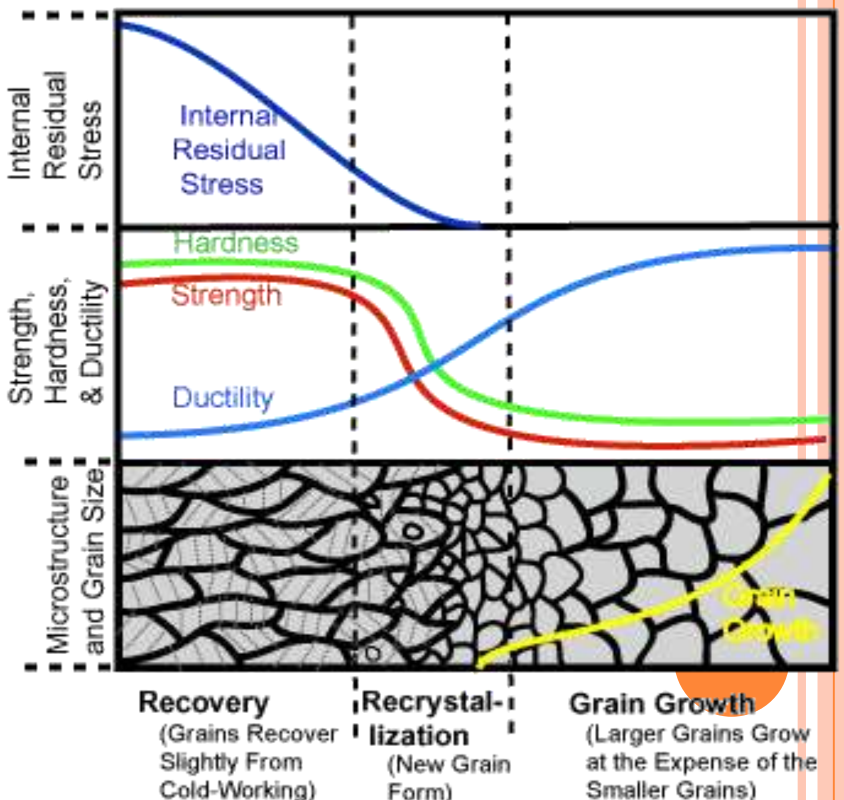
Comparison of Hot and Cold Working

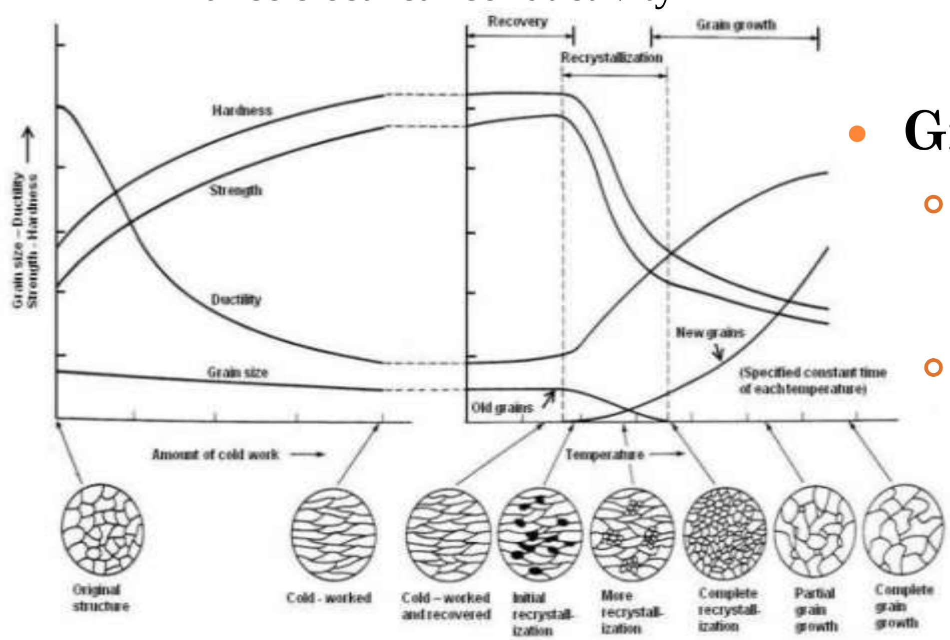
S.No	Hot Working	Cold Working
1	Working above recrystallization temperature	Working below recrystallization temperature
2	Formation of new crystals	No crystal formation
3	Surface finish not good	Good surface finish
4	No stress formation	Internal Stress formation
5	No size limit	Limited size

Strain Hardening

- **Work-hardening or cold-working** is the process of making a metal harder and **stronger through plastic deformation**.
- When a metal is **plastically deformed**, **dislocations move** and **additional dislocations** are generated.
- The **more dislocations** within a material, the more they **will interact** and become **pinned or tangled**.
- This will result in a decrease in the mobility of the dislocations and a **strengthening of the material**. This type of strengthening is commonly called **cold-working**.
- It is called cold-working because the **plastic deformation must occurs** at a **temperature low** enough that atoms cannot rearrange themselves.
- When a metal is worked at **higher temperatures** (**hot-working**) the dislocations can rearrange and little strengthening is achieved.

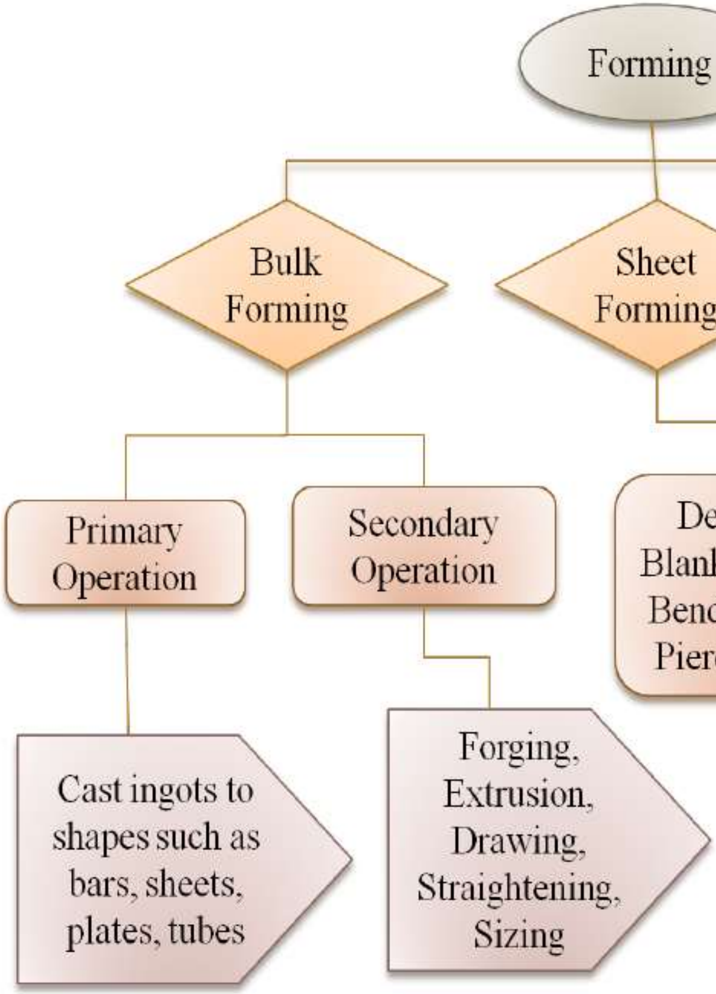


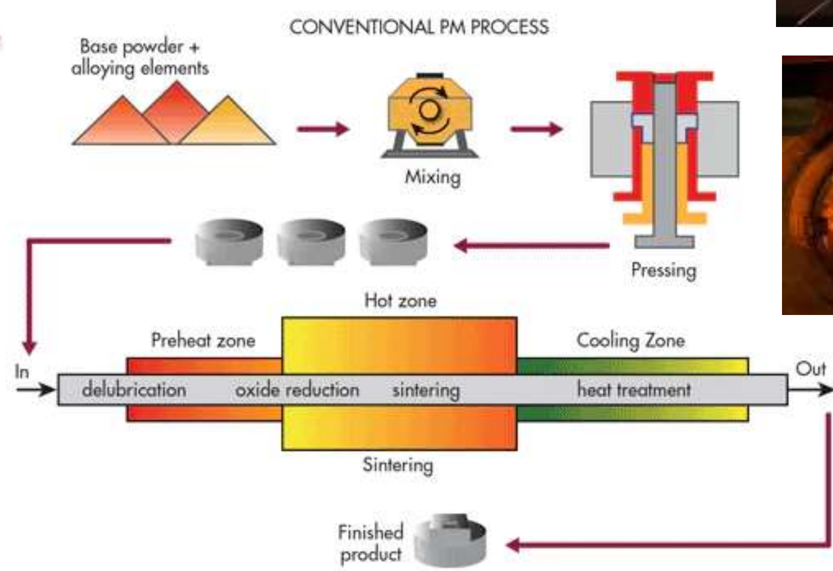
- **Annealing** involves **heating to a specified temperature** and then **cooling at a very slow** and **controlled rate**.
- Heat treatments are used to alter the **physical and mechanical properties** of metal without changing its shape.
    - Soften a metal for cold working
    - Improve machinability
    - Enhance electrical conductivity



Schematic Representation of the Cold-worked and Anneal Cycle showing the effects on Properties and Microstructure

- **Recovery:**
    - **Softening of the metal** occurs through removal of primarily **linear defects called dislocations** and the **internal stresses**.
    - Recovery occurs at the lower temperature stage of all annealing processes and before the appearance of **new strain-free grains**. The grain size and shape do not change.
- **Recrystallization:**
    - **New strain-free grains nucleate and grow** to replace those deformed by internal stresses.
- **Grain growth:**
    - If annealing is allowed to continue once recrystallization has completed, then **grain growth** (the third stage) occurs.
    - In grain growth, the **microstructure starts to coarsen** and may cause the metal to lose a substantial part of its original strength. This can however be **regained with hardening.**


Forming
Bulk Forming
Sheet Forming
Powder Metal Forming
Primary Operation
Secondary Operation
Deep Drawing, Blanking, Punching, Bending, Spinning, Piercing, Shearing
Powder Forging, Powder Extrusion, Powder Injection Molding
Cast ingots to shapes such as bars, sheets, plates, tubes
Forging, Extrusion, Drawing, Straightening, Sizing


CONVENTIONAL PM PROCESS
Base powder + alloying elements
Mixing
Pressing
Hot zone
Preheat zone
Cooling Zone
In
delubrication
oxide reduction
sintering
heat treatment
Out
Sintering
Finished product

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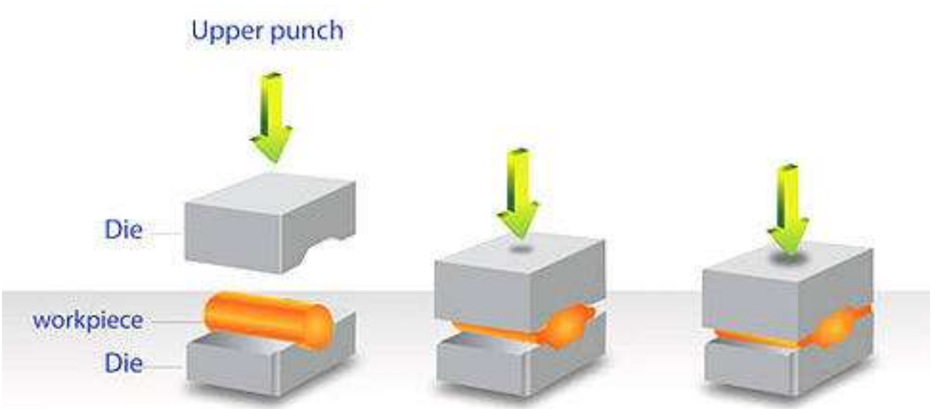
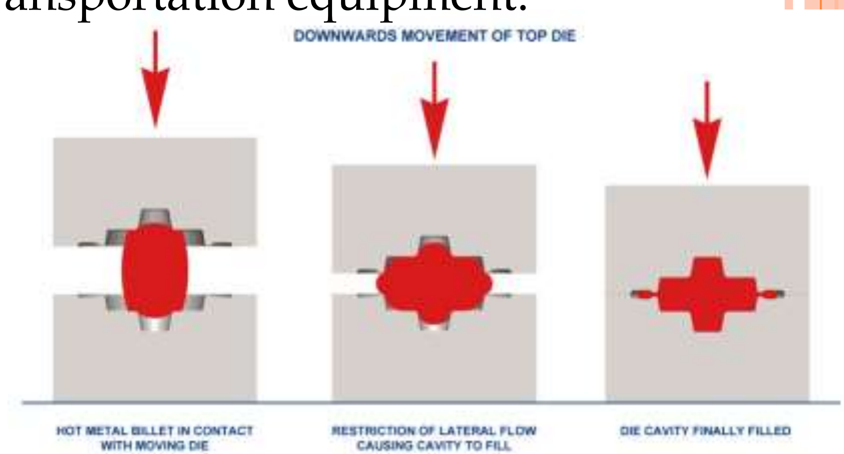
Forging

- **Forging** is a process in which the **work piece is shaped by compressive forces** applied through **various dies and tools**. It is one of the oldest metalworking operations. Most **forgings require a set of dies and a press** or **a forging hammer**.

- Unlike **rolling operations**, which generally produce continuous plates, sheets, strip, or various structural cross-sections, forging operations produce **discrete parts.**

- Typical forged products are **bolts and rivets**, connecting rods, **shafts for turbines, gears, hand tools**, and structural components for machinery, aircraft, railroads and a variety of other transportation equipment.





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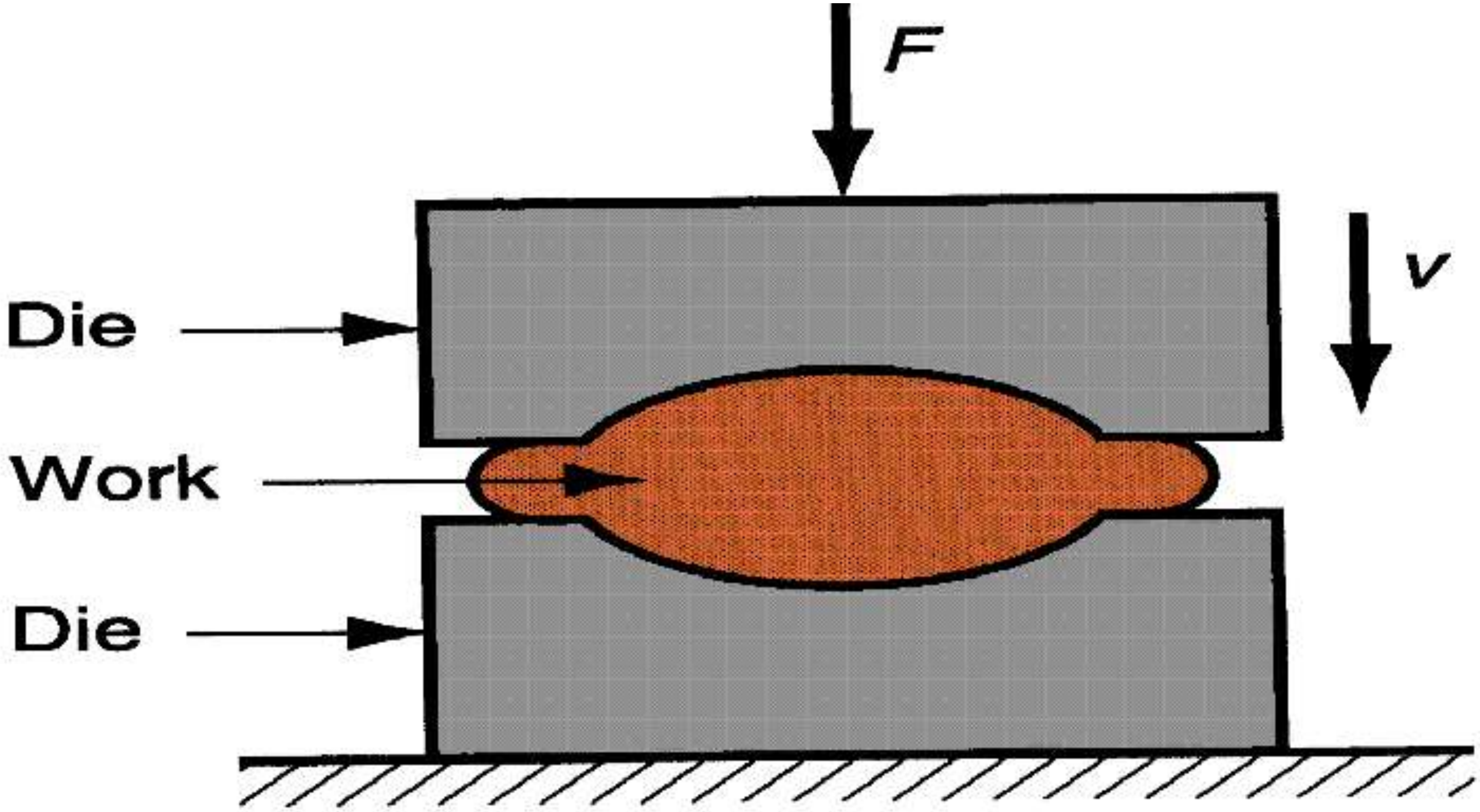
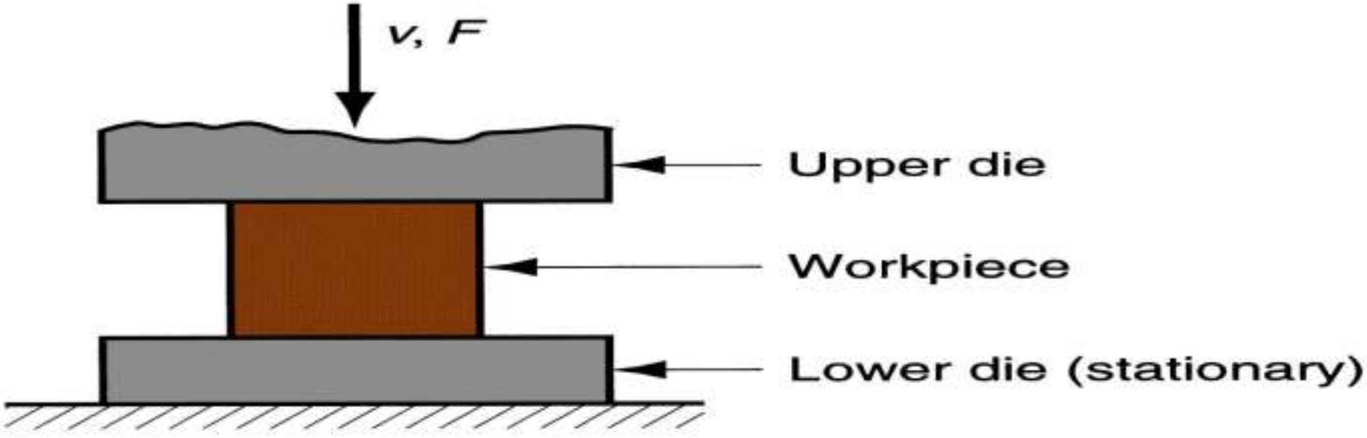
Forging



Forging Methods

Open-Die Forging

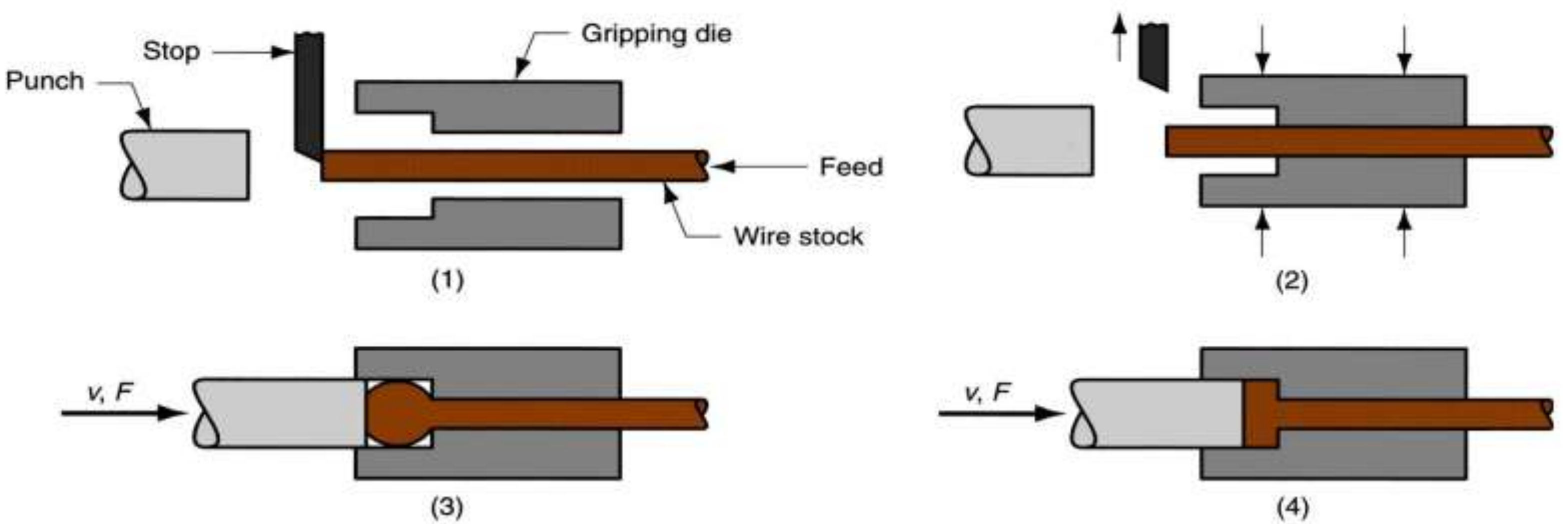
- Compression of work part between two flat dies
- Deformation operation **reduces height and increases diameter** of work
- Common names include ***upsetting*** **or** ***upset forging***



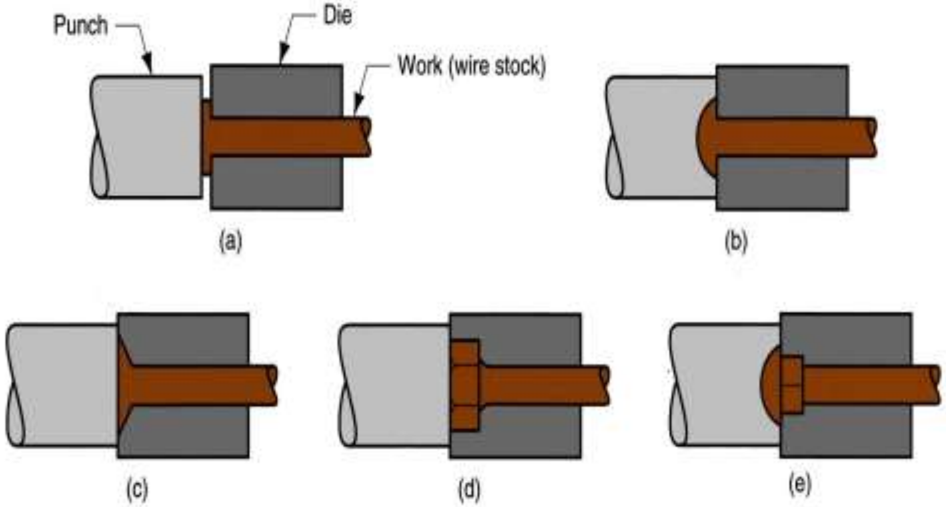
(a)

Upset Forging

- An **upset forging operation** to form a **head on a bolt** or similar hardware item
- The cycle consists of:
- (1) **wire stock** is fed to the stop,
- (2) **gripping dies close** on the stock and the stop is retracted,
- (3) punch moves forward,
- (4) bottoms to form the head.

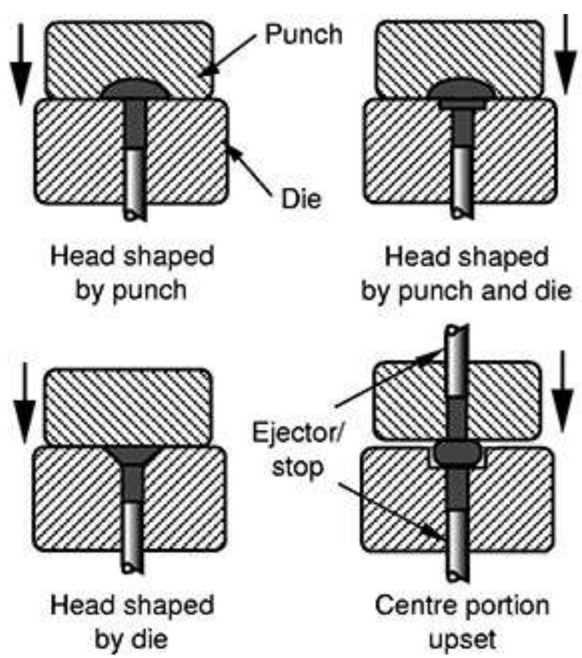


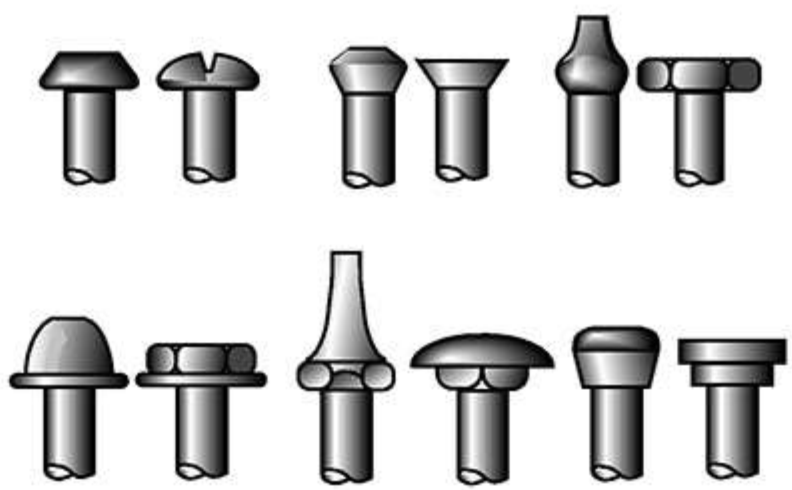
Heading



Examples of heading (upset forging) operations:

- (a) **heading a nail** using open dies,
- (b) **round head** formed by punch,
- (c) and (d) two common head styles for screws formed by die
- (e) carriage bolt head formed by punch and die.

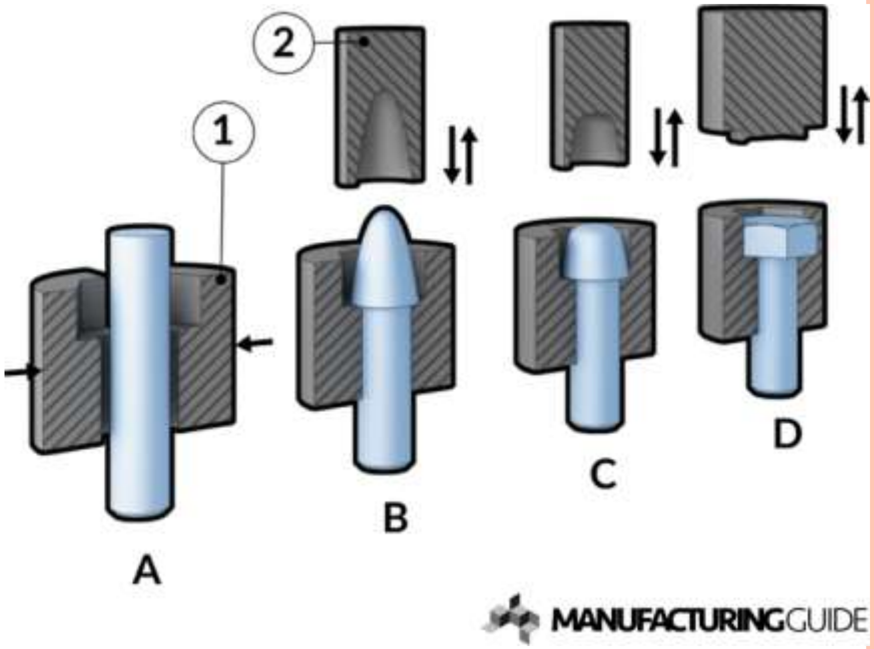




Some coned and finished head shapes two-blow upsetting

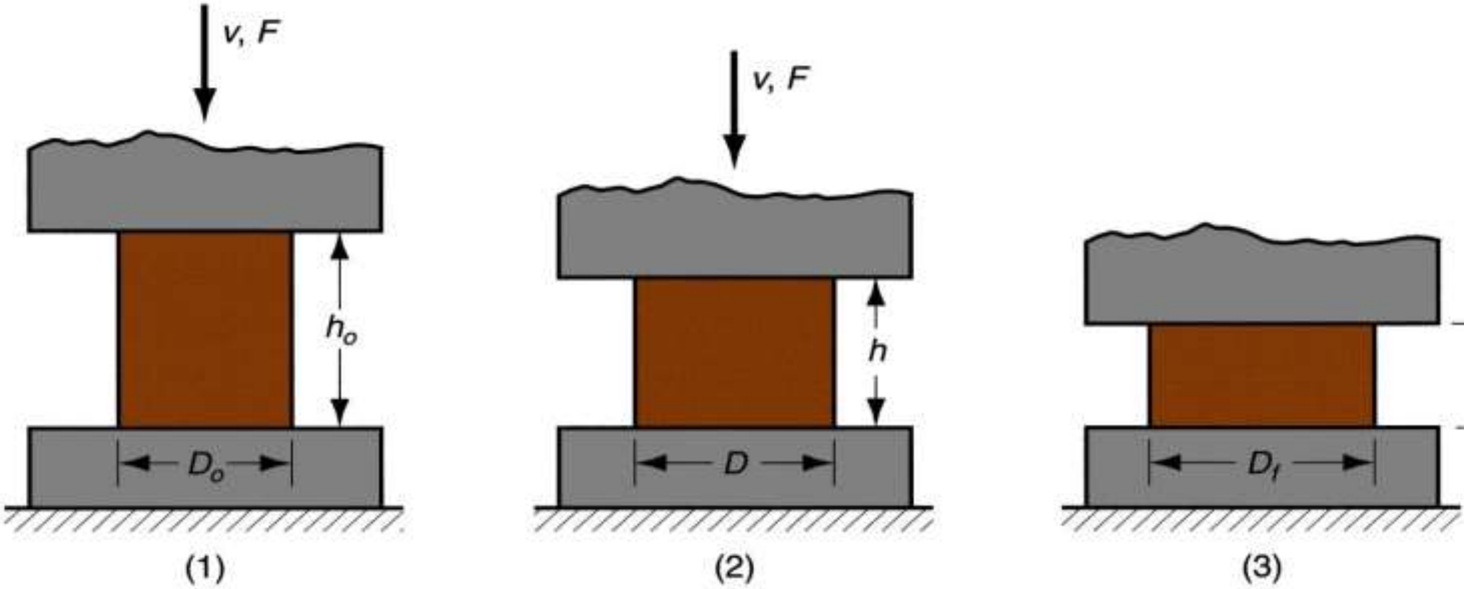
Upsetting and Heading

- Forging process used to form **heads on nails, bolts**, and similar hardware products
- More parts produced by **upsetting** than any other forging operation
- Performed cold, warm, or hot on machines called ***headers*** or ***formers***
- **Wire or bar stock** is fed into machine, **end is headed**, then piece is **cut to length**
- For bolts and screws, thread rolling is then used to form threads



Open-Die Forging with No Friction

- If **no friction occurs between work and die** surfaces, then **homogeneous deformation** occurs, so that radial flow is uniform throughout work part height

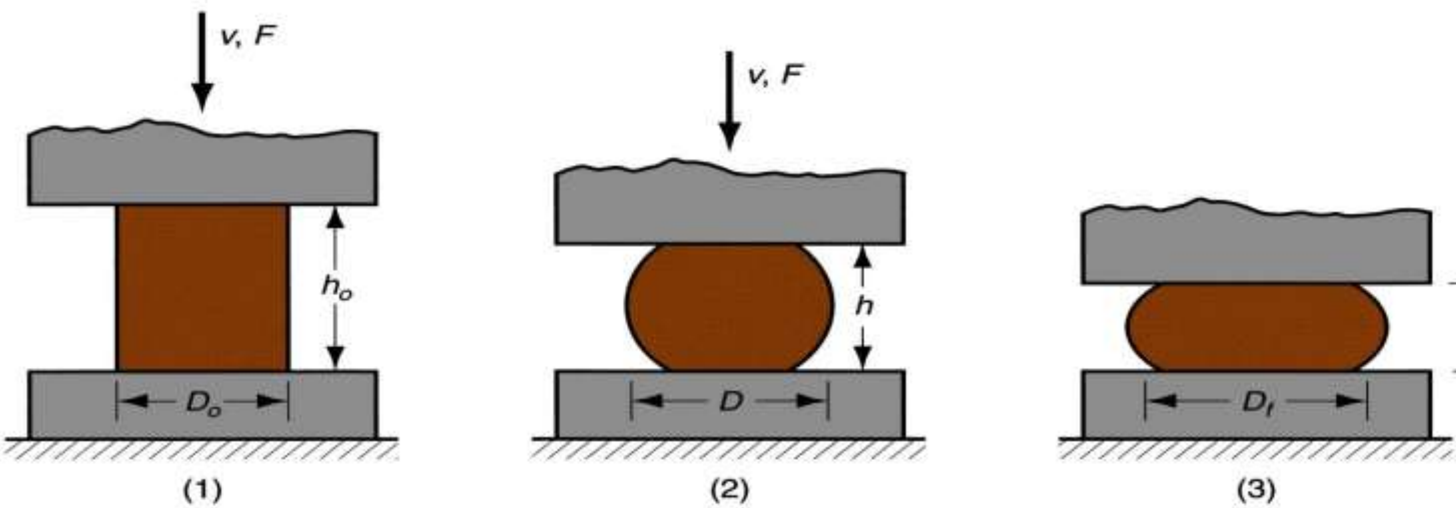


Homogeneous deformation of a cylindrical work part

1. start of process with work piece at its original length and diameter,
2. partial compression, 3. final size.

Open-Die Forging with Friction

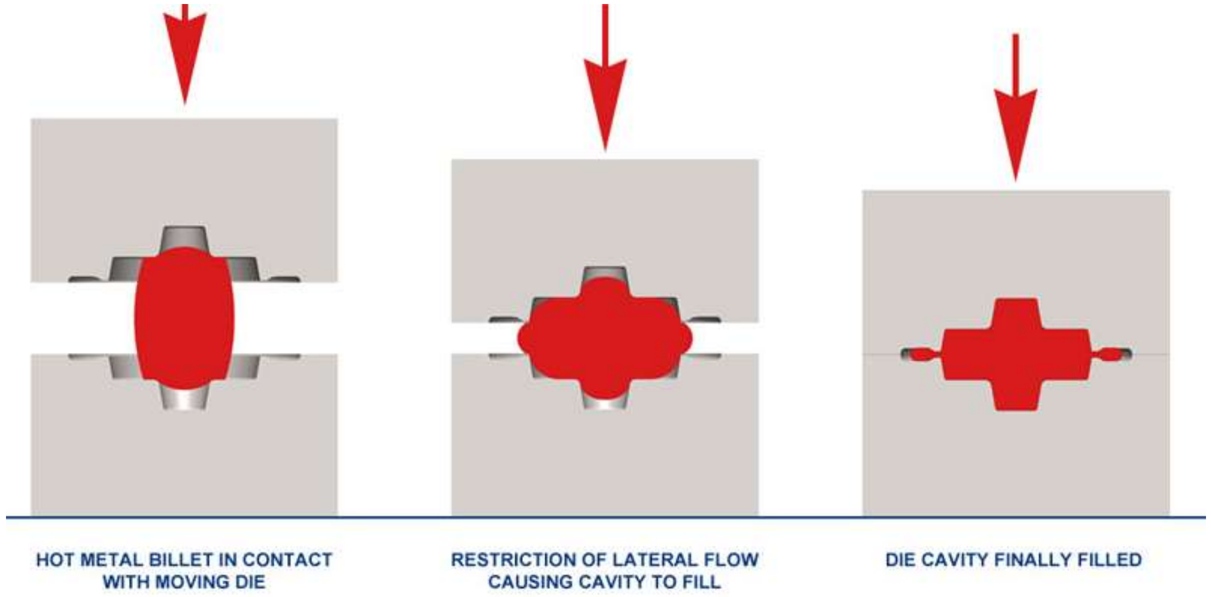
- **Friction between work and die** surfaces constrains lateral flow of work, resulting in **barreling effect**
- In hot open-die forging, effect is even more pronounced **due to heat transfer at and near die** surfaces, which cools the metal and increases its resistance to deformation



Deformation of a cylindrical work part in open-die forging, showing pronounced *barreling* (1) start of process, (2) partial deformation, (3) final shape.

Impression-Die Forging

- Compression of work part by dies with inverse of desired part shape
- **Flash is formed** by metal that flows beyond die cavity into small gap between die plates
- Flash serves an important function:
  - As flash forms, friction resists continued metal flow into gap, **constraining material to fill die** cavity
  - In hot forging, metal flow is further restricted by cooling against die plates

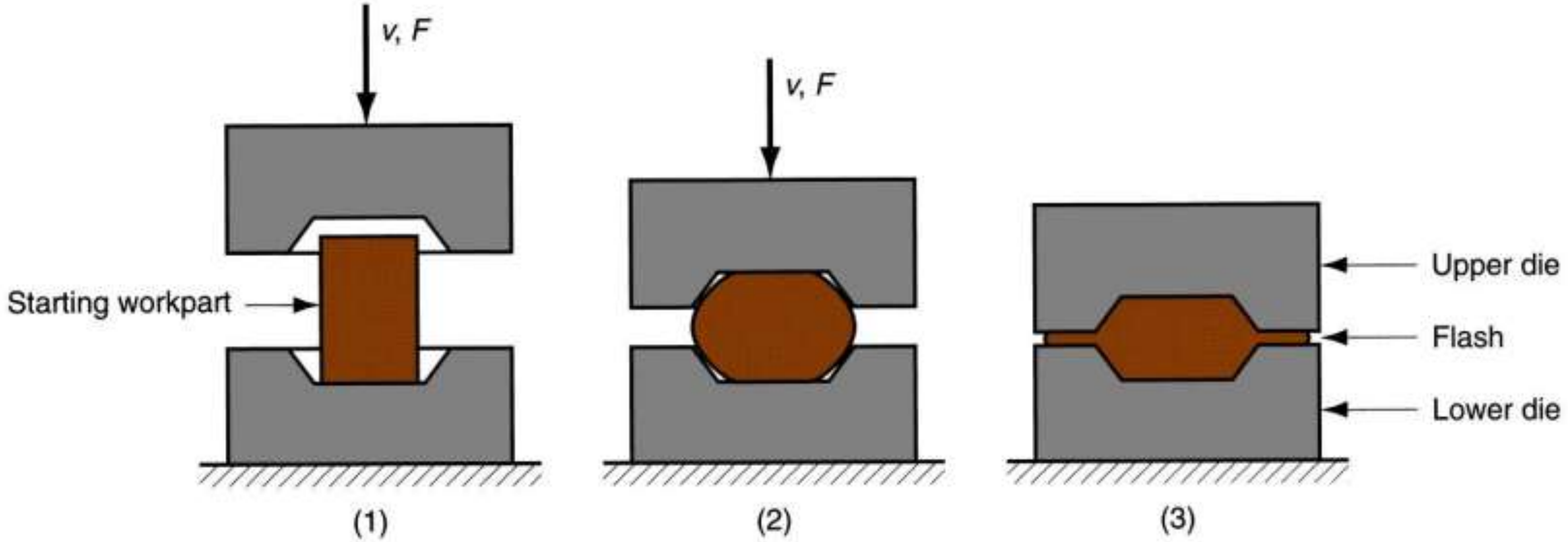


Impression-Die Forging

(1) just prior to initial contact with raw work piece,

(2) partial compression,

(3) final die closure, causing flash to form in gap between die plates.



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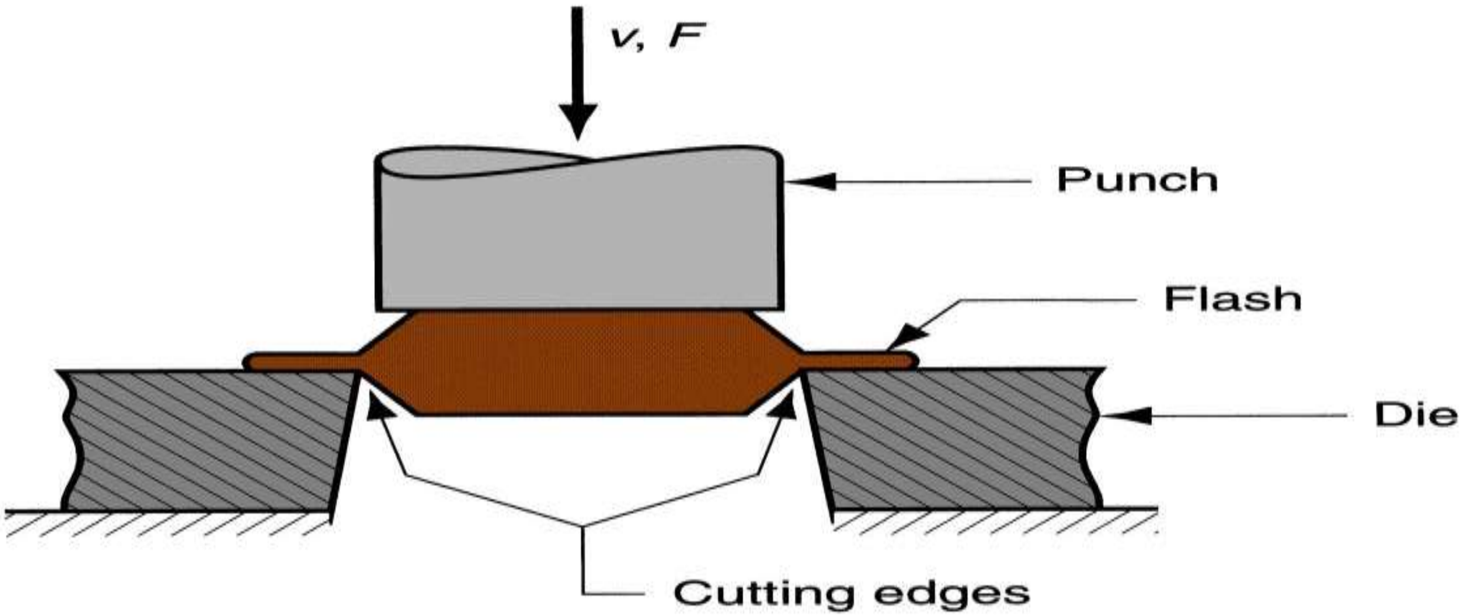
Trimming After Impression-Die Forging

- Trimming operation (**shearing process**) to remove the flash after impression-die forging.



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- Advantages of impression-die forging compared to machining from solid stock:
  - Higher production rates
  - Less waste of metal
  - Greater strength
  - Favorable grain orientation in the metal
- Limitations:
  - Not capable of close tolerances
  - Machining often required to achieve accuracies and features needed

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Flash less Forging

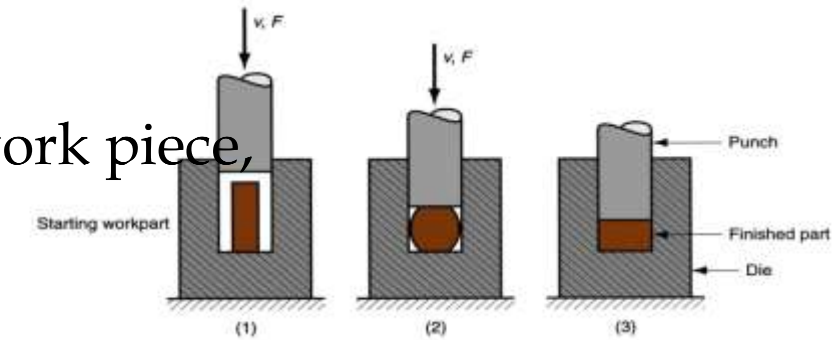
- Compression of work in punch and die tooling whose **cavity does not allow for flash**
- **Starting work part** volume must **equal die cavity** volume within very close tolerance
- Process control **more demanding** than impression-die forging
- Best suited to part geometries that are simple and symmetrical
- Often classified as a ***precision forging*** **process**

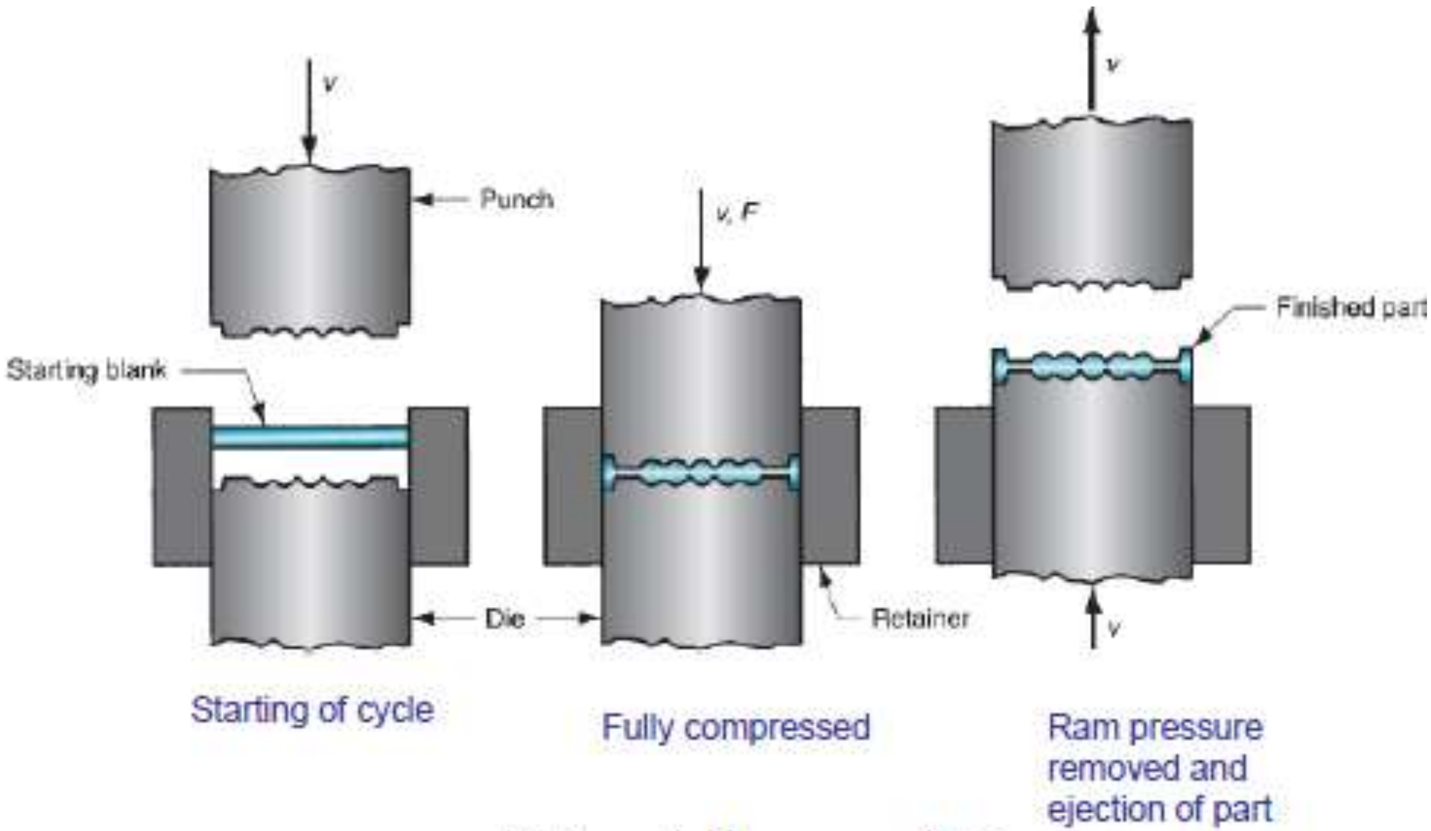
Flash less Forging

(1) just before initial contact with work piece,

(2) partial compression,

(3) final punch and die closure.





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Forging Hammers (Drop Hammers)

- Apply impact load against work part

Two types

- Gravity drop hammers - impact energy from falling weight of a heavy ram
- Power drop hammers - accelerate the ram by pressurized air or steam

- Disadvantage: impact energy transmitted through anvil into floor of building
- Commonly used for impression-die forging

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Drop Hammer Details

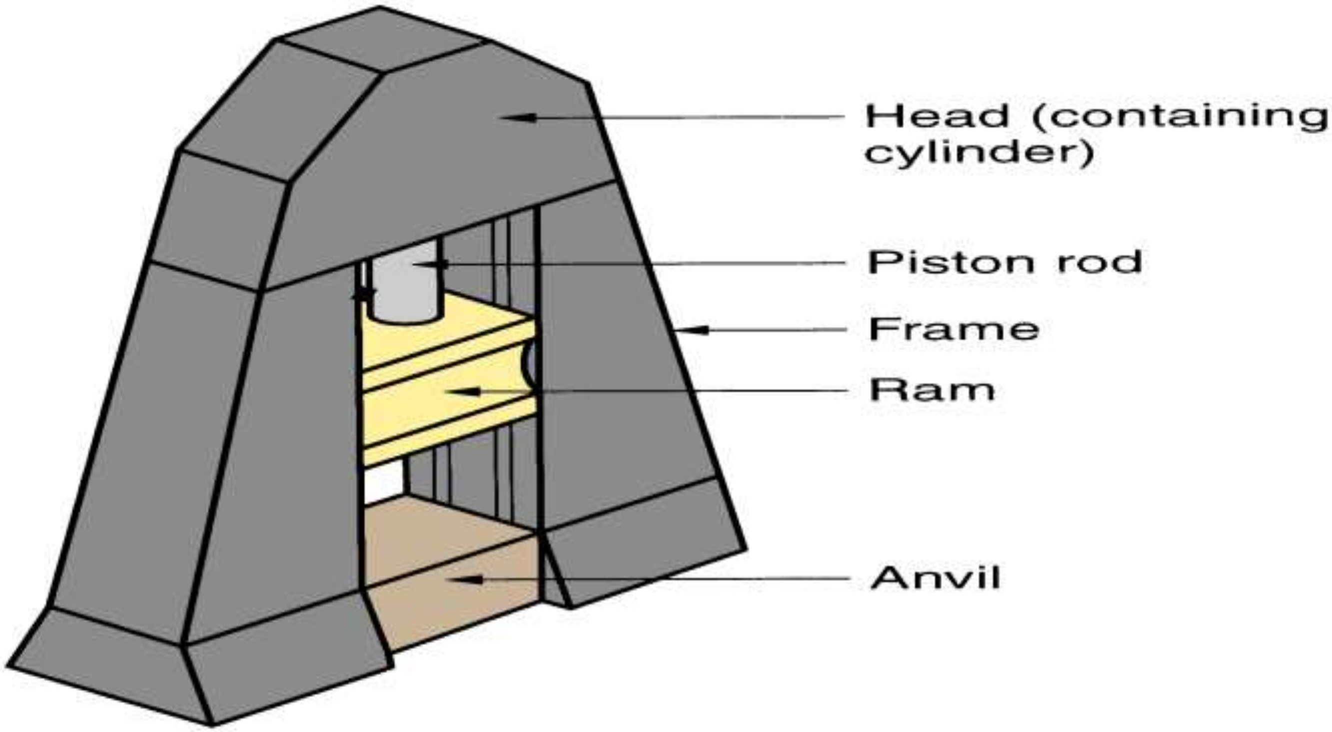

Diagram showing details of a drop hammer for impression-die forging.

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Forging Presses

- Apply gradual pressure to accomplish compression operation

Types

  - Mechanical press - converts rotation of drive motor into linear motion of ram
  - Hydraulic press - hydraulic piston actuates ram
  - Screw press - screw mechanism drives ram

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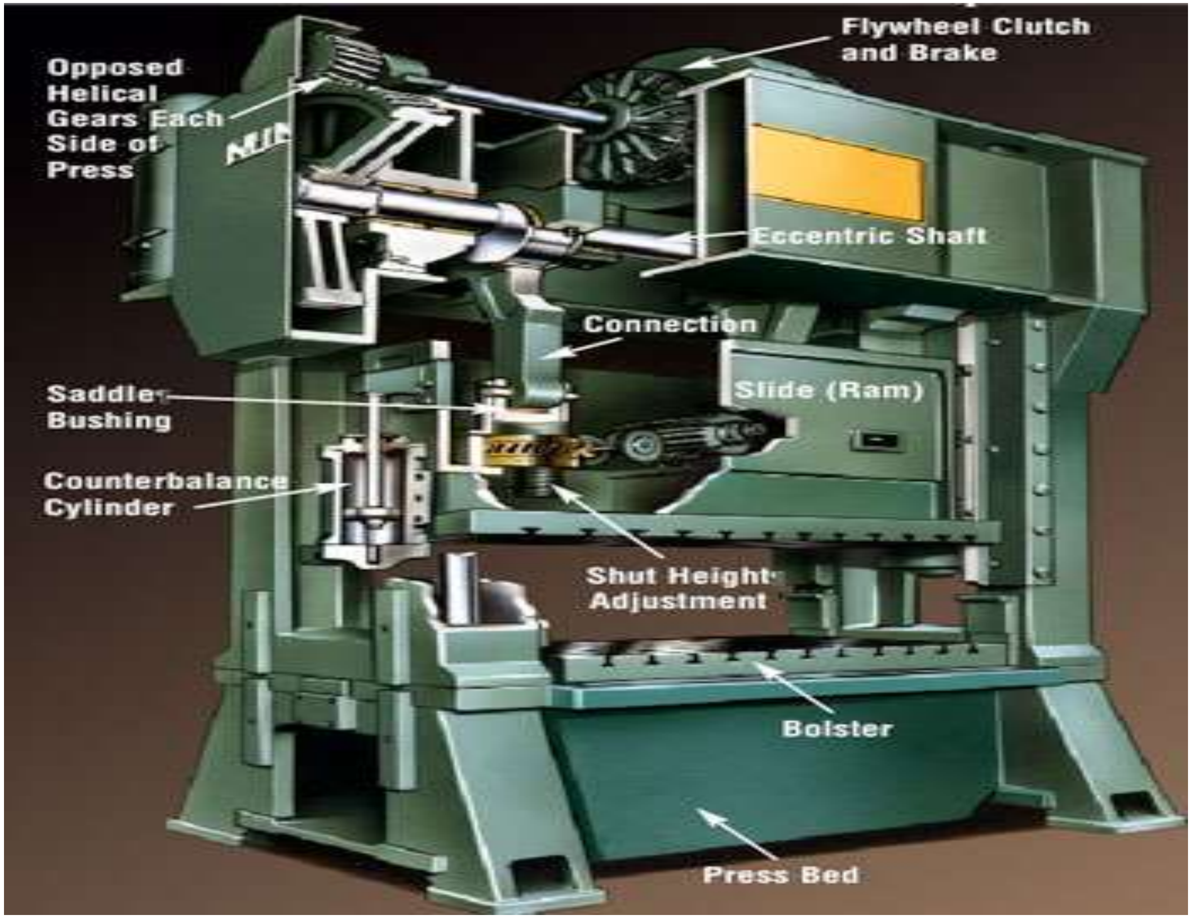
Mechanical press



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Hydraulic press

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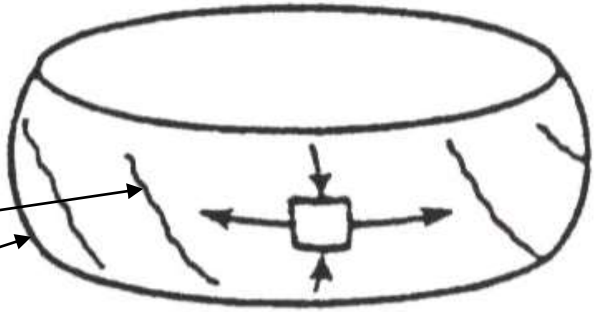
Forging Defects

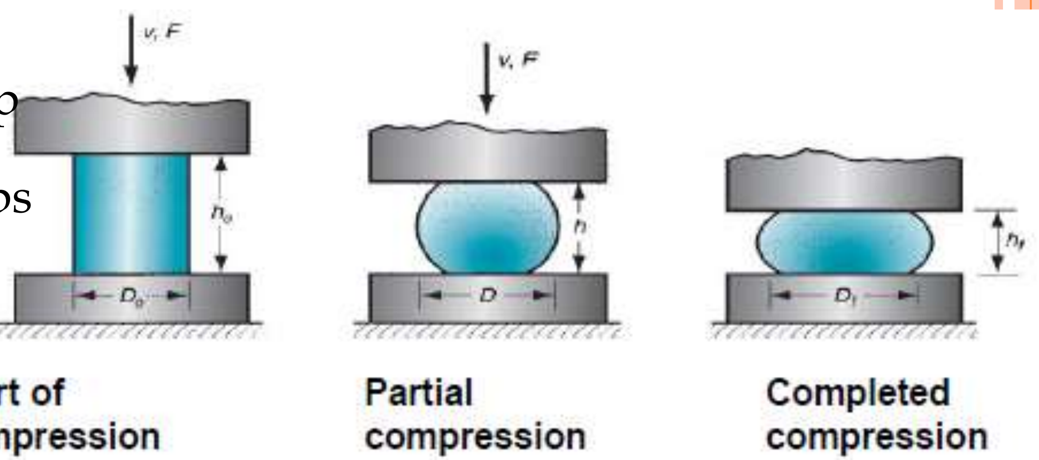
- Fracture
  - Exhausted ductility
  - Inter-granular fracture



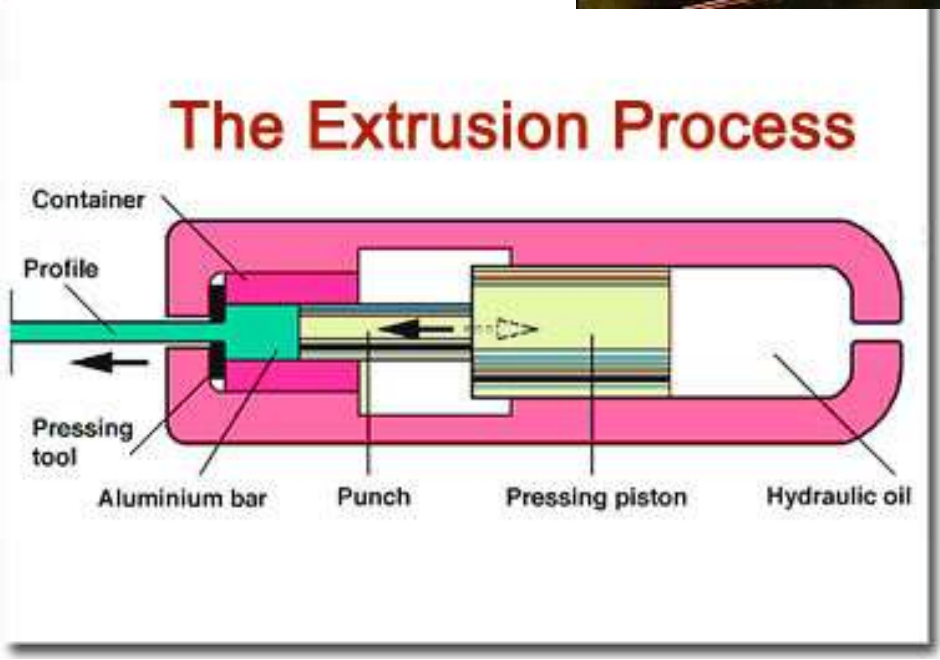
- Barreling - Friction

Solution

- limited deformation per step
- Process anneal between steps



Extrusion Process



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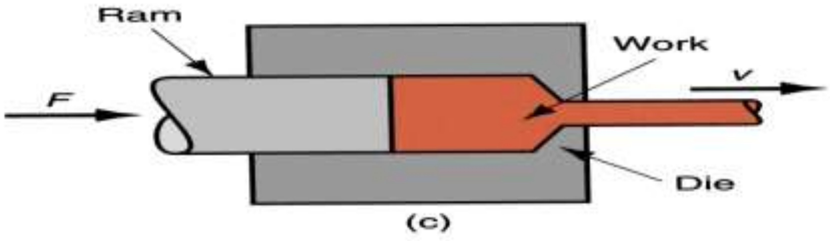
Extrusion

- A **plastic deformation process** in which metal is **forced under pressure** to flow through a single, or series of dies until the desired shape is produced.
- Process is similar to **squeezing toothpaste** out of a toothpaste tube
- In general, **extrusion is used to produce long parts** of uniform cross sections
- Typical products made by extrusion are **railings** for **sliding** doors, **tubing** having carious cross-sections, structural and architectural shapes, door and **windows frames**.



- Extrusion Ratio
  - $ER = A_o / A_f$
  - A_o – cross-sectional area of the billet
  - A_f - cross-sectional area of extruded product
- Extrusion Force
  - $F = A_o K \ln (A_o / A_f)$
  - K-extrusion constant
  - A_o, A_f billet and extruded product areas
- Types
  - Direct Extrusion (Forward Extrusion)
  - Indirect Extrusion (Backward Extrusion)
  - Hydrostatic Extrusion
  - Impact Extrusion

Factors Influencing the Extrusion Force

- Friction
- Material Properties
- Reduction In Area
- Speed
- Temperature
- Geometry Of The Die

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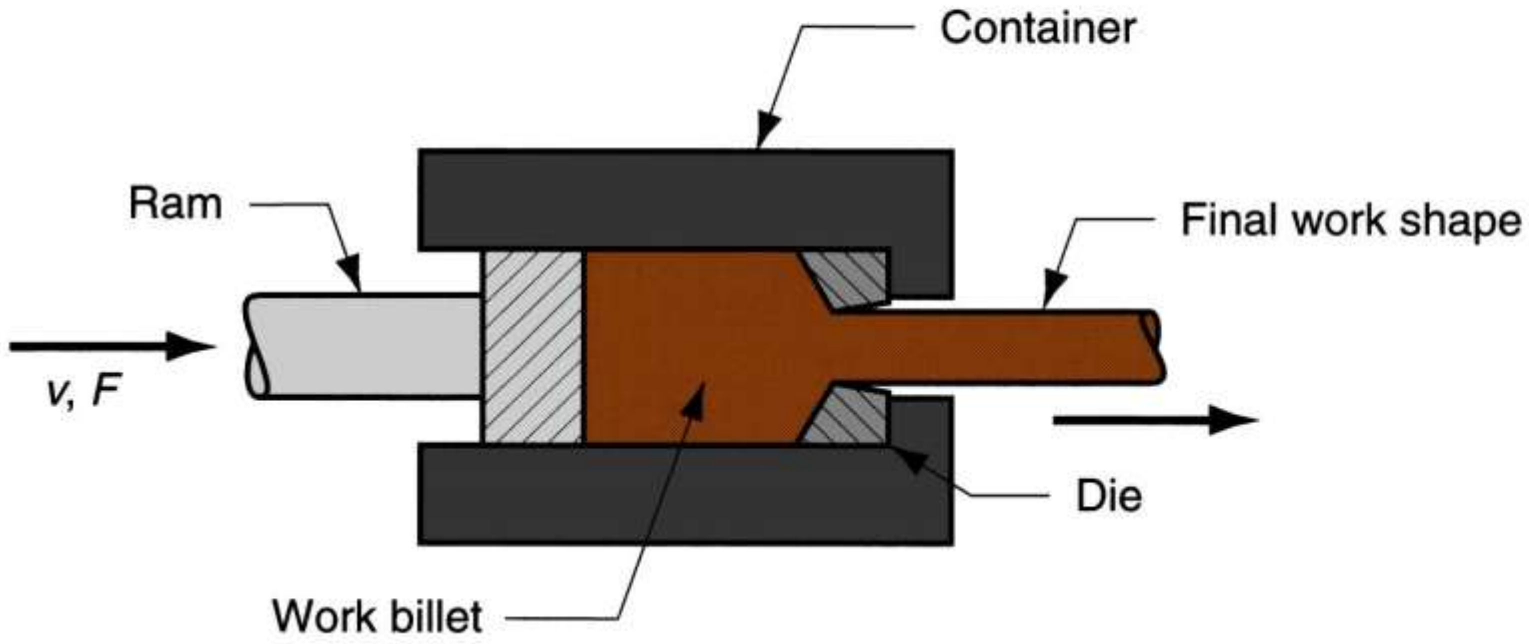
Direct Extrusion

- **Billet is placed** in a chamber and **forced through a die** opening by a **hydraulically-driven ram** or pressing stem.
- Dies are machined to the desired cross-section



Friction increases the extrusion force

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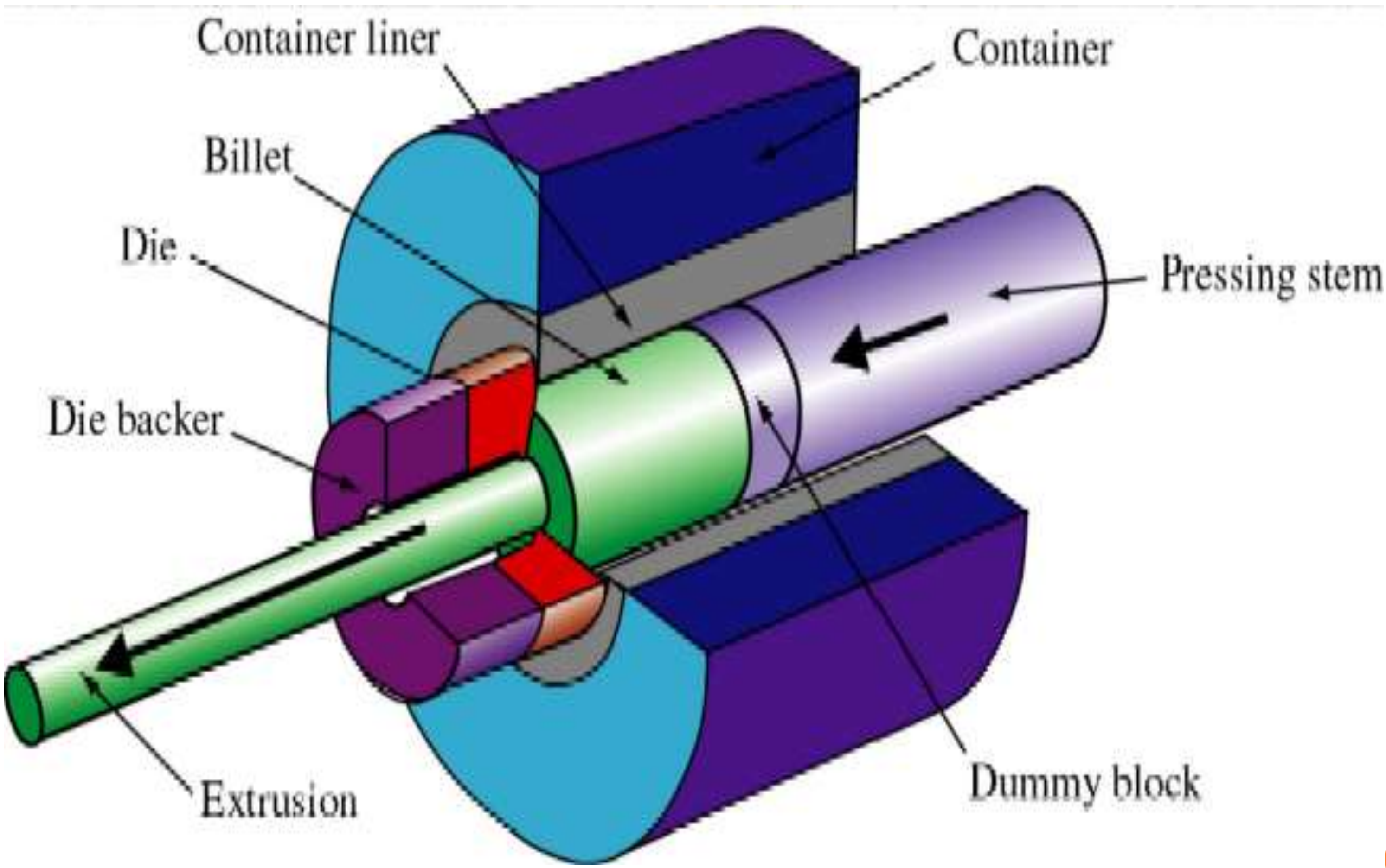
Direct Extrusion



Schematic illustration of direct extrusion process

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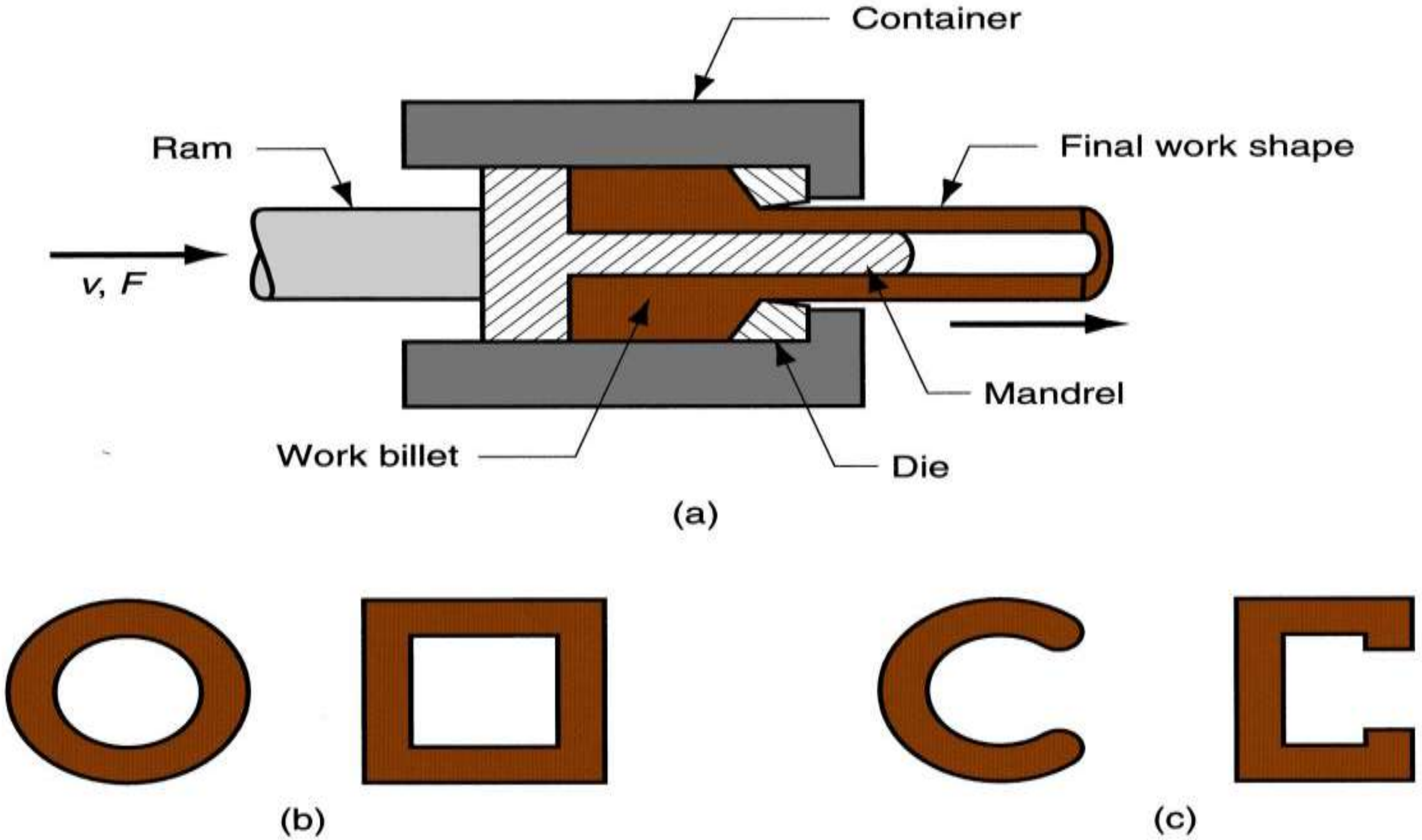
Direct Extrusion



Hollow and Semi Hollow section is formed using a mandrel

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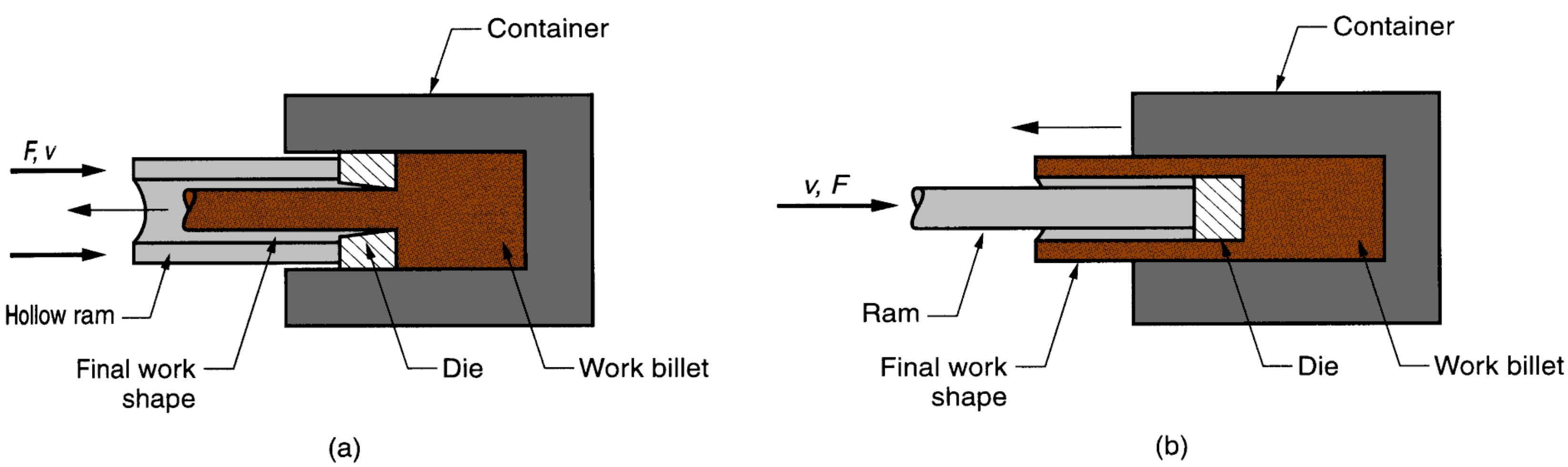
Indirect Extrusion

- **Metal is forced to flow** through the die in an **opposite direction** to the ram's motion.
- **Lower extrusion force** as the work billet metal is not moving relative to the container wall.

Limitations

- Lower rigidity of hollow ram
- Difficulty in supporting extruded product as it exits die



Indirect extrusion to produce (a) a solid cross section and (b) a hollow cross section.

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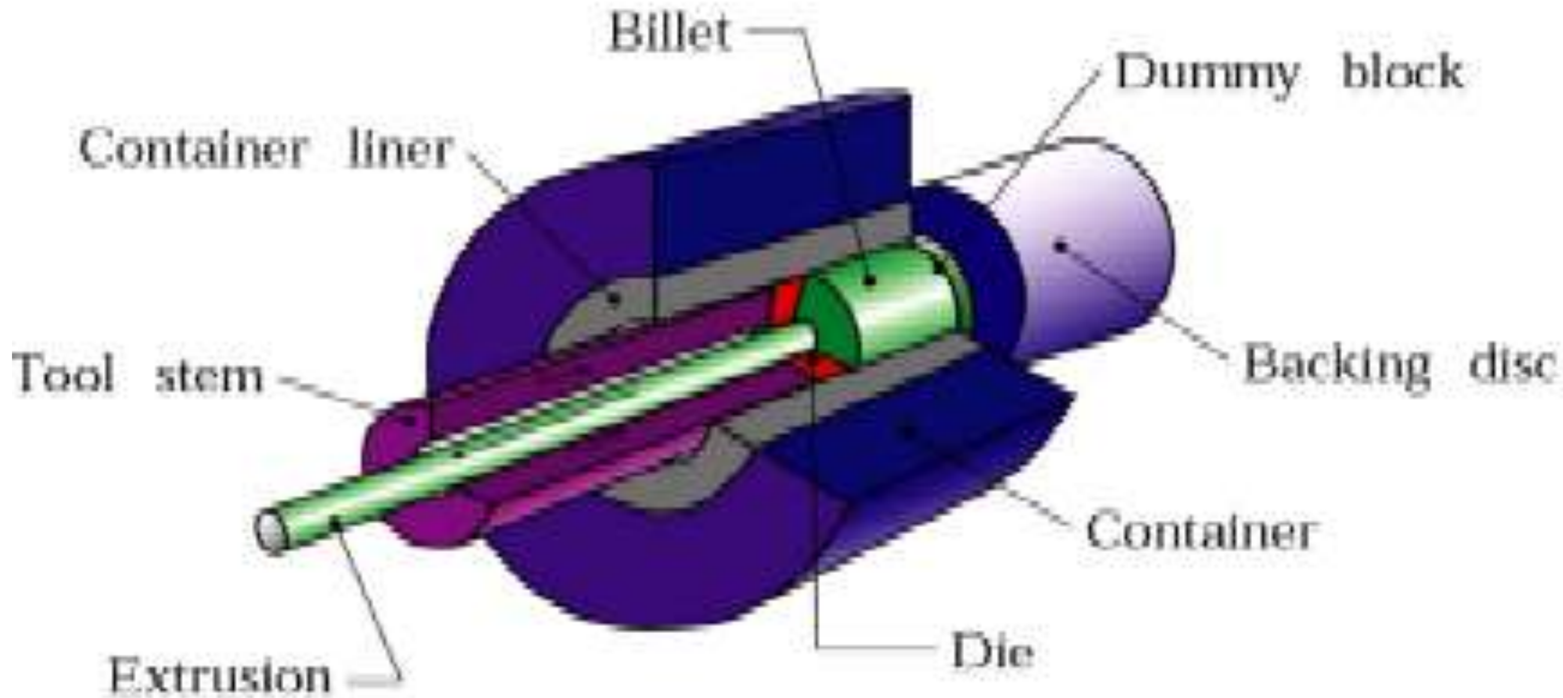
Indirect Extrusion



Schematic illustration of indirect extrusion process

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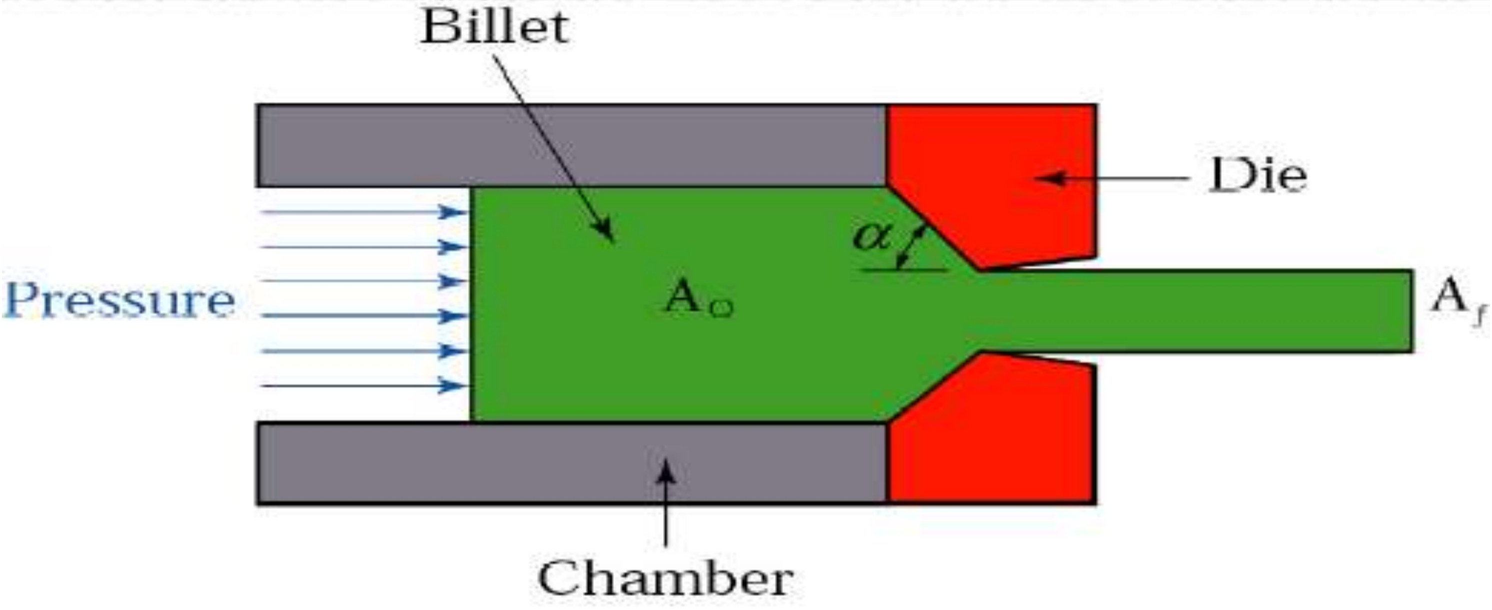
Process Variables in Direct & Indirect Extrusion

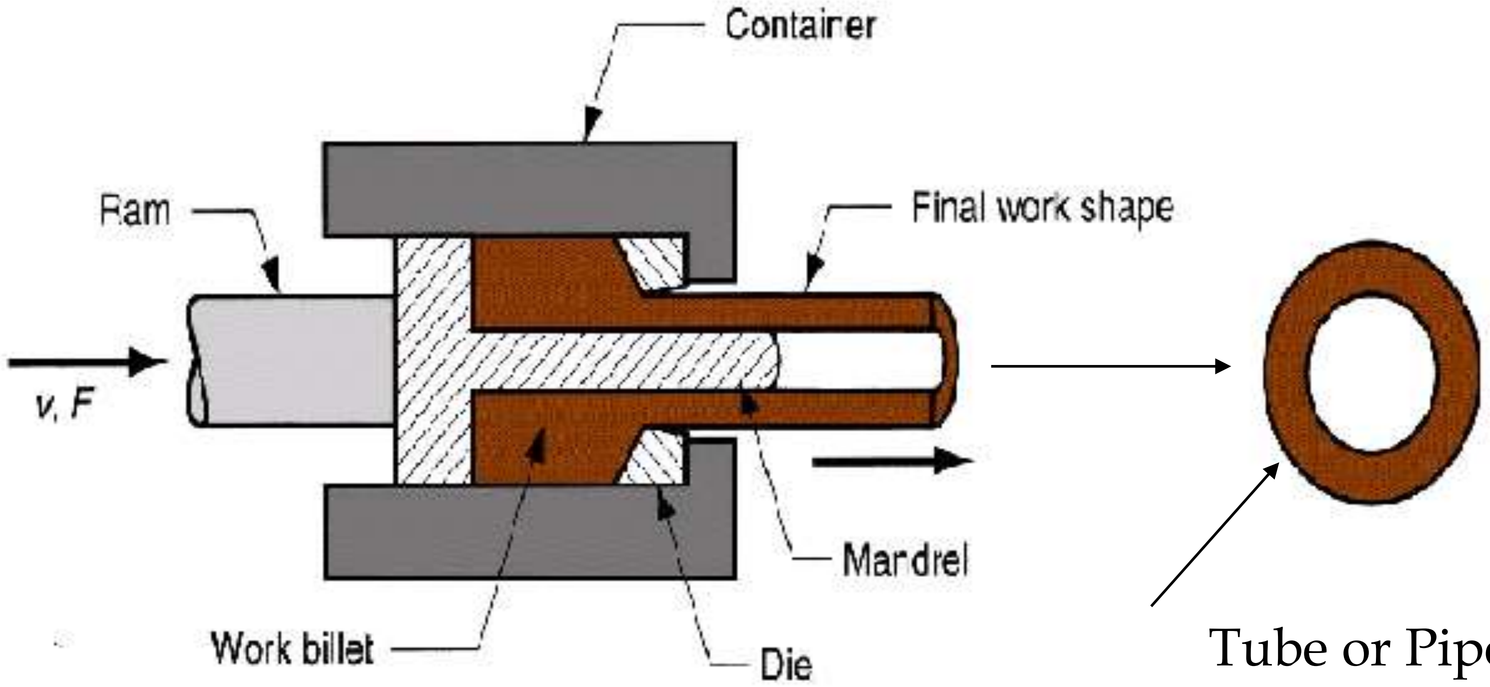
- *The die angle α*
- *Reduction in cross-section A_f*
- *Extrusion speed*
- *Billet temperature,*
- *Extrusion pressure.*



Manufacturing Technology

Tube Extrusion

- Accomplished by forcing the stock through the sides of the mandrel placed between dies

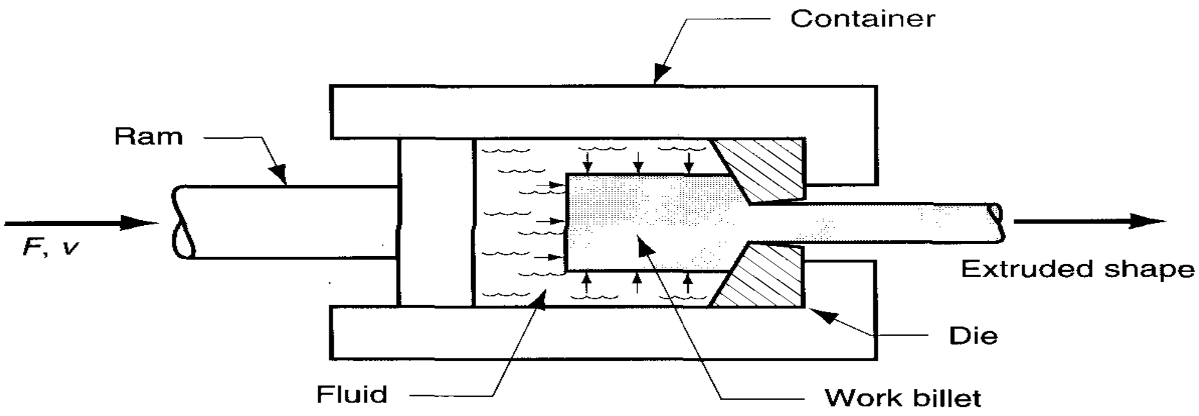


Tube or Pipe

Manufacturing Technology

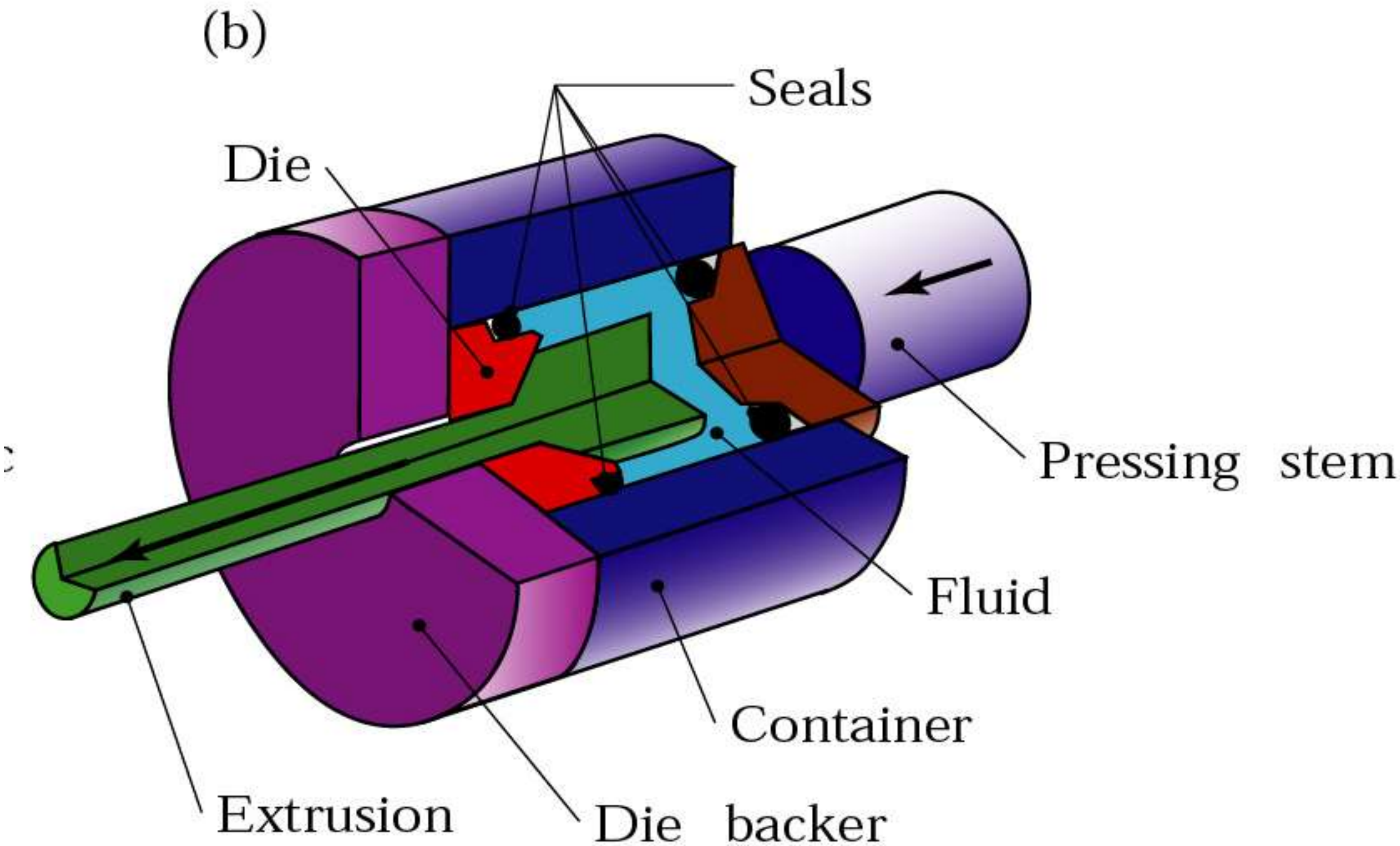
Hydrostatic Extrusion

- The **pressure required for extrusion** is supplied through and **incompressible fluid medium** surrounding the billet
- Usually carried at room temperature, typically using vegetable oils as the fluid
- **Brittle materials are extruded** generally by this method
- It **increases ductility** of the material
- It has complex nature of the tooling



Manufacturing Technology

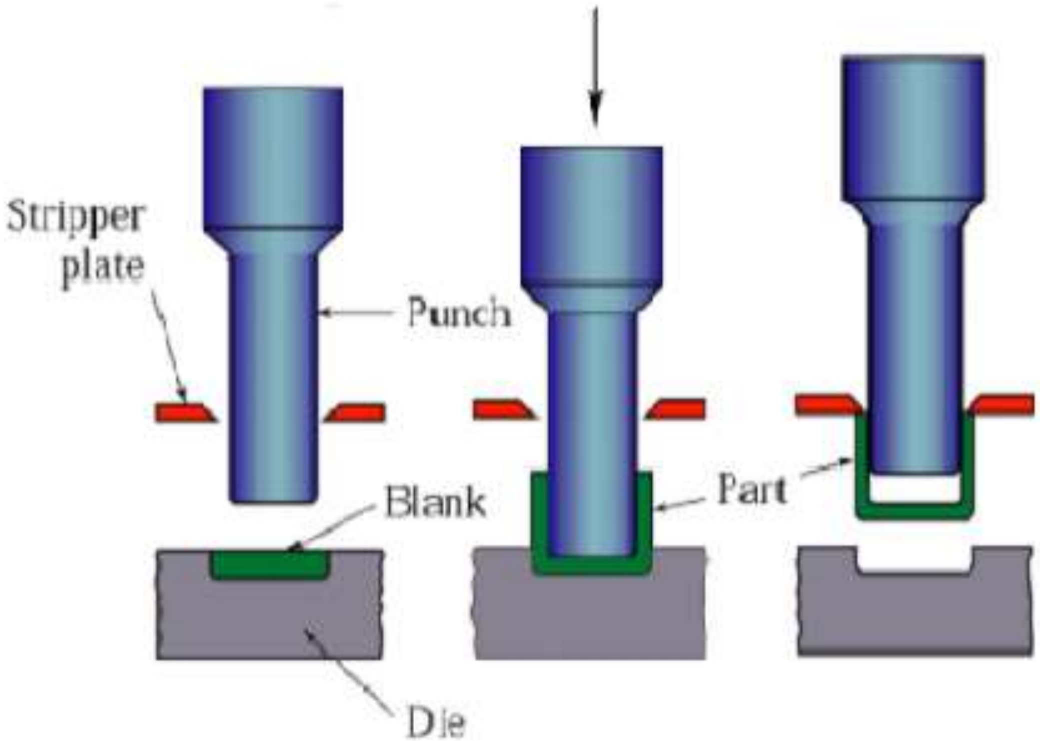
Hydrostatic Extrusion



Schematic illustration Hydrostatic Extrusion process

Impact Extrusion

- Similar to indirect extrusion
- Punch descends rapidly on the blank, which is extruded backward



Schematic illustration of the impact-extrusion process. The extruded parts are stripped by the use of a stripper plate, because they tend to stick to the punch

Manufacturing Technology

Hot extrusion

- prior heating of billet to above its recrystallization temperature

Cold extrusion

- prior heating of billet to below its recrystallization temperature

Advantages

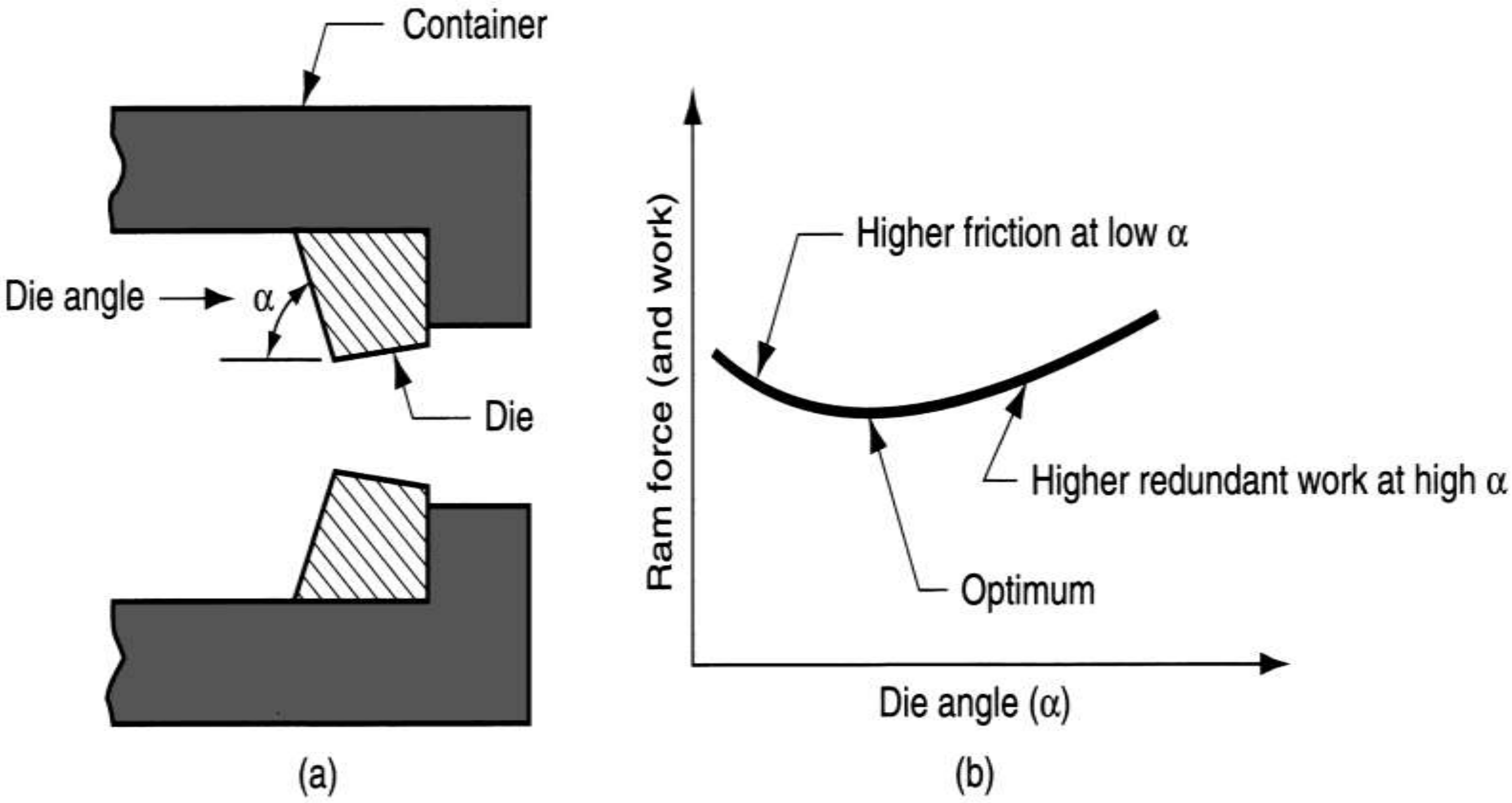
- Wide variety of shapes
- High production rates
- Improved microstructure and physical properties
- Close tolerances are possible
- Economical
- Design flexibility

Limitation

- part cross section must be uniform throughout length

Manufacturing Technology

Extrusion Die Features



(a) Definition of die angle in direct extrusion; (b) effect of die angle on ram force.

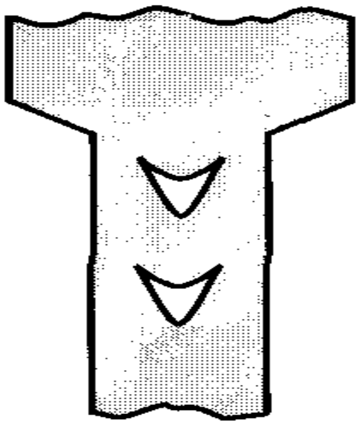
Manufacturing Technology

Extrusion Defects

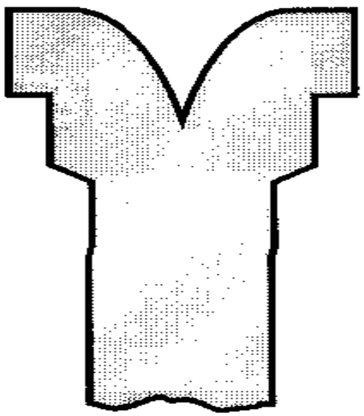
a. Centre-burst: **internal crack** due to **excessive tensile stress** at the center possibly because of high die angle, low extrusion ratio.

b. Piping: **sink hole at the end** of billet under direct extrusion.

c. Surface cracking: High part temperature due to **low extrusion speed** and high strain rates.



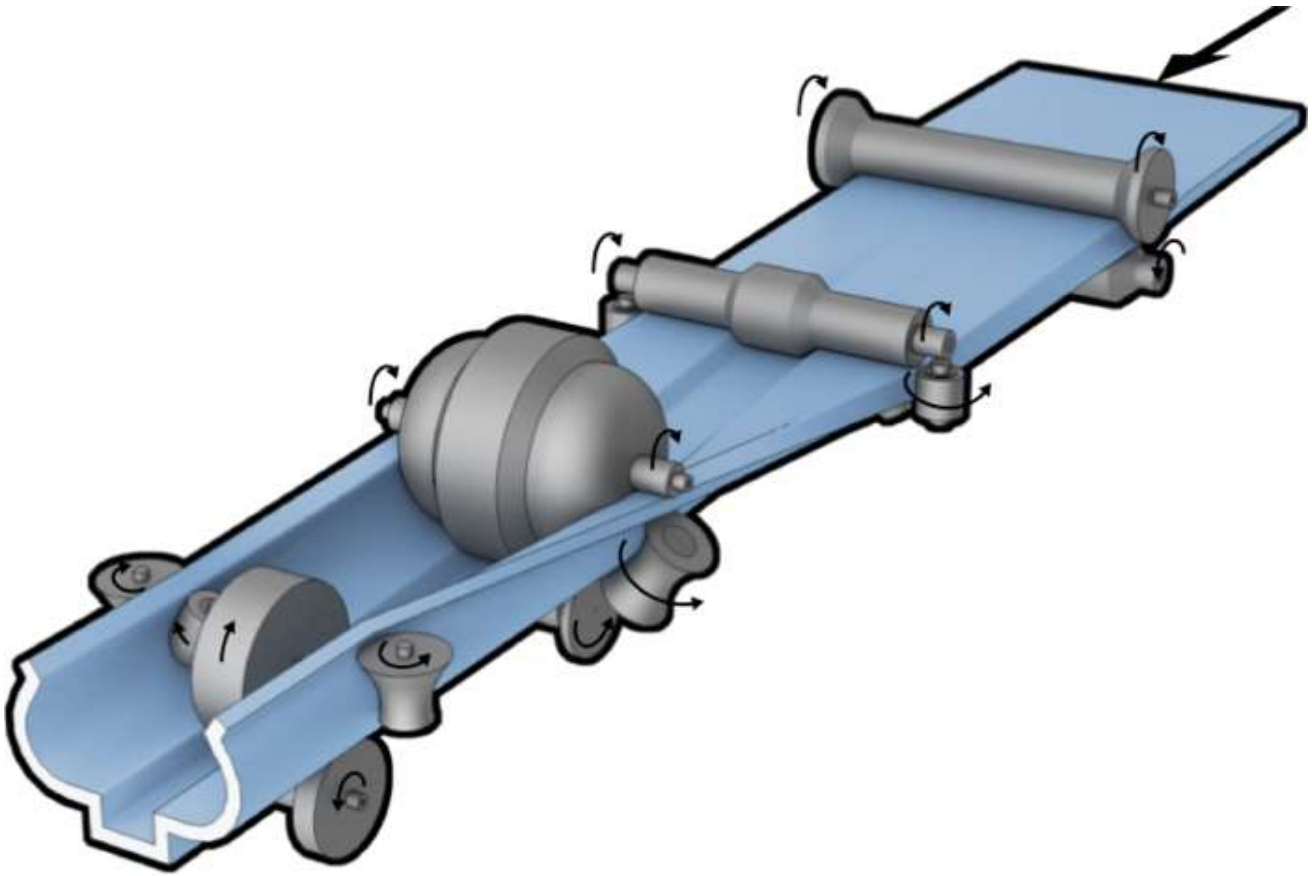
(a)



(b)

(c)

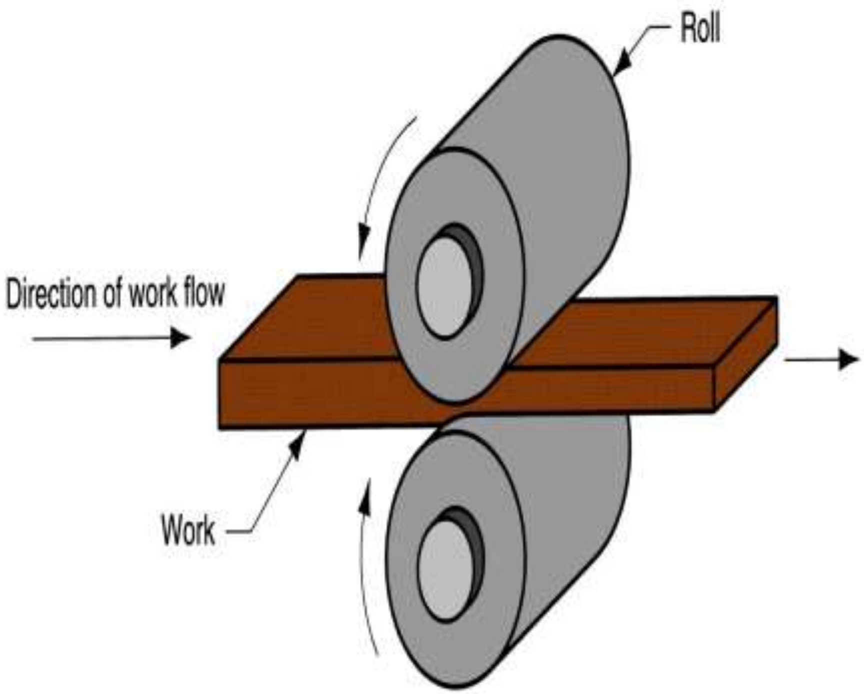
Rolling Operation



Manufacturing Technology

Rolling

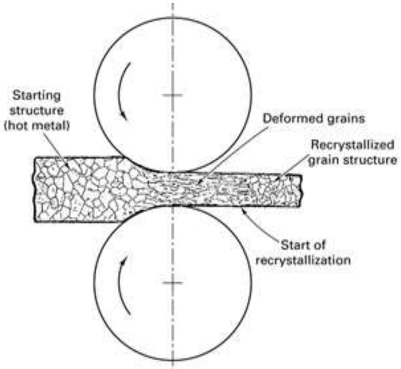
- **Deformation process** in which **work thickness is reduced** by **compressive forces** exerted by **two opposing rolls**

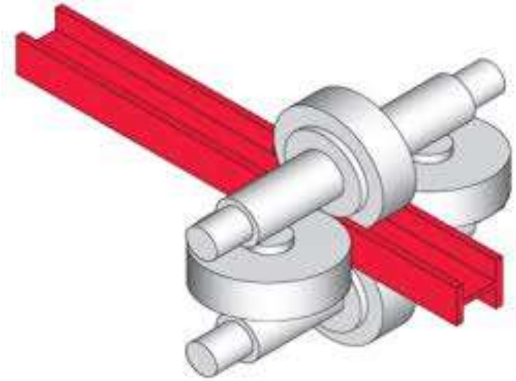


The rolling process (specifically, flat rolling)

Rolling:

- **Initial breaking down of an ingot (**or a continuously cast slab) is done by **hot rolling**.
  - A **cast structure** includes **coarse and non-uniform grains**. This structure is **usually brittle** and may **contain porosities**.
- **Hot rolling converts the cast structure** to a **wrought structure**.
  - This structure has **finer grains and enhanced ductility**, both resulting from **the breaking up of brittle grain boundaries** and the **closing up of internal defects**, especially porosity.
- The product of the **first hot rolling operation** is called **bloom or slab**.
  - **A Bloom** usually has a **square cross-section**, **at least 150 mm (6in)** on the side; Blooms are processed further, by shape rolling, into structural shapes, such as **I-beams and railroad rails**.
  - **A Slab** is usually **rectangular in cross section**. Slabs are rolled into **planes and sheet**.
  - **Billets** are usually **square**, with a cross-sectional **area smaller than blooms**; they are later rolled into various shapes, such as **round rods and bars**, by the use of shaped rolls.
  - Hot-rolled round rods are used as the **starting material** for **rod and wire drawing**. They are called **wire rods**.



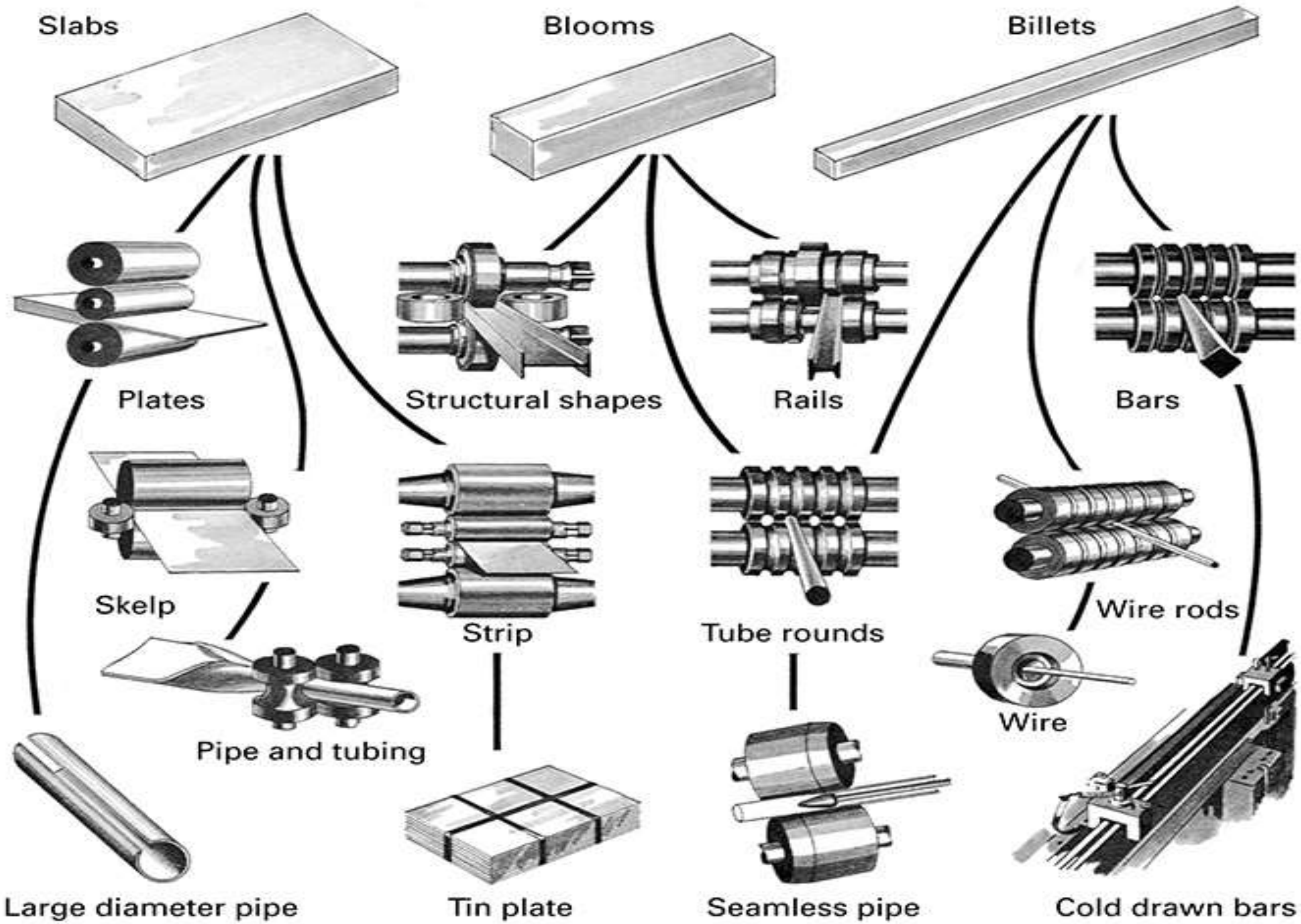


Rolling

- One of the primary first process to convert **raw material into finished product**.
- Starting **material (Ingots) are rolled into blooms, billets, or slabs** by **feeding material** through successive pairs of rolls.
    - **Bloom** - **square or rectangular cross section** with a thickness greater than 6" and a width no greater than 2x's the thickness
    - **Billets - square or circular cross section** - - smaller than a bloom
    - **Slabs - rectangular in shape** (width is greater than 2x's the thickness), slabs are rolled into plate, sheet, and strips.

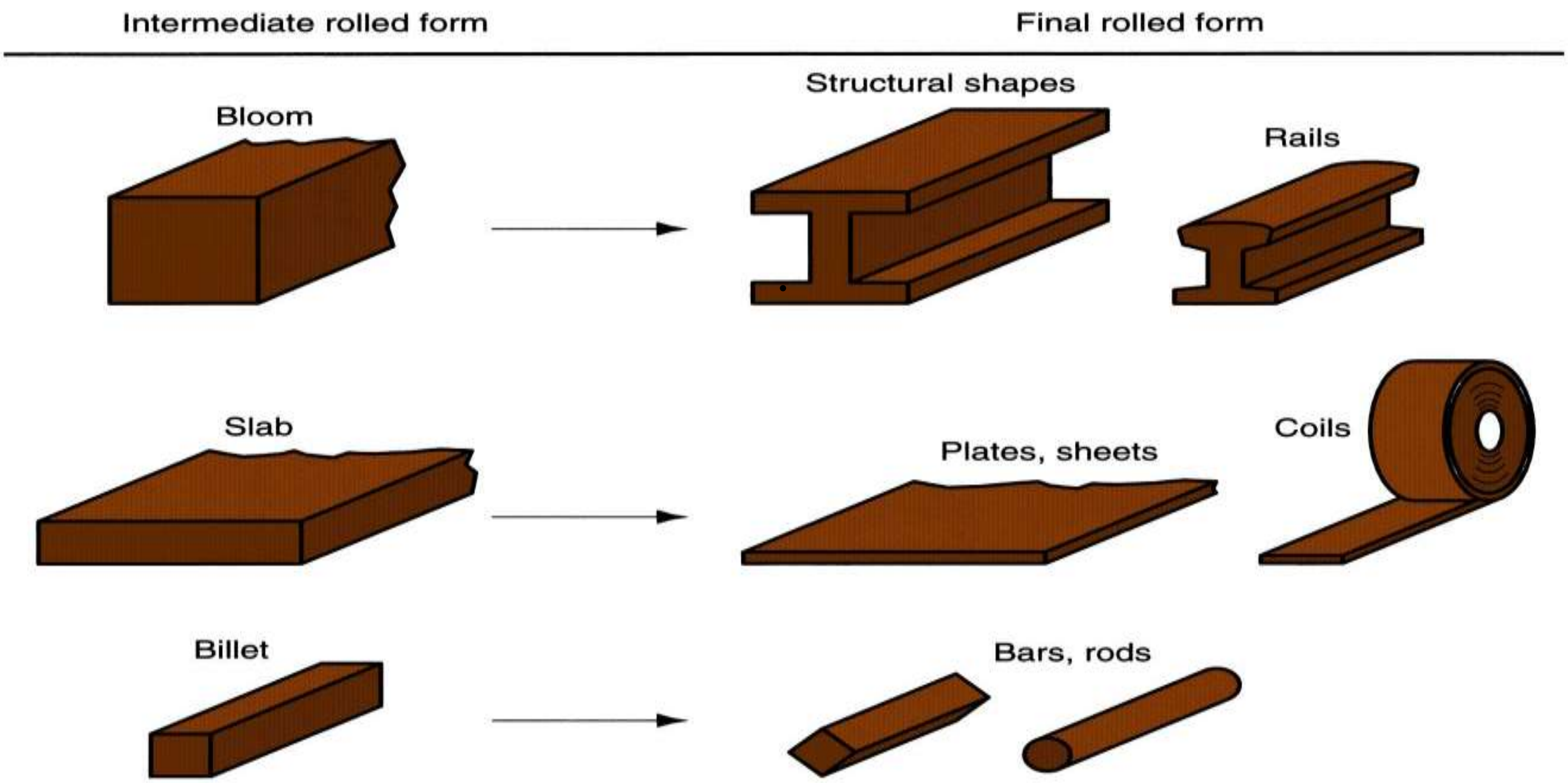
MANUFACTURING TECHNOLOGY

Rolling



Rolled Products Made of Steel

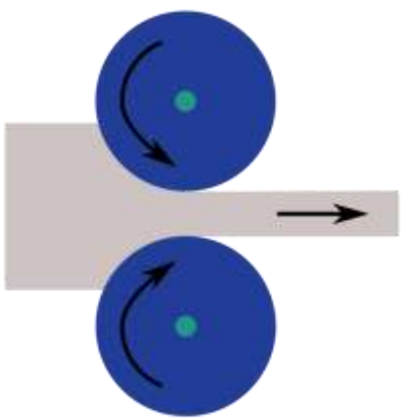
- Some of the steel products made in a rolling mill

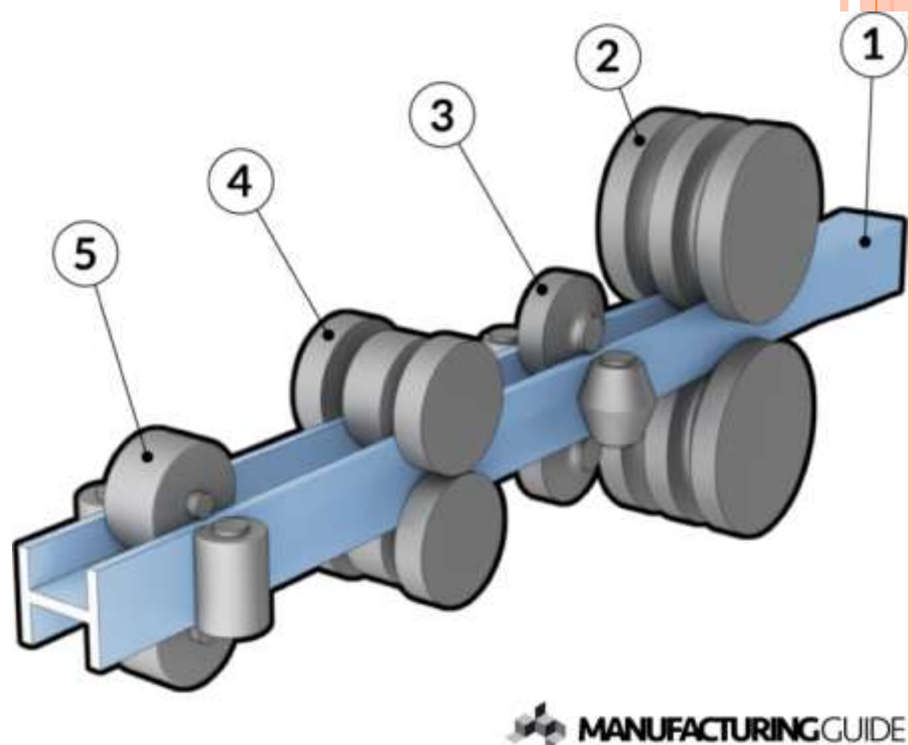


MANUFACTURING TECHNOLOGY

Rotating rolls perform two main functions:

- **Pull the work** into the gap between them by friction between **work part and rolls**
- **Simultaneously squeeze** the work **to reduce its cross section**





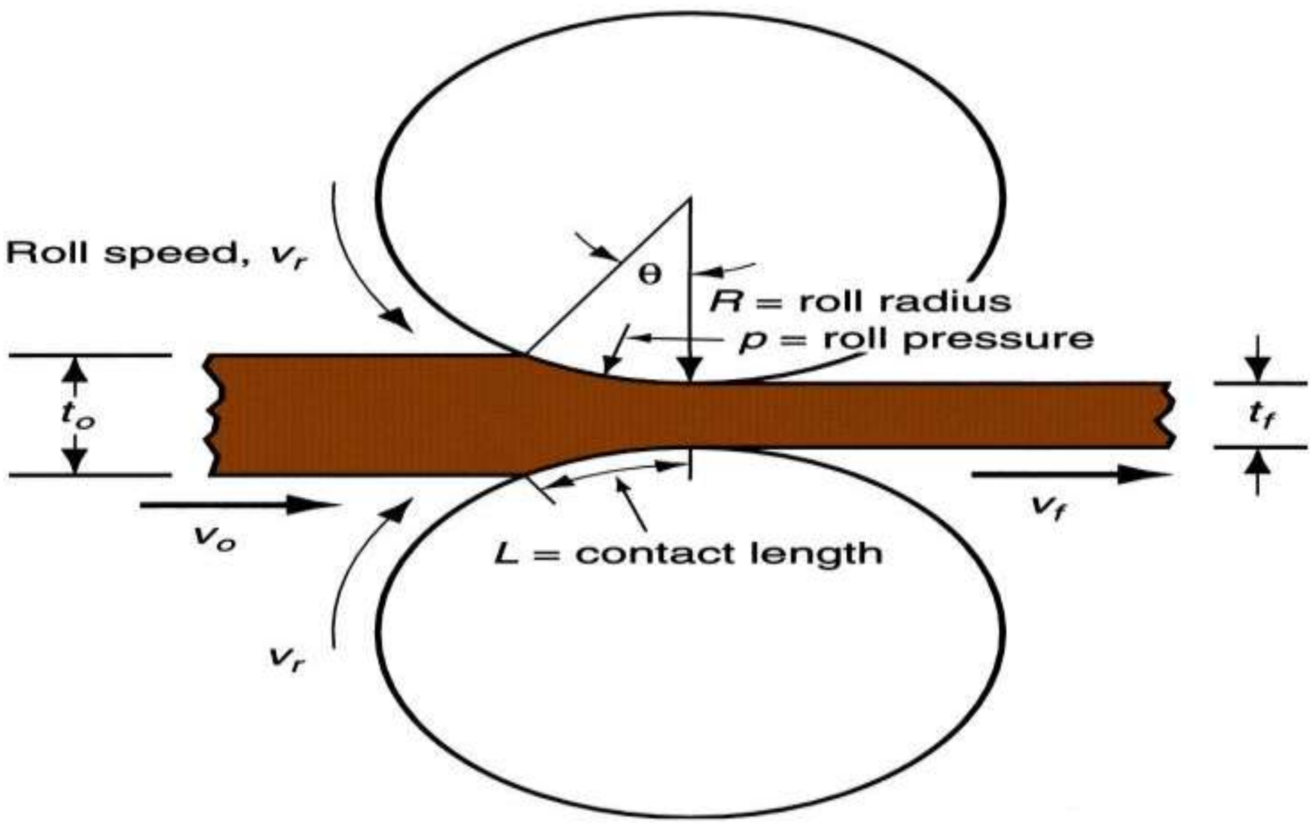
Manufacturing Technology

Types of Rolling

- Based on work piece geometry :
  - Flat rolling - used to reduce thickness of a rectangular cross section
  - Shape rolling - square cross section is formed into a shape such as an I-beam
- Based on work temperature :
  - Hot Rolling – most common due to the large amount of deformation required
  - Cold rolling – produces finished sheet and plate stock

Flat Rolling

- **Heated metal is passed** between **rotating rolls** to **reduce the cross-section**.
- Side view of **flat rolling**, indicating **before and after thicknesses**, **work velocities**, **angle of contact with rolls**, and other features.

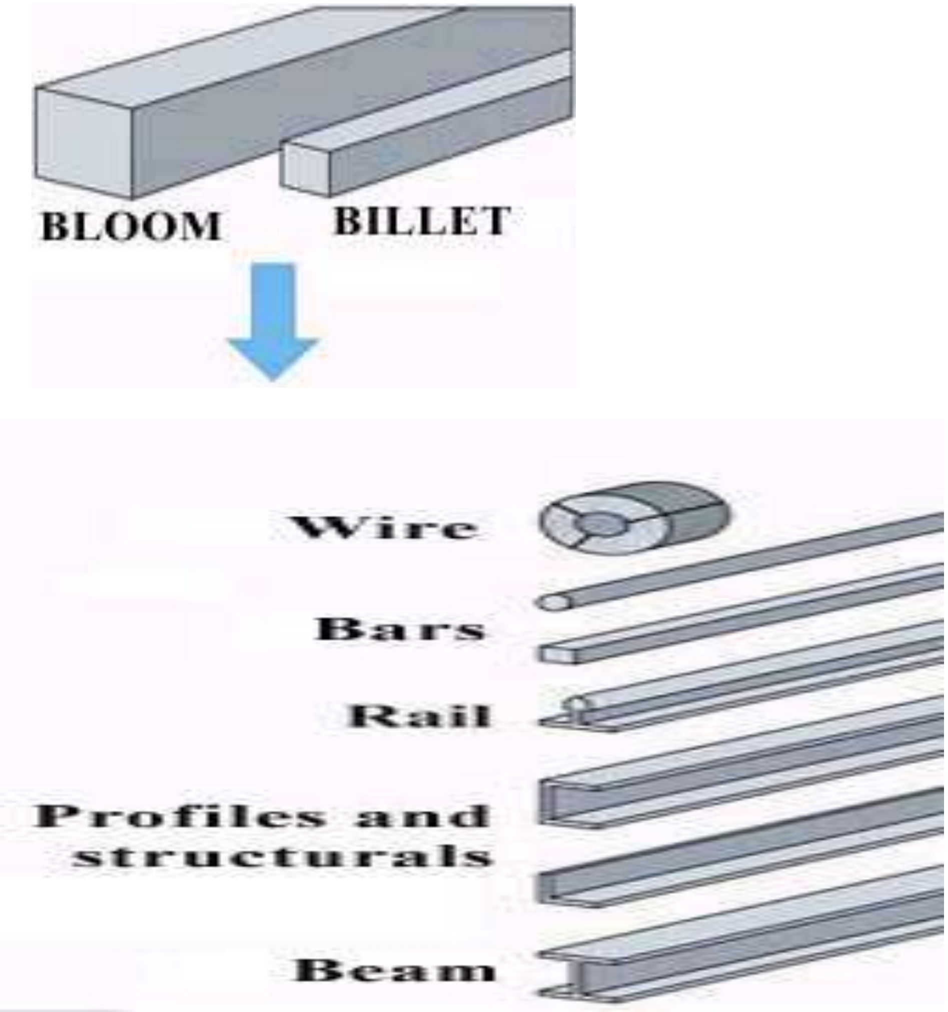


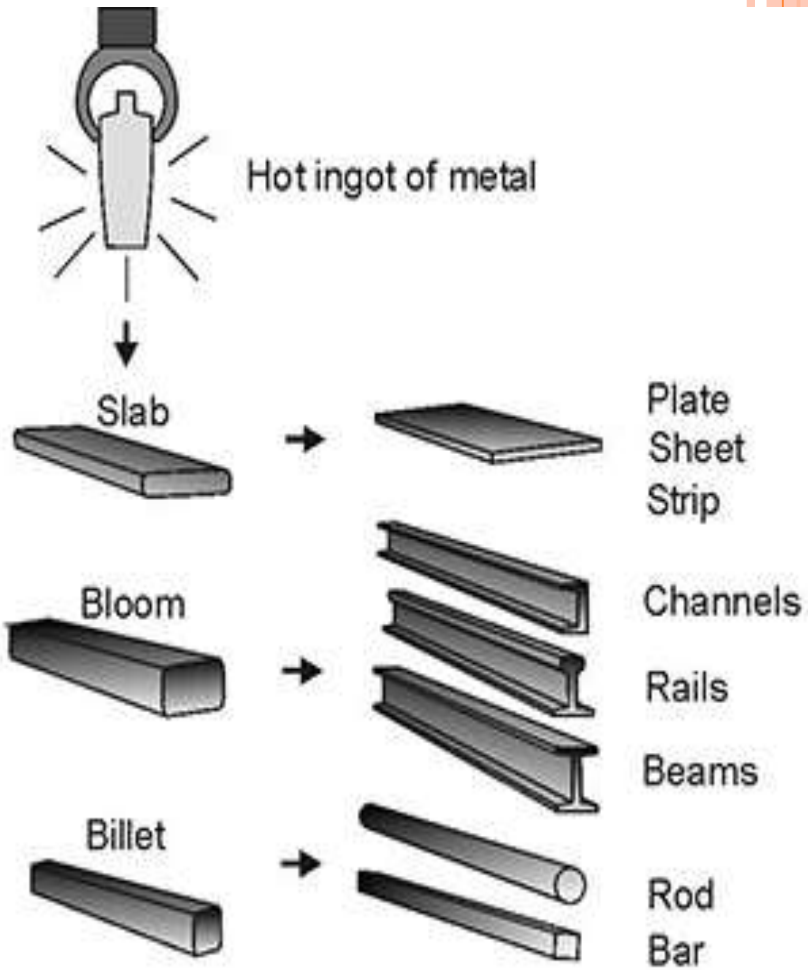
Shape Rolling

- **Work is deformed into a contoured cross section** rather than flat (rectangular)
- Accomplished by passing work through rolls that have the **reverse of desired shape**
- Products include:
  - Construction shapes such as I-beams, L-beams, and U-channels
  - Rails for railroad tracks
  - Round and square bars and rods

Manufacturing Technology

Shape Rolling





Examples of flat and shape rolled products

Manufacturing Technology

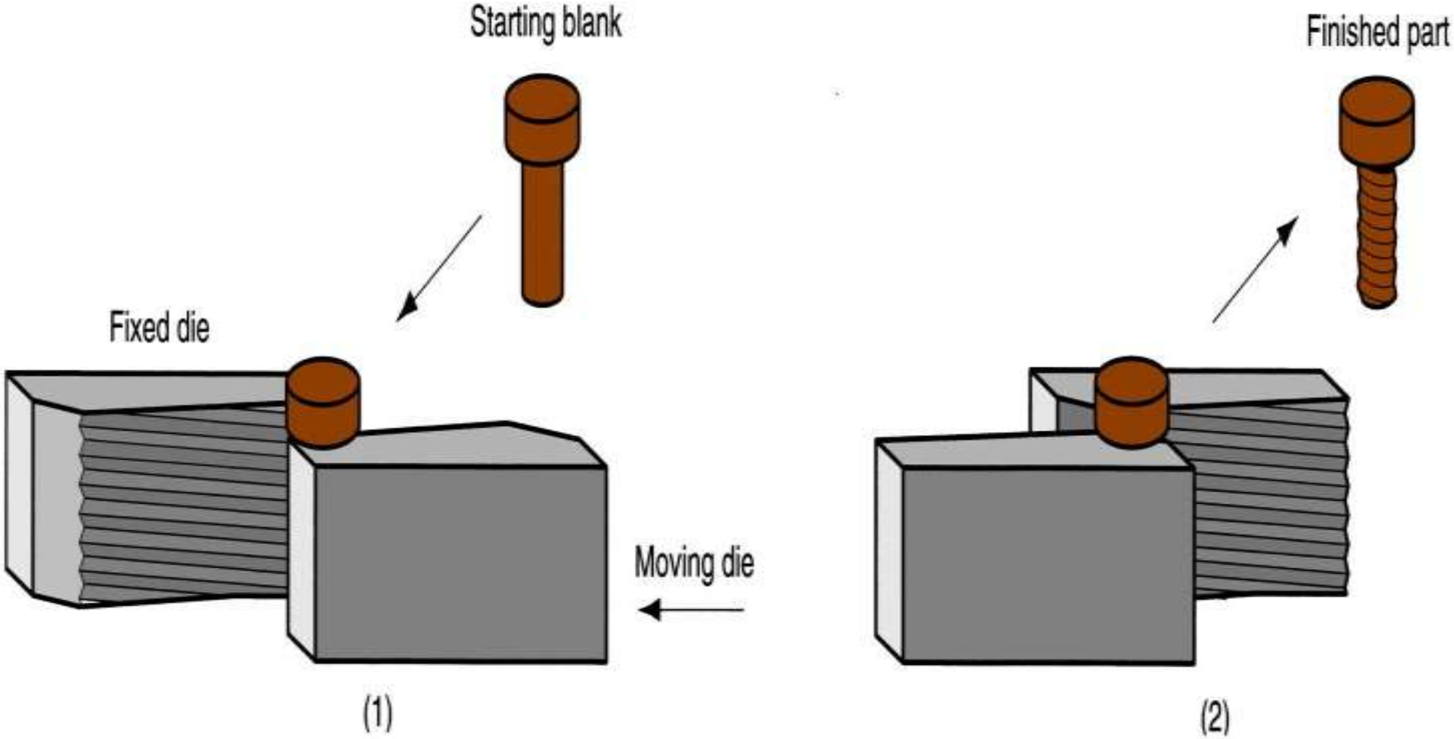
Thread Rolling

Bulk deformation process used to **form threads on cylindrical** parts by **rolling them between two dies**

- Important commercial process for mass producing bolts and screws
- Performed by cold working in thread rolling machines
- Advantages over thread cutting (machining):
  - Higher production rates
  - Better material utilization
  - Stronger threads and better fatigue resistance due to work hardening

Manufacturing Technology

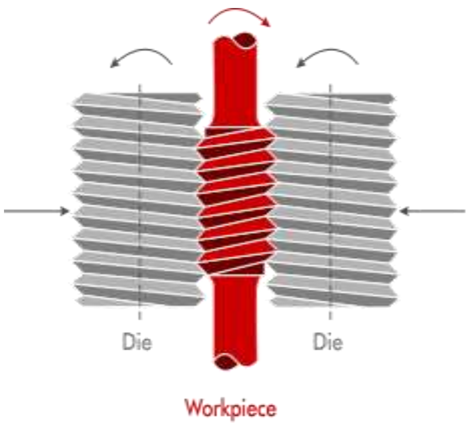
- Thread rolling with flat dies

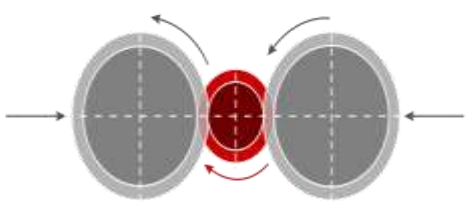


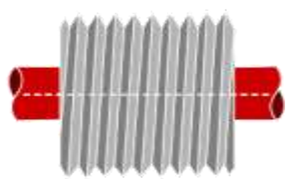
(1) start of cycle (2) end of cycle

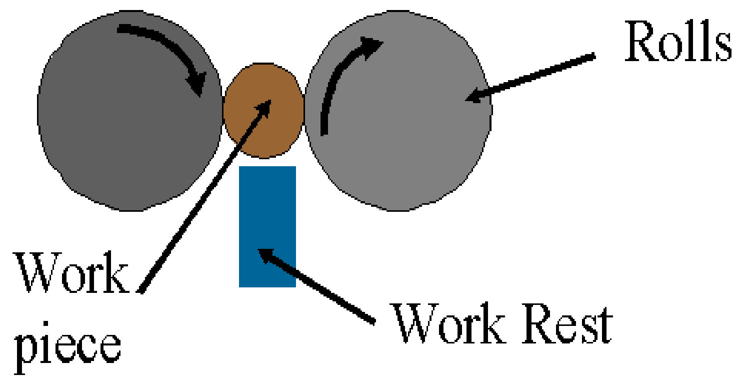
Manufacturing Technology

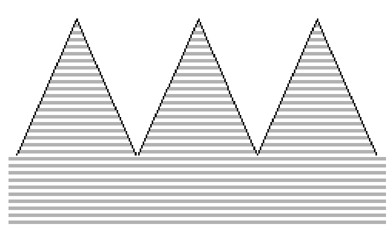
Thread Rolling

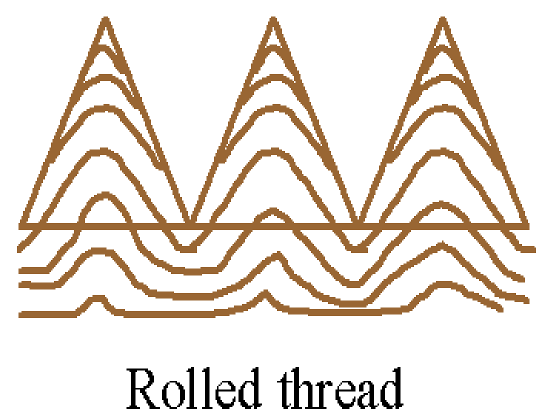












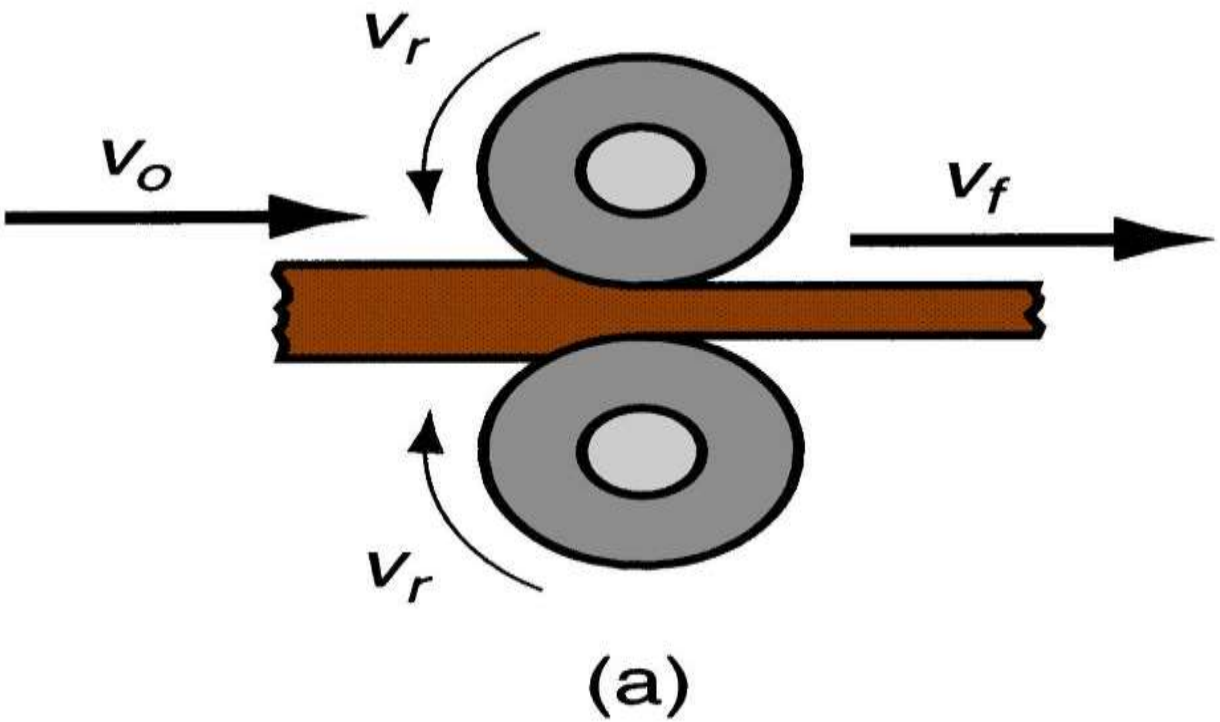
Manufacturing Technology

Rolling Mills

- Equipment is massive and expensive
- Rolling mill configurations:
  - Two-high – two opposing rolls
  - Three-high – work passes through rolls in both directions
  - Four-high – backing rolls support smaller work rolls
  - Cluster mill – multiple backing rolls on smaller rolls
  - Tandem rolling mill – sequence of two-high mills

Manufacturing Technology

Two-High Rolling.



a -2-high rolling mill.

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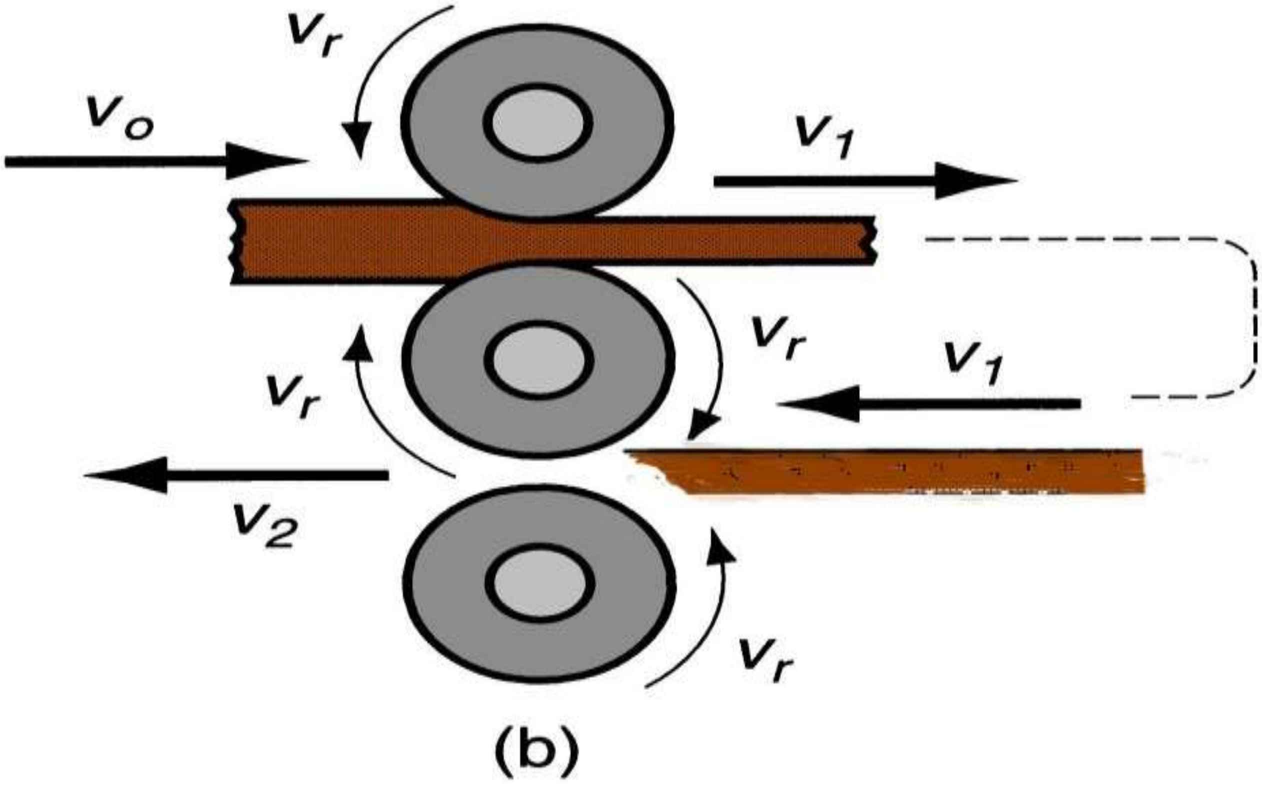
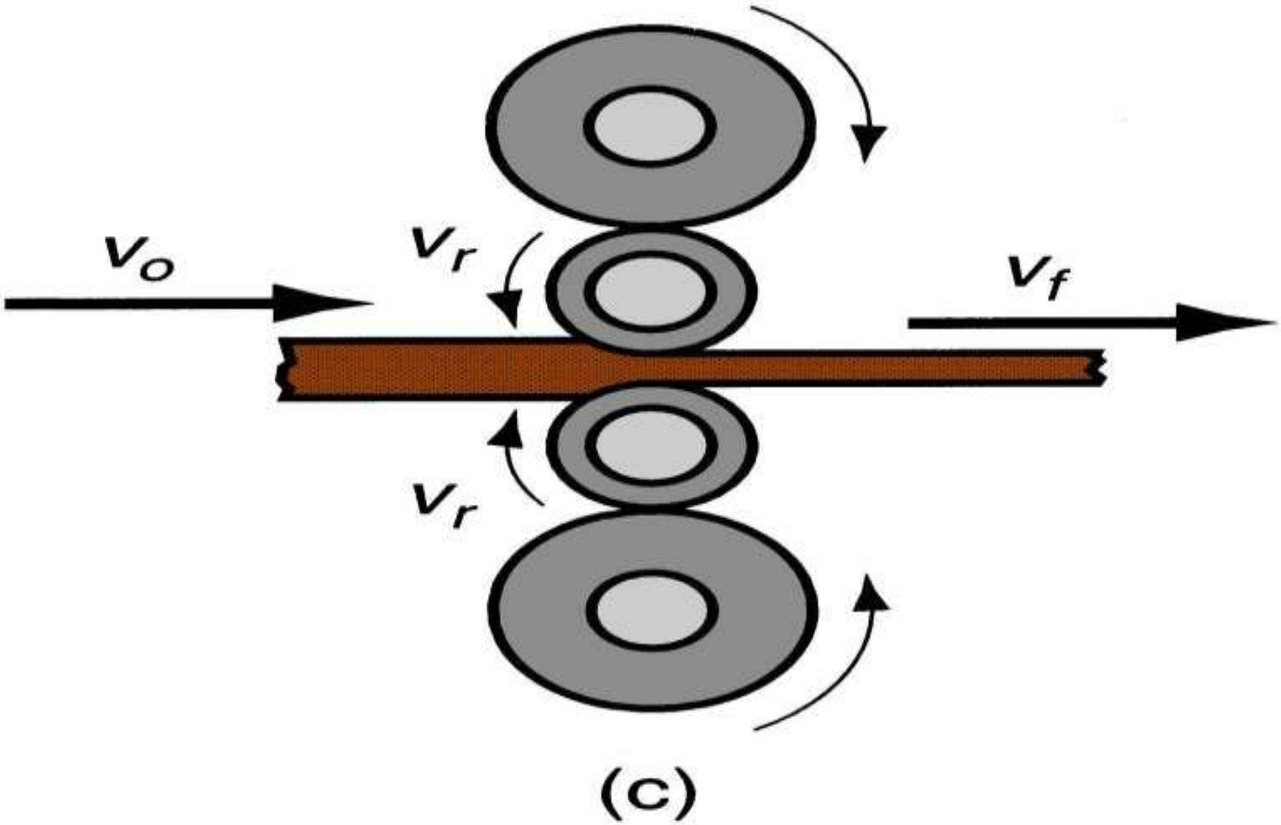
Three-High Rolling.



b -3-high rolling mill.

Manufacturing Technology

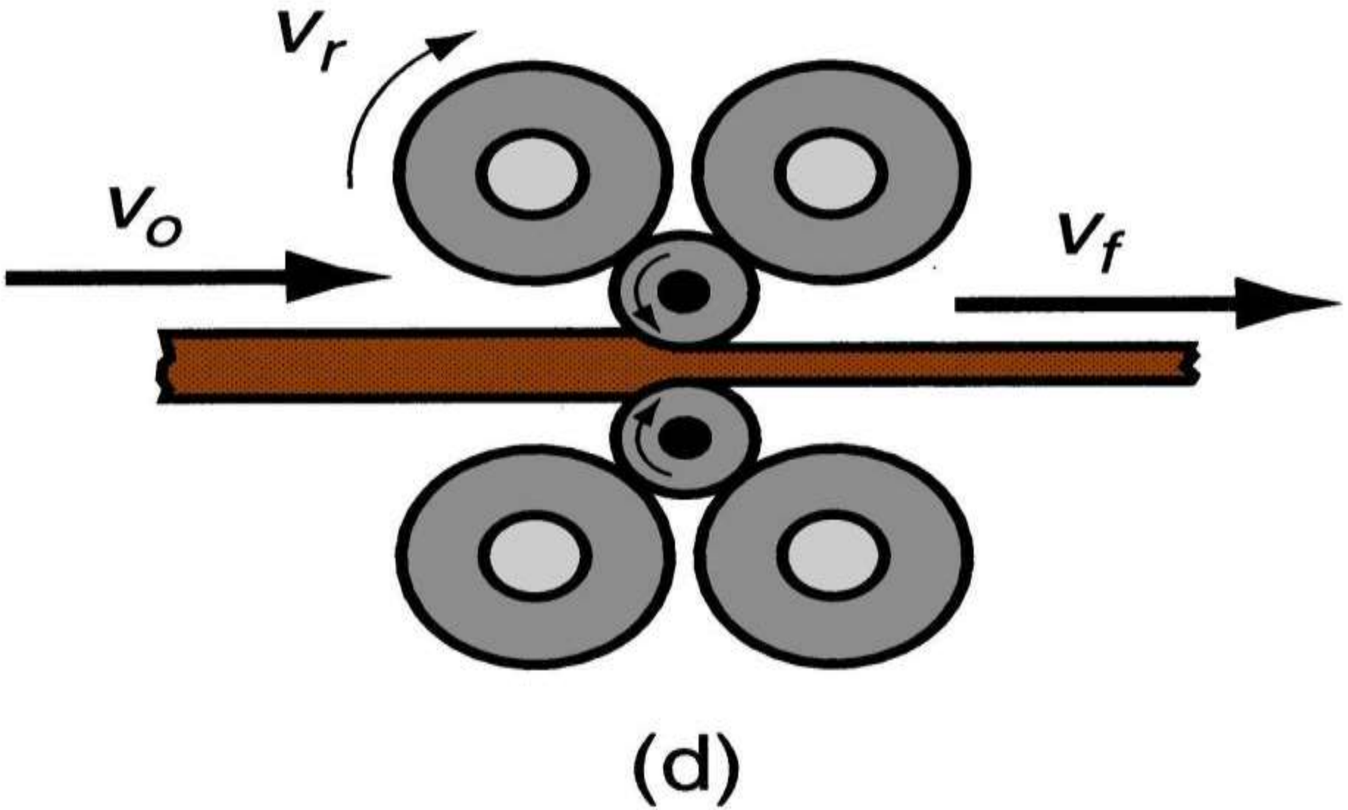
Four-High Rolling.



b -4-high rolling mill.

Manufacturing Technology

Cluster Mill

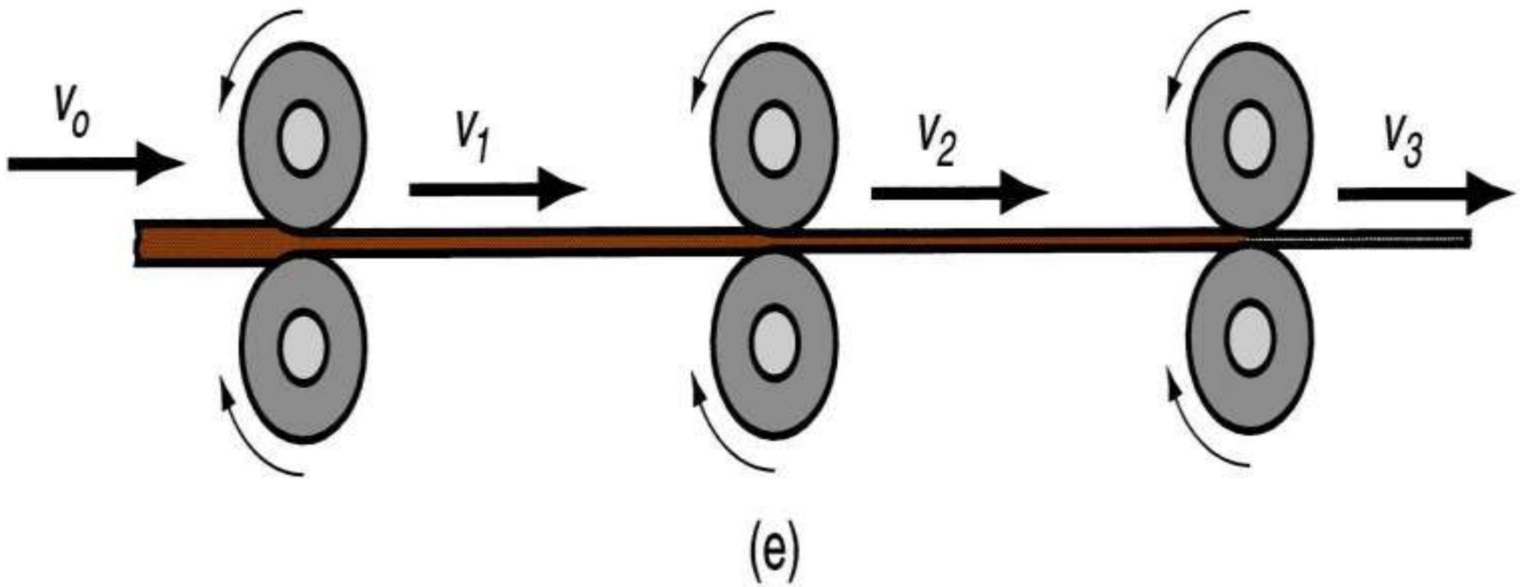


d -Cluster mill.

Manufacturing Technology

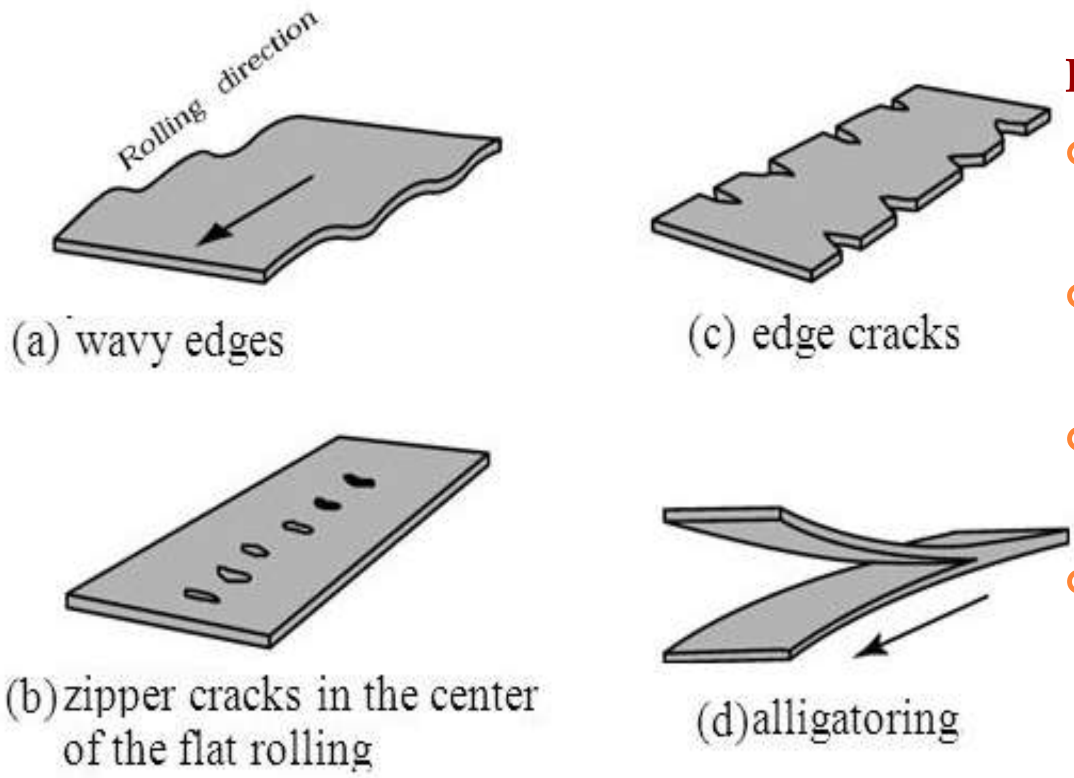
Tandem Rolling Mill

- A series of rolling stands in sequence



e –Tandem Rolling mill.

Manufacturing Technology

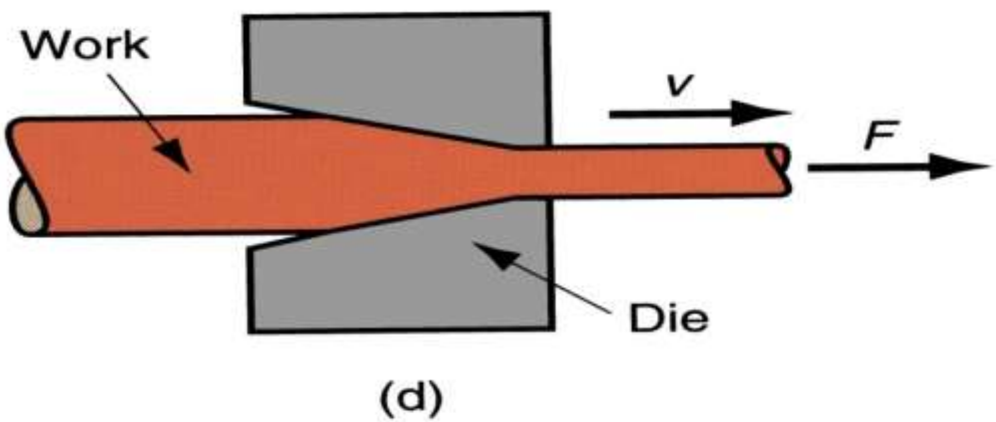


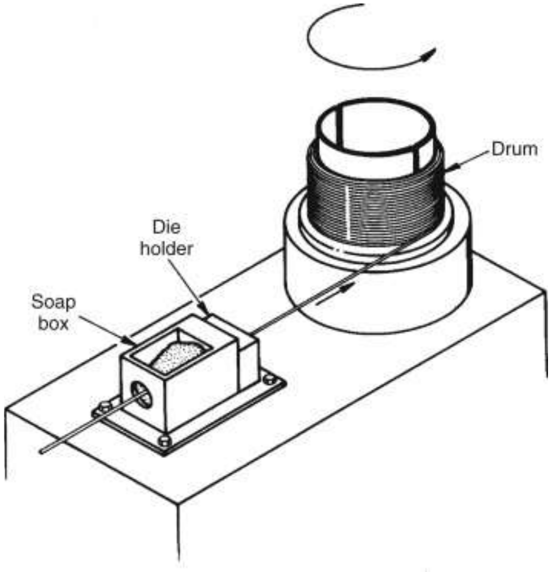
Rolling Defects

- (a) Waviness
  - Improper roller speeds
- (b) Zipper cracks
  - Too much rolling in center
- (c) Edge cracks
  - Too much rolling on outside
- (d) Alligatoring
  - Too much induced tensile stress in the part, or defects

DRAWING

- **Drawing** is an operation in which the **cross-section of solid rod, wire or tubing** is **reduced or changed in shape** by pulling it **through a die**.
  - Drawn rods are used for **shafts, spindles, and small pistons** and as the raw material for fasteners such as **rivets, bolts, screws**.
- Drawing also improves **strength and hardness** when these properties are **developed by cold work** and not by subsequent heat treatment.

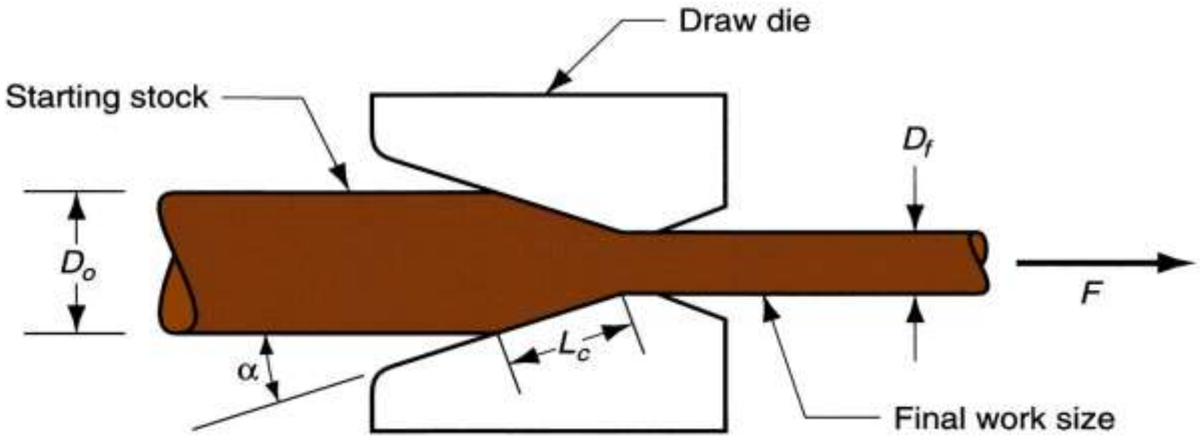




Manufacturing Technology

Drawing Types

- Wire Drawing
  - **Cross-section of a bar, rod, or wire is reduced by pulling it** through a die opening
  - Similar to extrusion **except work is *pulled* through die** in drawing (it is *pushed* through in extrusion)
  - Although drawing applies tensile stress, compression also plays a significant role since **metal is squeezed as it passes through die opening**



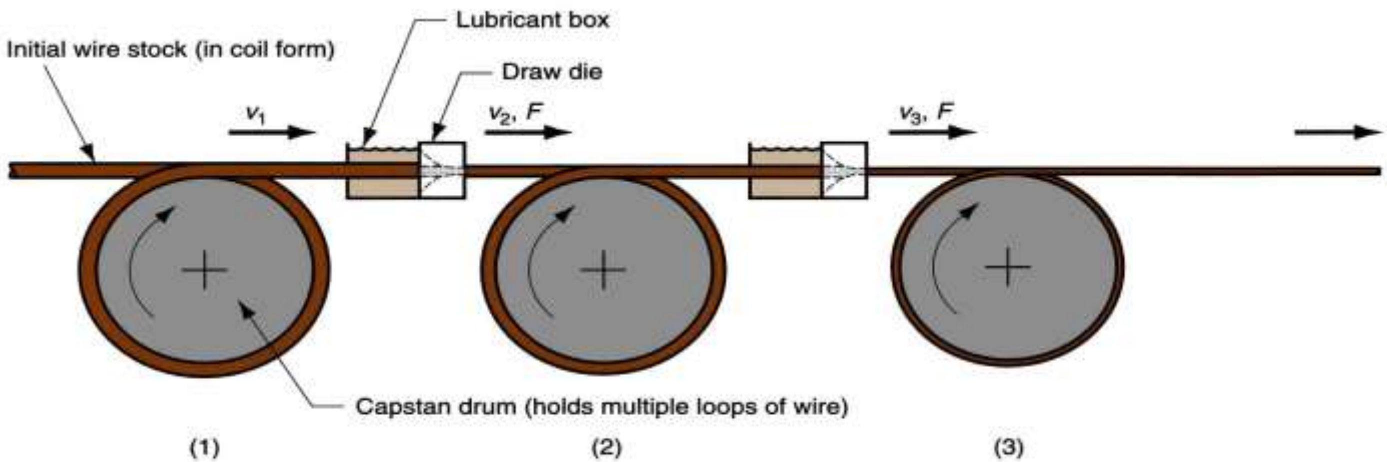
Drawing of wire.

r = area reduction in drawing;
A_o = original area of work;
A_f = final work

$$r = \frac{A_o - A_f}{A_o}$$

MANUFACTURING TECHNOLOGY

- Wire drawing machines consisting of multiple draw dies (typically 4 to 12) separated by accumulating drums
  - **Each drum (*capstan*)** provides **proper force to draw** wire stock through upstream die
  - Each die provides a small reduction, so desired total reduction is achieved by the series
  - **Annealing sometimes required between dies** to relieve work hardening



Continuous drawing of wire

Manufacturing Technology

Area Reduction in wire Drawing

- Change in size of work is usually given by area reduction

$$r = \frac{A_o - A_f}{A_o}$$

  - where r = area reduction in drawing; A_o = original area of work; and A_f = final work

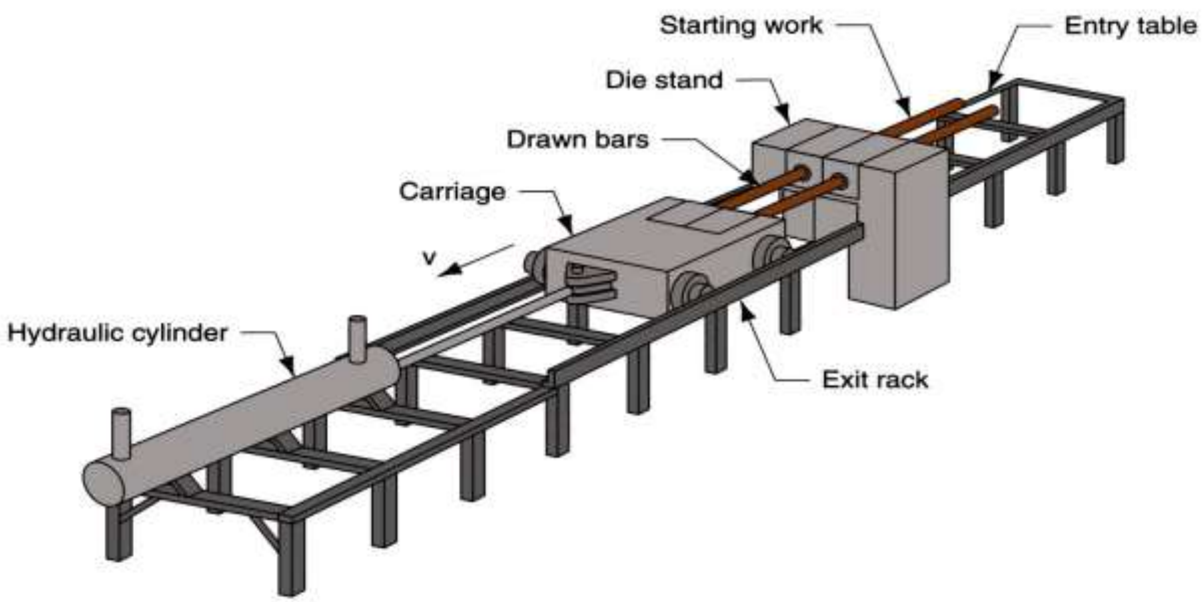
Die Materials

- Commonly used materials are **Tool Steels and Carbides**
- **Diamond dies** are used for **fine wire**.
- For improved **wear resistance**, steel dies may be **chromium plated**, and **carbide dies** may be coated with **titanium nitride**
- For Hot drawing, **cast-steel dies** are used

Manufacturing Technology

Bar or Rod Drawing

- Accomplished as a ***single-draft* operation** - the stock is pulled through one die opening
- **Beginning stock** has large diameter and is a straight cylinder
- Requires a batch type operation



Hydraulically operated draw bench for drawing metal bars

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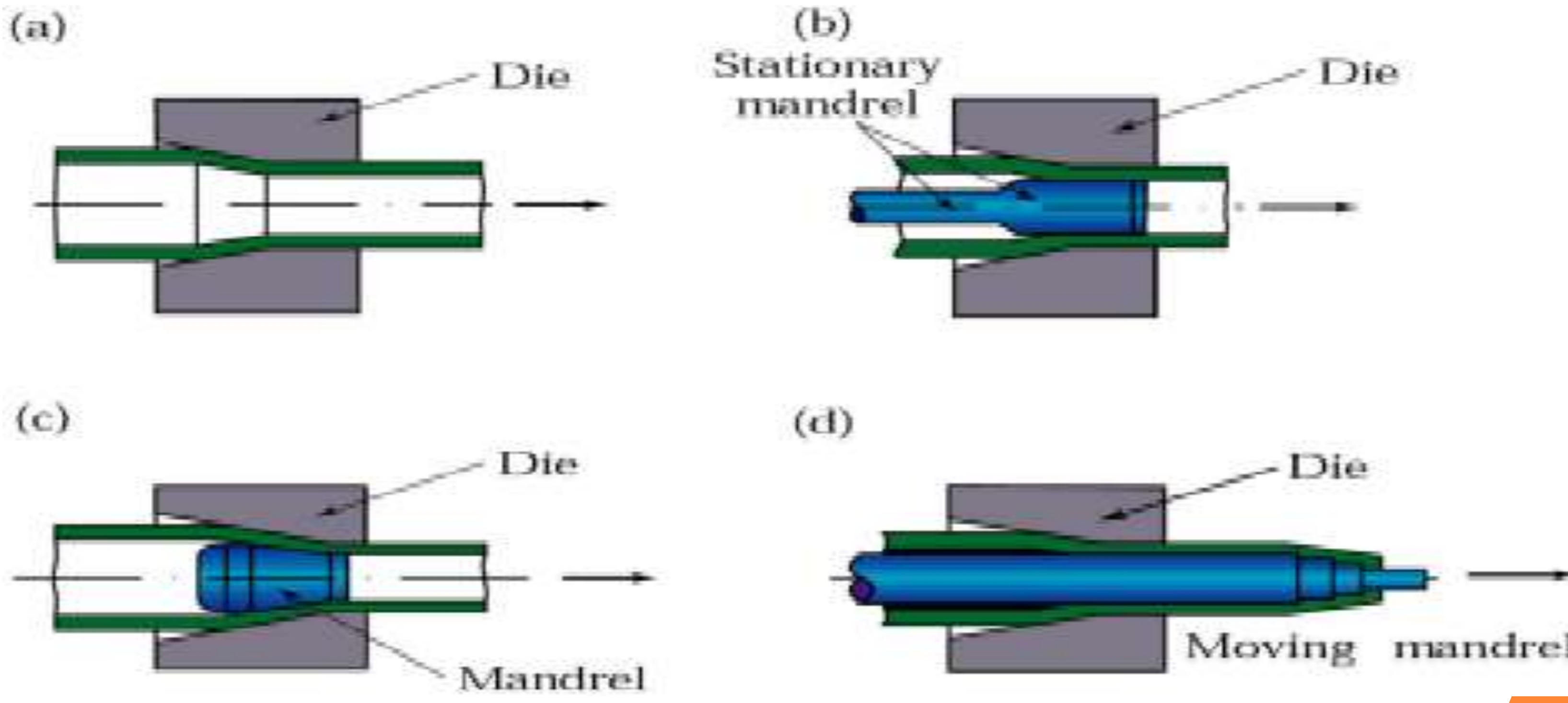
Tube Drawing

- **Accomplished by pulling the stock** through the sides of the **mandrel placed between dies**



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Wire Drawing vs. Bar Drawing

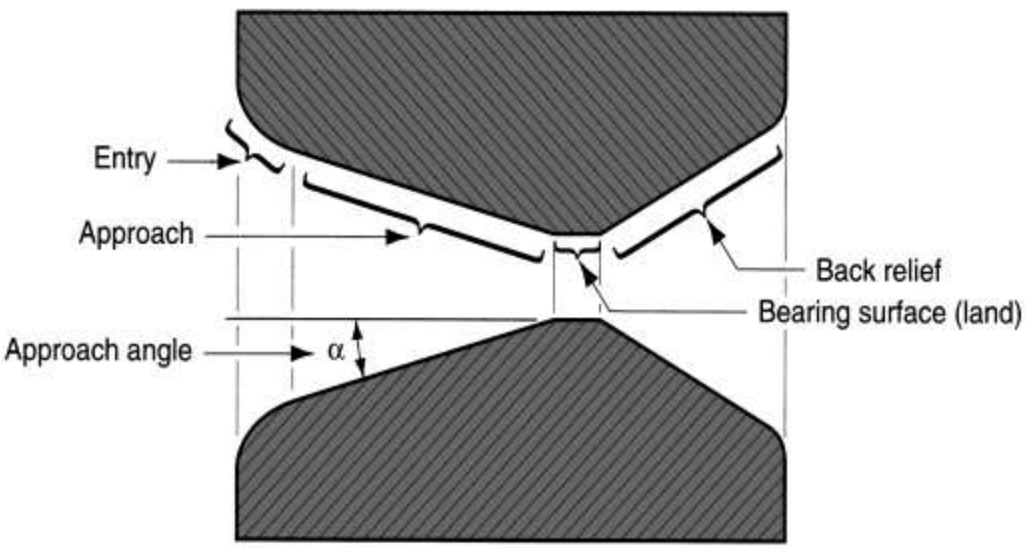
- Difference between **bar drawing and wire drawing** is **stock size**
  - Bar drawing - large diameter bar and rod stock
  - Wire drawing - small diameter stock - wire sizes down to 0.03 mm (0.001 in.) are possible
- Although the mechanics are the same, the methods, equipment, and even terminology are different

Preparation of Work for Drawing

- Annealing – to increase ductility of stock
- Cleaning - to prevent damage to work surface and draw die
- Pointing – to reduce diameter of starting end to allow insertion through draw die

Features of a Draw Die

- Entry region - funnels lubricant into the die to prevent scoring of work and die
- Approach - cone-shaped region where drawing occurs
- Bearing surface - determines final stock size
- Back relief - exit zone - provided with a back relief angle (half-angle) of about 30°
- Die materials: tool steels or cemented carbides



MANUFACTURING TECHNOLOGY
SHEET METAL FORMING PROCESSES





Manufacturing Technology

Introduction to Sheet Metal

- **Metal is formed into thin and flat pieces**. It is one of the fundamental forms used in **metalworking**, and can be **cut and bent** into a variety of **different shapes**.
- Countless everyday objects are constructed by this process. Thicknesses can vary significantly,
    - extremely thin sheets are considered as foil or leaf,
    - sheets thicker than 6 mm (0.25 in) are considered as plate.

Manufacturing Technology

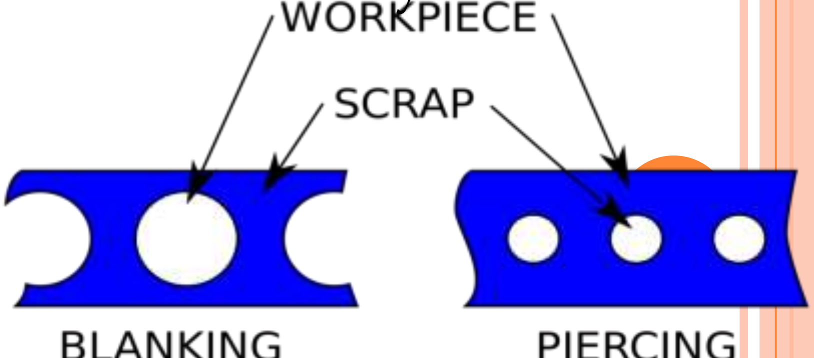
Sheet Metal Processing

- The **raw material for sheet metal** manufacturing processes is the **output of the rolling process**.
- Typically, sheets of metal are sold as flat, rectangular sheets of standard size.
- If the sheets are **thin and very long**, they may be in the **form of rolls**. Therefore the first step in any **sheet metal process is to cut** the correct shape and **sized blank from larger sheet**.

Manufacturing Technology

Sheet Metal Working

- **Cutting and Forming operations** are performed on **relatively thin sheets of metal**
- Thickness of **sheet metal =** 0.4 mm to 6 mm
- Thickness of **plate stock** > 6 mm
- Operations are usually performed as cold working
- **Sheet metals process** are characterized by **high strength**, **good dimensional accuracy, better surface finish** and relatively **low cost**.



Manufacturing Technology

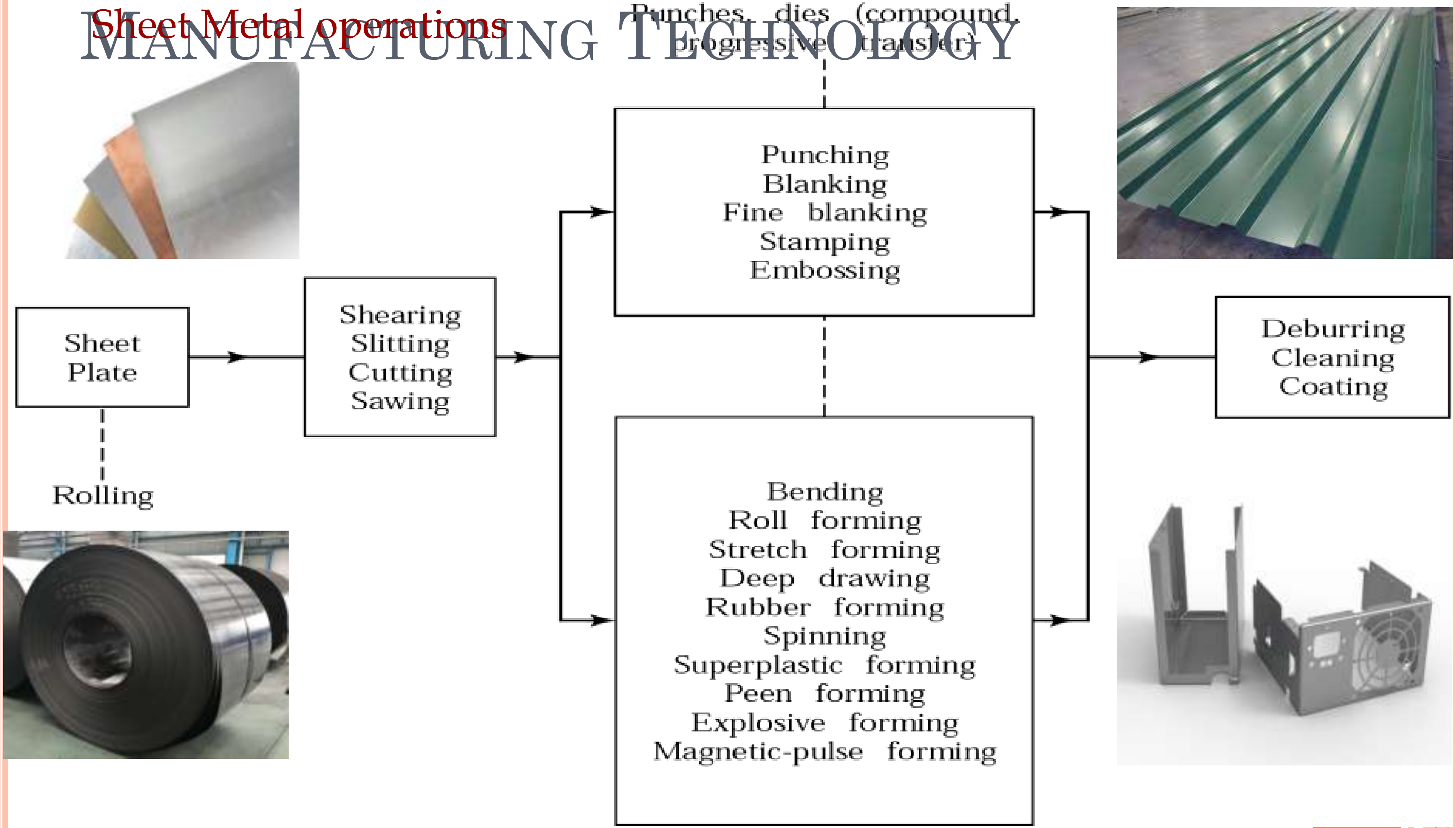
Sheet Metal operations

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.**

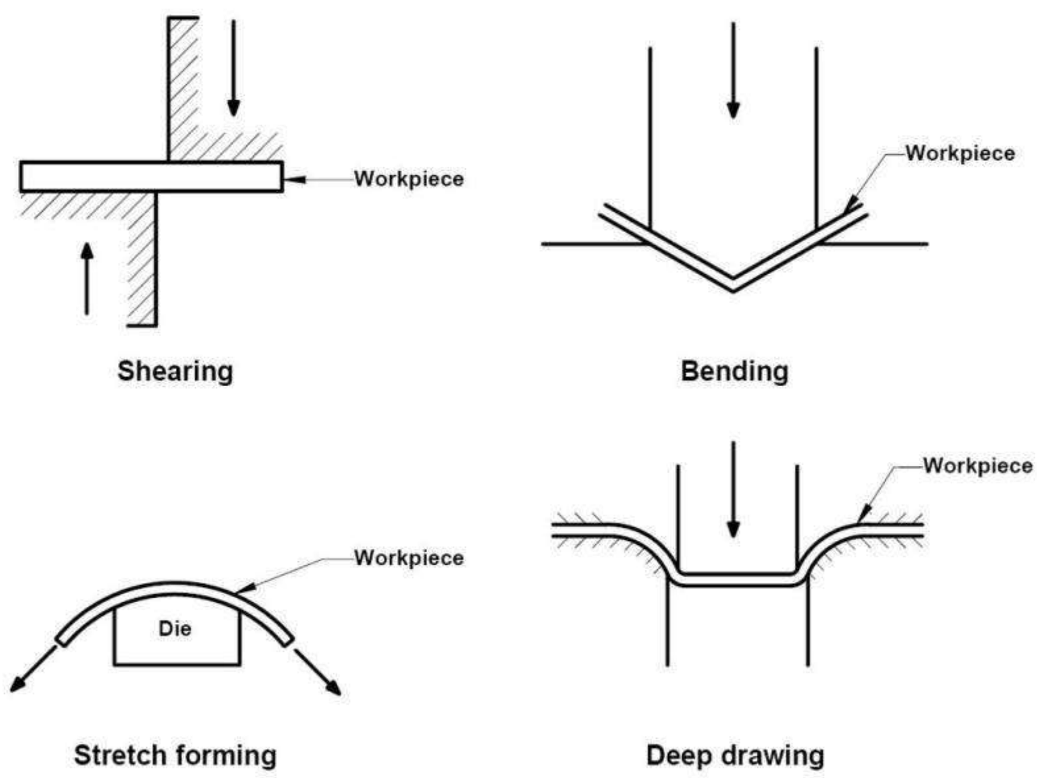
Manufacturing Technology

Sheet Metal operations

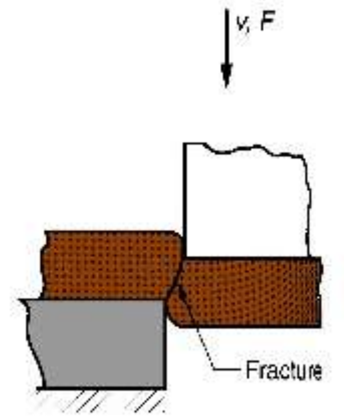


Sheet Metal operations

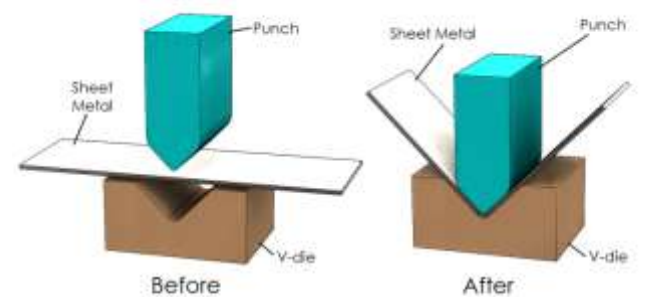
- The **art of sheet metal lies** in the making of **different shapes** by adopting different operations. The major types of operations are given below
  - Shearing (Cutting)
  - Bending
  - Drawing
  - Squeezing



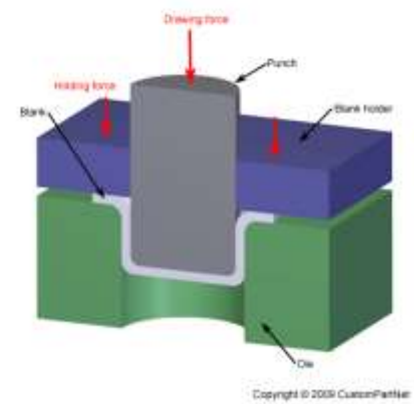
Sheet Metal operations



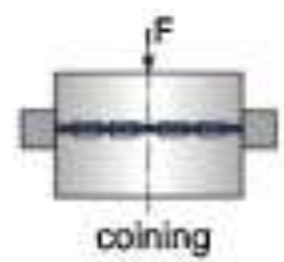
- Shearing (Shearing between Punch & Die)
  - **Cutting to separate large sheets**; or cut part perimeters or make holes in sheets



- Bending
  - **Straining sheet** around a straight axis
- Drawing
  - Forming of sheet into **convex or concave** shapes

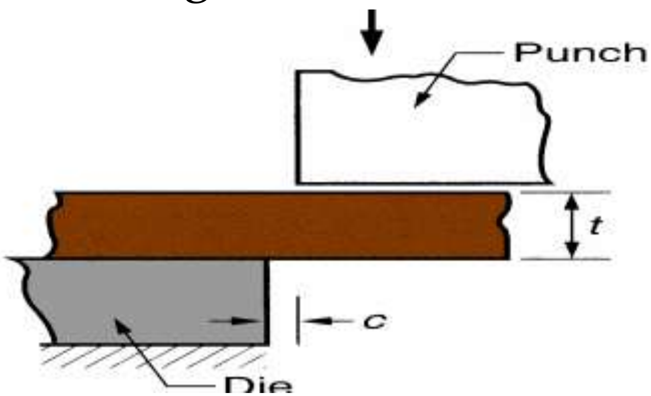


- Squeezing
  - Forming of sheet by **gripping and pressing** firmly – **Coining & Embossing**

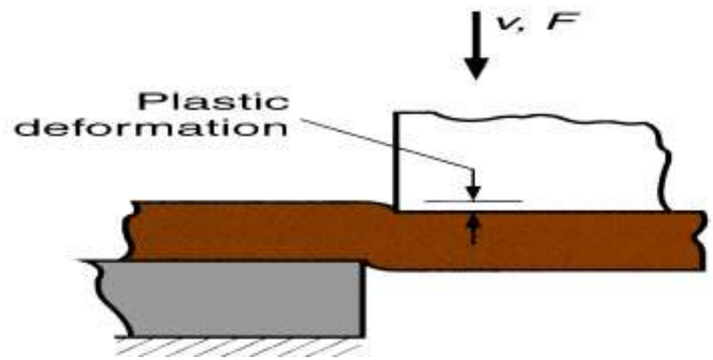


Shearing (Cutting)

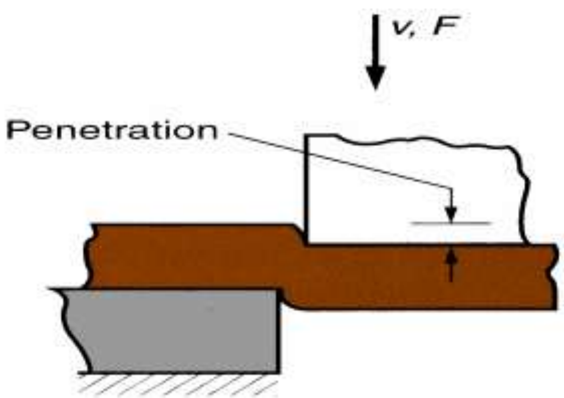
- Shearing of sheet metal between two sharp cutting edges



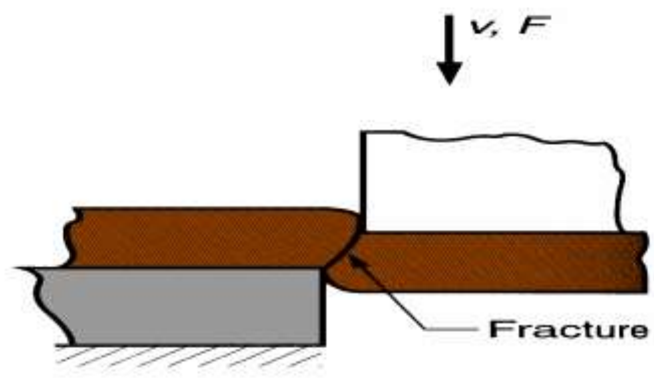
A. Just before the punch contacts work



B. Punch begins to push into work, causing plastic deformation



C. Punch compresses and penetrates into work causing a smooth cut surface

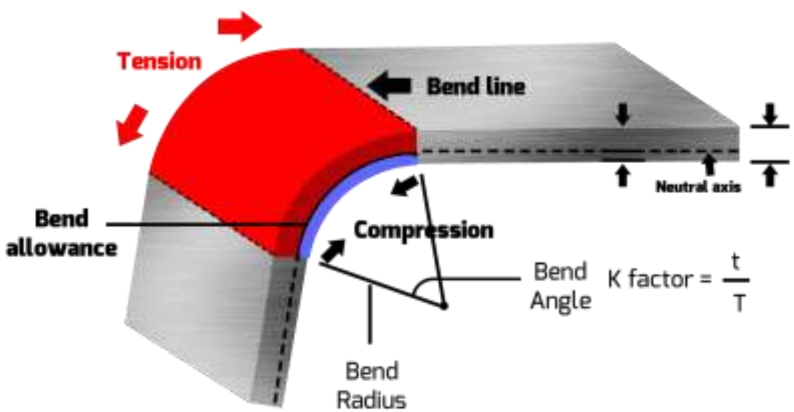


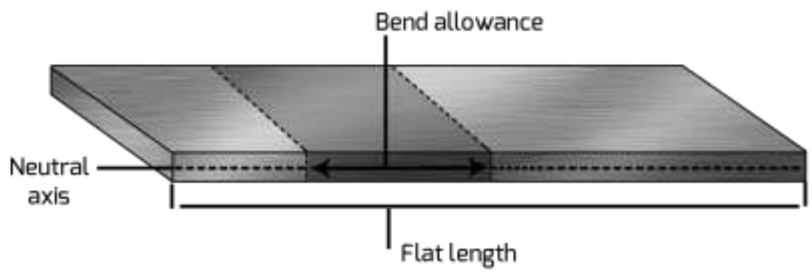
D. Fracture is initiated at the opposing cutting edges which separates the sheet

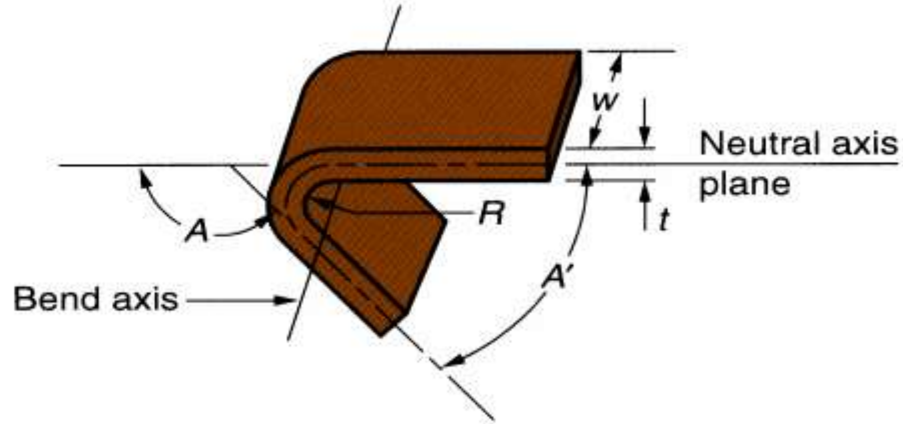
MANUFACTURING TECHNOLOGY

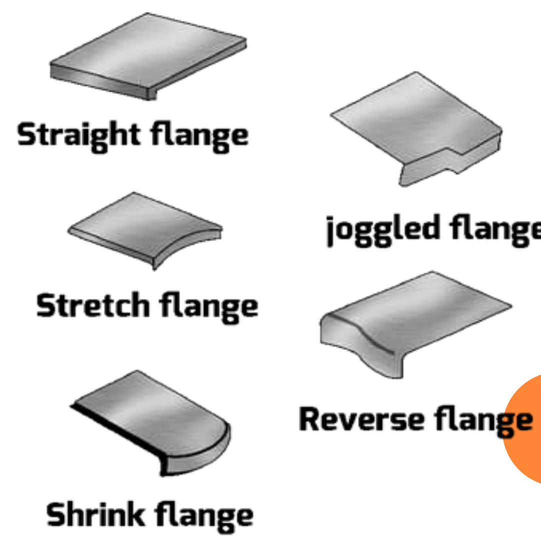
Bending

- **Straining sheet metal** around a **straight axis to take a permanent bend**





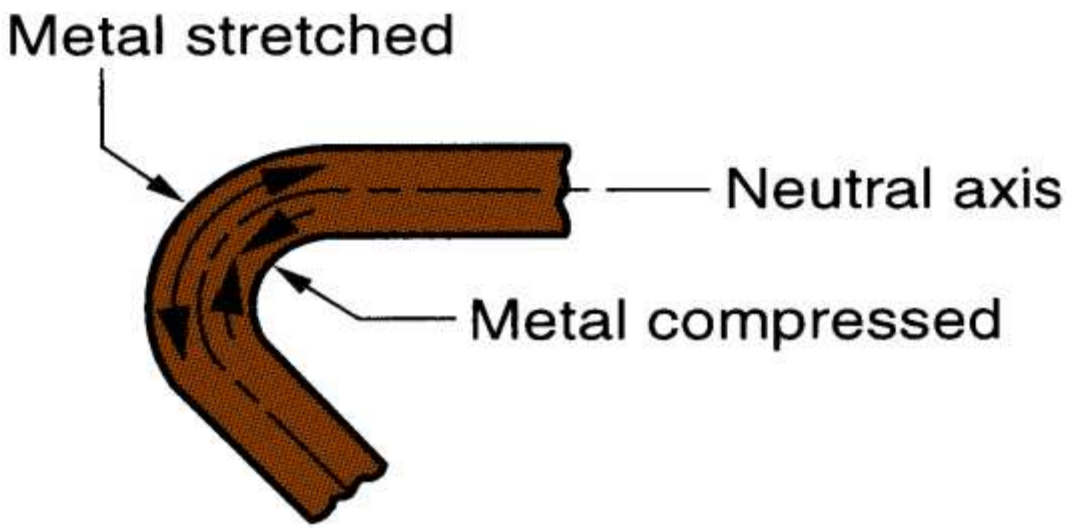


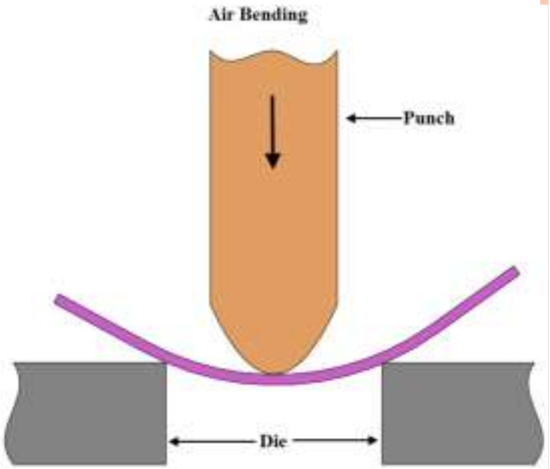


Bending of sheet metal

MANUFACTURING TECHNOLOGY

- **Metal on inside of neutral plane** is compressed, while metal on **outside of neutral plane is stretched**





Both compression and tensile elongation of the metal occur in bending

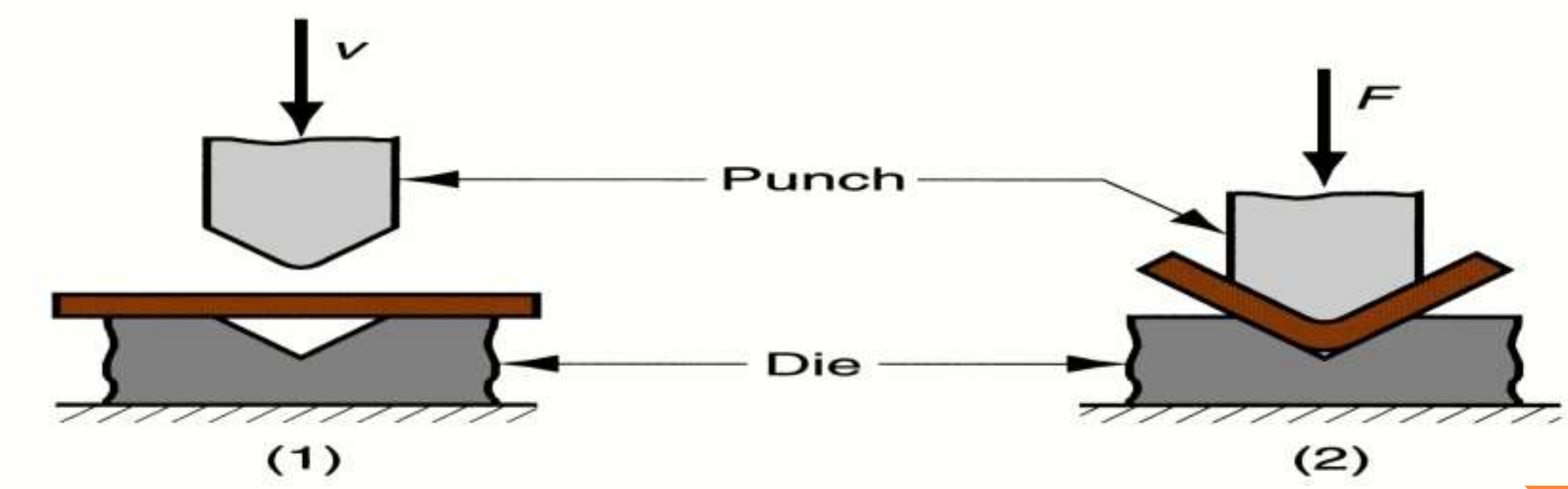
Manufacturing Technology

Types of Sheet metal Bending

- V-bending- performed with a **V - shaped die**
- Edge bending - performed with a **wiping Die**

V-Bending

- For low production
- Performed on a **press brake**
- V-dies are simple and **inexpensive**

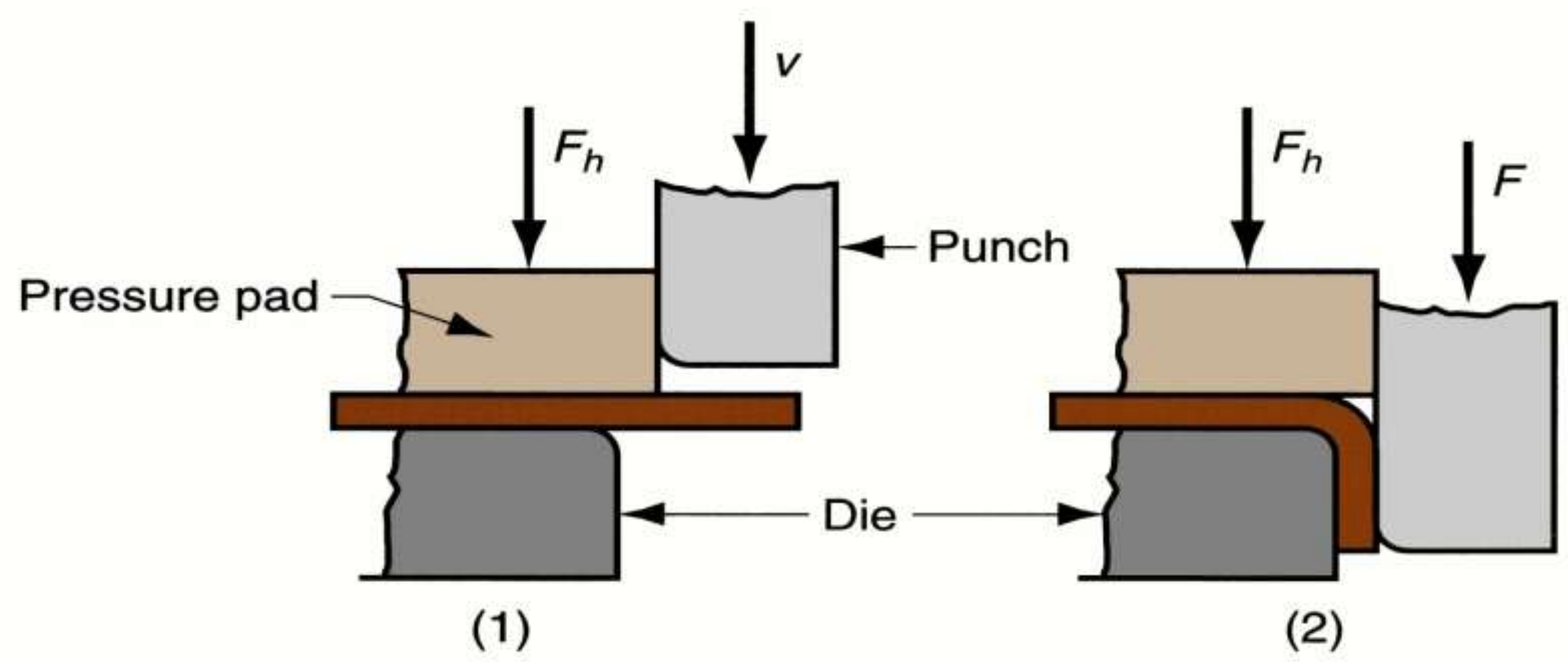


V-bending

Manufacturing Technology

Edge Bending

- For **high production**
- **Pressure pad** required
- **Dies are more complicated** and costly



Edge bending

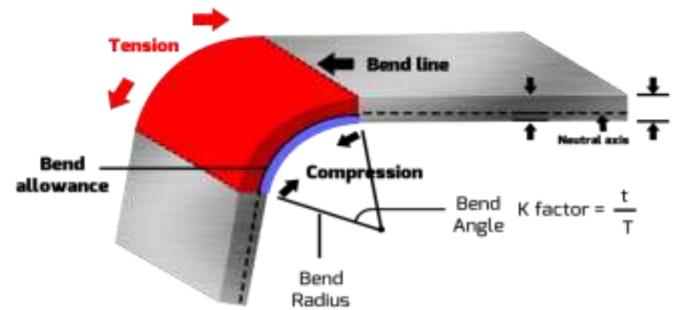
Manufacturing Technology

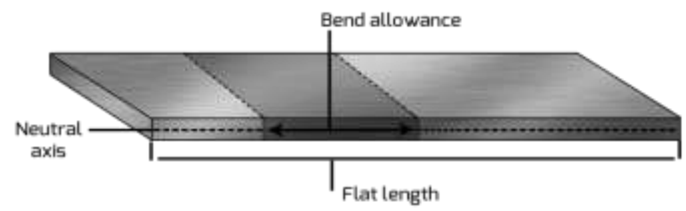
Stretching during Bending

- If **bend radius is small** relative to **stock thickness, metal tends to stretch** during bending, so that **estimation of amount of stretching** (final part length) is important.

Bending Allowance

$$BA = 2\pi \frac{A}{360}(R + K\,T)$$





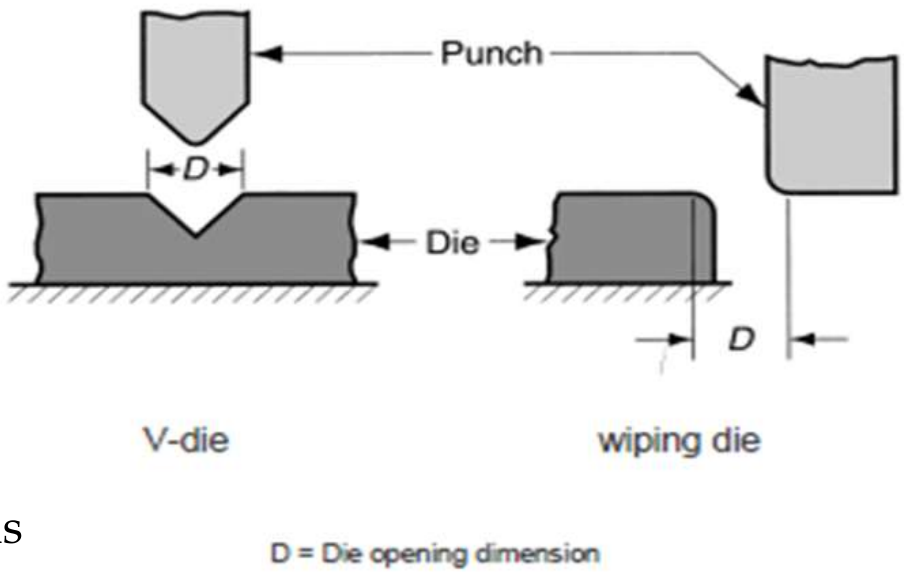
Where

- BA = Bend allowance;
- A = Bend angle;
- R= Bend radius;
- T = Stock thickness and **K is factor to estimate stretching**
- If $R < 2T$, $K = 0.33$
- If $R = 2T$, $K = 0.50$

Bending Force

Maximum bending force estimated as follows

$$F = \frac{K_{bf} T_S W T^2}{D}$$



Where

- F = Bending Force
- T_S = Tensile strength of sheet metal
- W= Part width in direction of bend axis
- D = Die opening dimension
- T = Stock thickness and K is factor estimates bend force
- For V-Bending- K_{bf} = 1.33
- For Edge-Bending - K_{bf} = 0.33 or 0.50

Bending Force Calculation

Example -1

- A sheet-metal part **3mm thick** and **20mm long is bent** to an included **angle of 60º and a bend radius of 7.5mm in a V-die**. The **die opening is 15mm**. The metal has tensile strength of **340 MPa**. Compute the **required force to bend** the part.

Solution

Bending force Required

$$F = \frac{K_{bf} T_S W T^2}{D}$$

$$F = \frac{1.33 \times 340 \times 10^6 \times 0.02 \times 0.003^2}{0.015} = 5426.4 \text{ N}$$

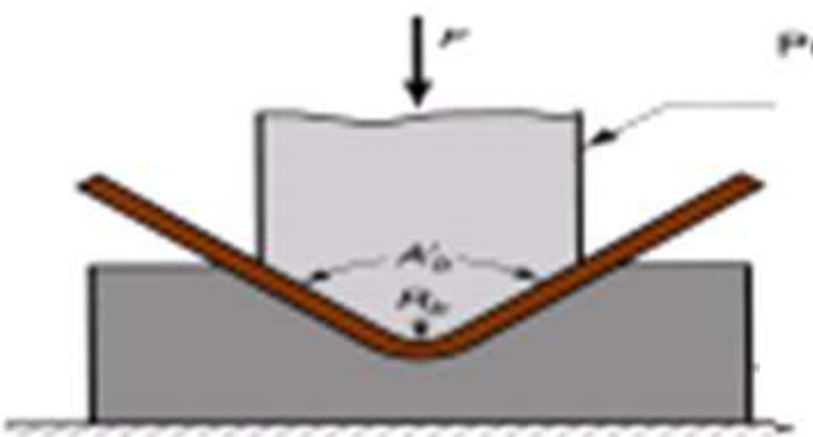
The bending force required to bend the part is 5426.4 N

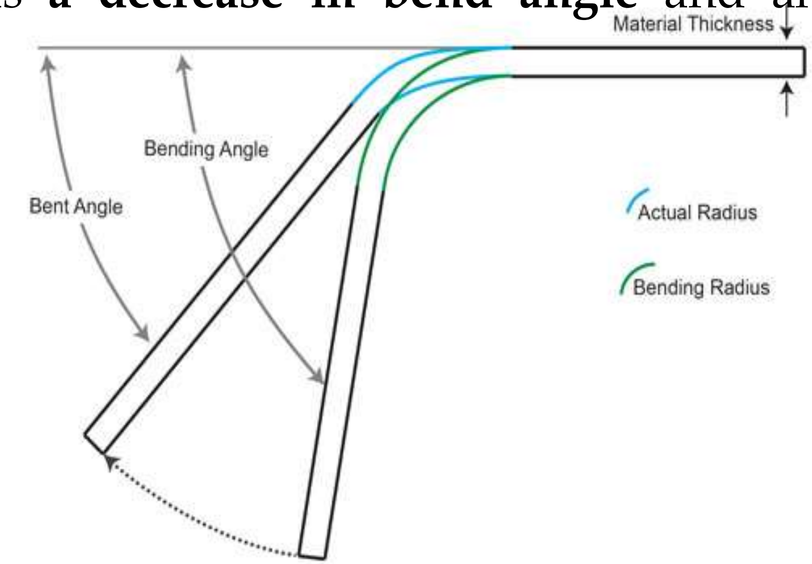
Spring back in Bending

- **Springback is the geometric change** in the part at the end of the forming process, **under the removal of forces**.
- **Spring back = increase in included angle of bent part** relative to **included angle of forming tool** after tool is removed

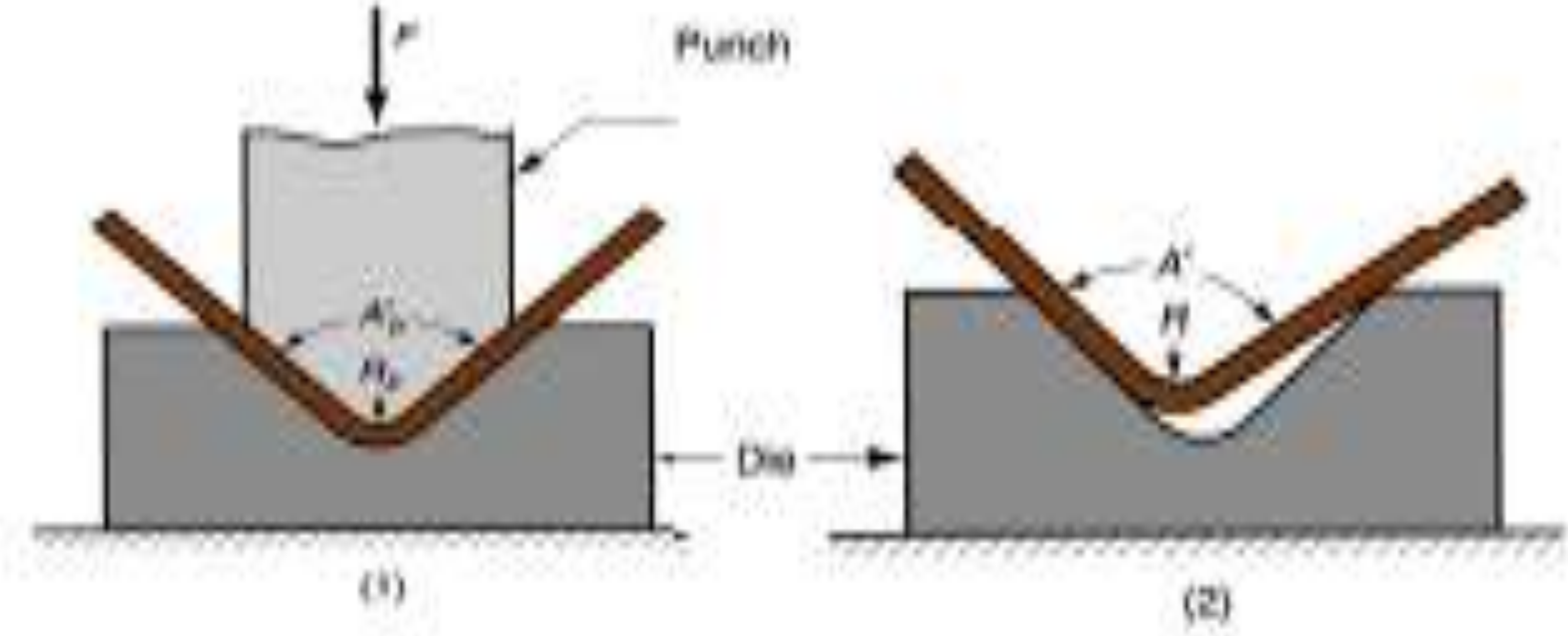
Reason for spring back

- When **bending pressure is removed**, elastic energy remains in bent part, causing it to **recover partially toward** its original shape
- Spring back in bending shows itself as **a decrease in bend angle** and an **increase in bend radius**





Spring back

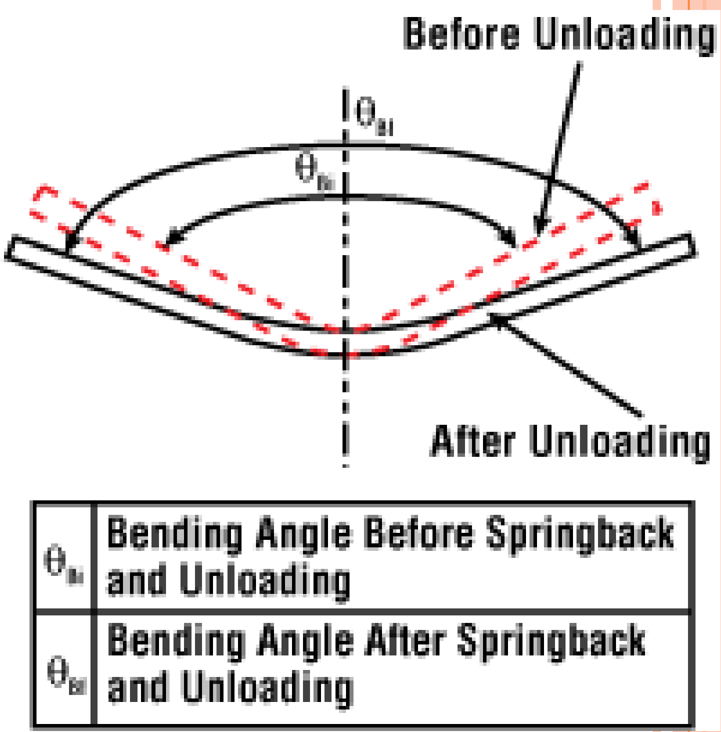


1. During bending the work is forced to take the radius R_b and include angle A_b of the bending tool (punch in v-bending)
2. After **punch is removed** the work springs back to radius R and angle A

Spring back

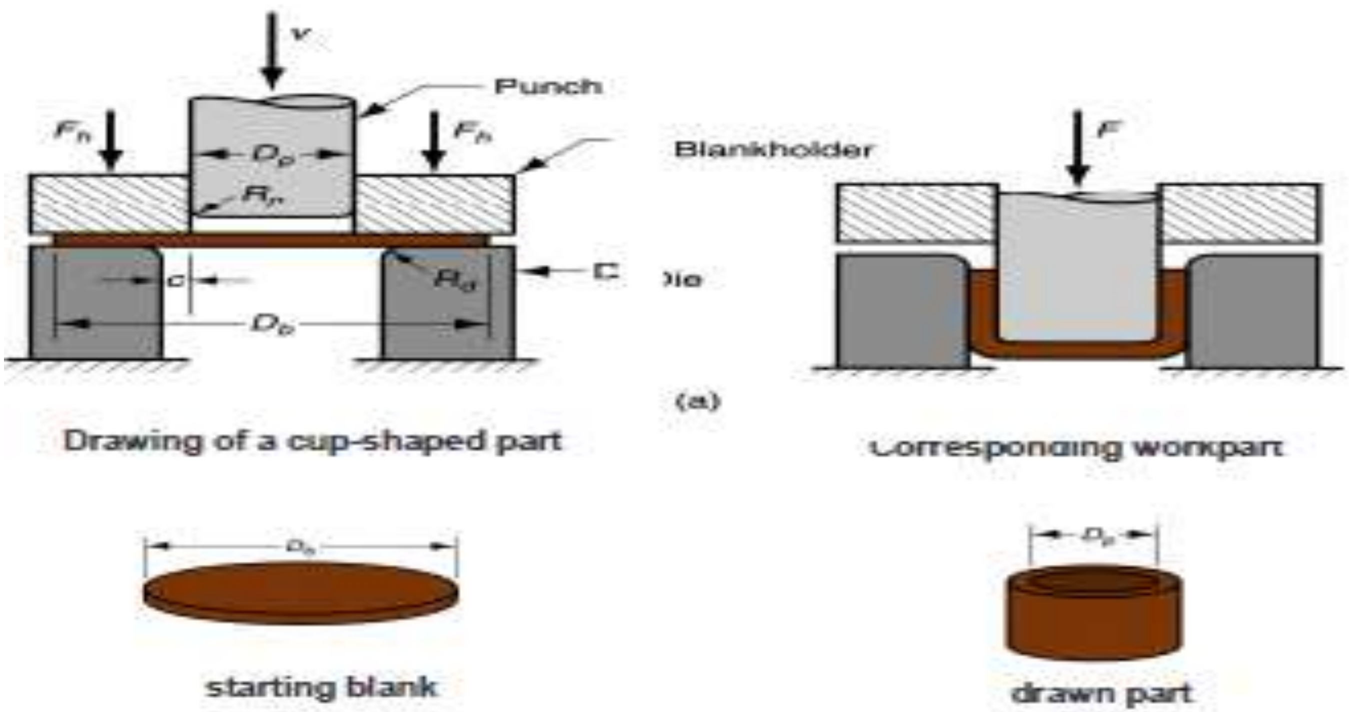
- When a plate is bent, using a bending tool, the **plate initially assumes the angle of the tool θ′.** As the plate is removed from the tool, it **springs back to an angle θ'_b less than the tool angle** .
- The spring back, S_b defined as follows

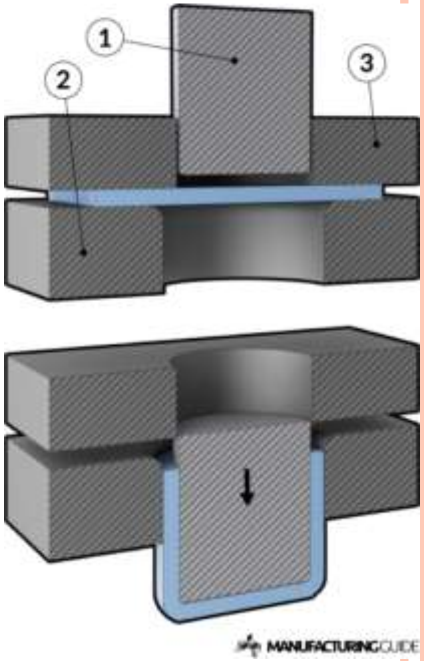
$$S_b = \frac{(\theta' - \theta'_b)}{\theta'_b}$$



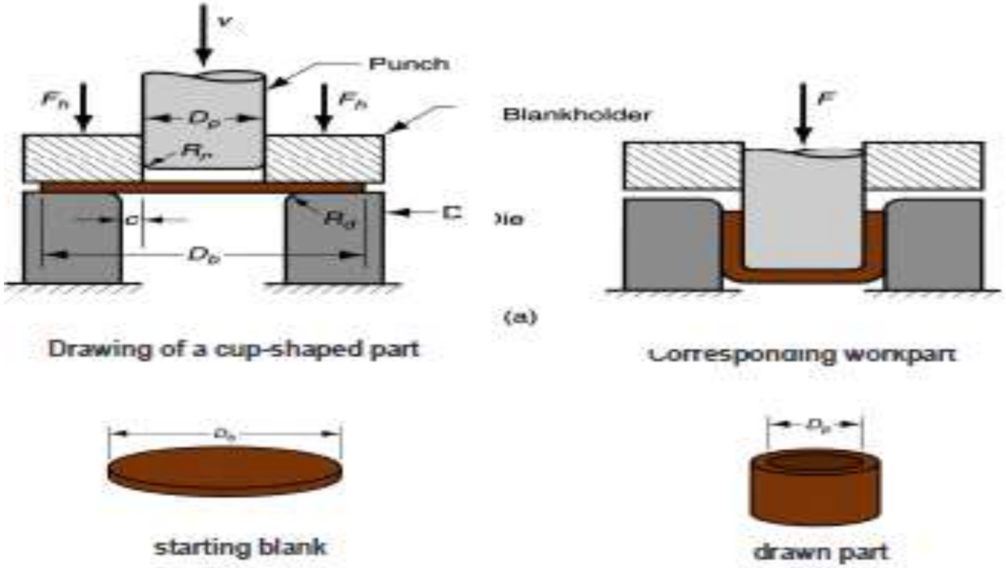
MANUFACTURING TECHNOLOGY

- **Drawing**
  - Forming of sheet into **convex or concave shapes**
  - **Sheet metal blank is positioned** over die cavity and than punch pushed **metal in to opening**
  - Products – **Beverage cans, automobile body parts and ammunition shells**





- Drawing Clearance
  - In drawing sides of punch and die separated by a clearance c is given by
    - C = 1.1 T
    - Where T – Stock thickness
- Drawing Ratio
  - The ratio between diameter of blank (D_b) to diameter of Punch (D_b)
  - $$DR = \frac{Db}{Dp} \leq 2$$
- Drawing Reduction Ratio
  - $$R = \frac{D_b - D_p}{D_p} \leq 0.5$$



- Drawing Thickness to Diameter Ratio

  - $D_{T/D} = T / D_b \geq 1\%$

- Drawing Force
  - The force required for the drawing operation, F_d is given as
  - $$D_F = \pi D_P T_S T (D_R - 0.7)$$
  - Where

    D_R = Drawing Ratio
    T_S = Tensile strength of sheet metal
    Dp = Diameter of punch
    T = Stock thickness

Holding force of the Blank

$$F_h = 0.015 S_y \pi [D_p^2 - (D_p + 2.2t + 2r_p)^2]$$

Where

S_y is the Yield Tensile strength of the blank
r_p - Punch Radius or Die radius

Manufacturing Technology

Example-2

- A cup drawing operation is performed in which the inside diameter is 80mm and the height is 50mm. The stock thickness is 3mm, and the starting diameter is 150mm. Punch and die radii = 4mm. The tensile strength of the material is 400Mpa and the yield strength is 180Mpa. Determine:
  - (i) Drawing ratio
  - (ii) Reduction
  - (iii) Drawing force
  - (iv) Blank holder force

Manufacturing Technology

Solution

(i) $DR = D_b / D_p = 150/80 = 1.875$

(ii) $R = \dfrac{D_b - D_p}{D_b} = 1 - \dfrac{1}{DR} = 1 - \dfrac{1}{1.875} = 0.4667$

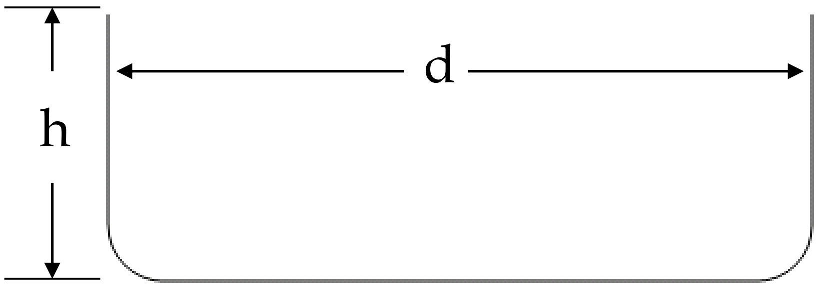
(iii) $D_f = \pi D_p T_S T(DR - 0.7) = \pi 0.08 * 0.003 * 400x10^6 (1.875 - 0.7) = 354{,}371.6N$

(iv) $F_h = 0.015 S_y \pi [D_p{}^2 - (D_p + 2.2t + 2r_p)^2]$

$F_h = 0.015 * 189x10^6 * \pi[0.15^2 - (0.08 + 2.2 * 0.003 + 2 * 0.004)^2] = 114{,}942.29N$

Blank Size Calculation

- For **final dimensions of drawn shape** to be correct, **starting blank diameter Db must be correct**.
- Solve Db by setting **starting sheet metal blank volume = final product volume**
- To facilitate calculation, **assume negligible thinning of part wall** with diameter (d) and height (h)

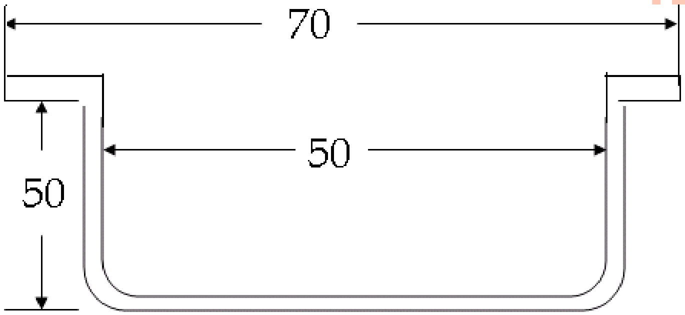


Manufacturing Technology

The Size or Diameter of the blank is given by

- Blank volume = Final product volume
- $\pi D^2/4 = \pi d_1^2/4 + \pi d_2 h$
- $D^2 = d_1^2 + 4d_2h$
- The Size or Diameter of the blank is

$$D = \sqrt{d_1^2 + 4d_2h}$$



$$D = \sqrt{70^2 + 4 \times 50 \times 50}$$

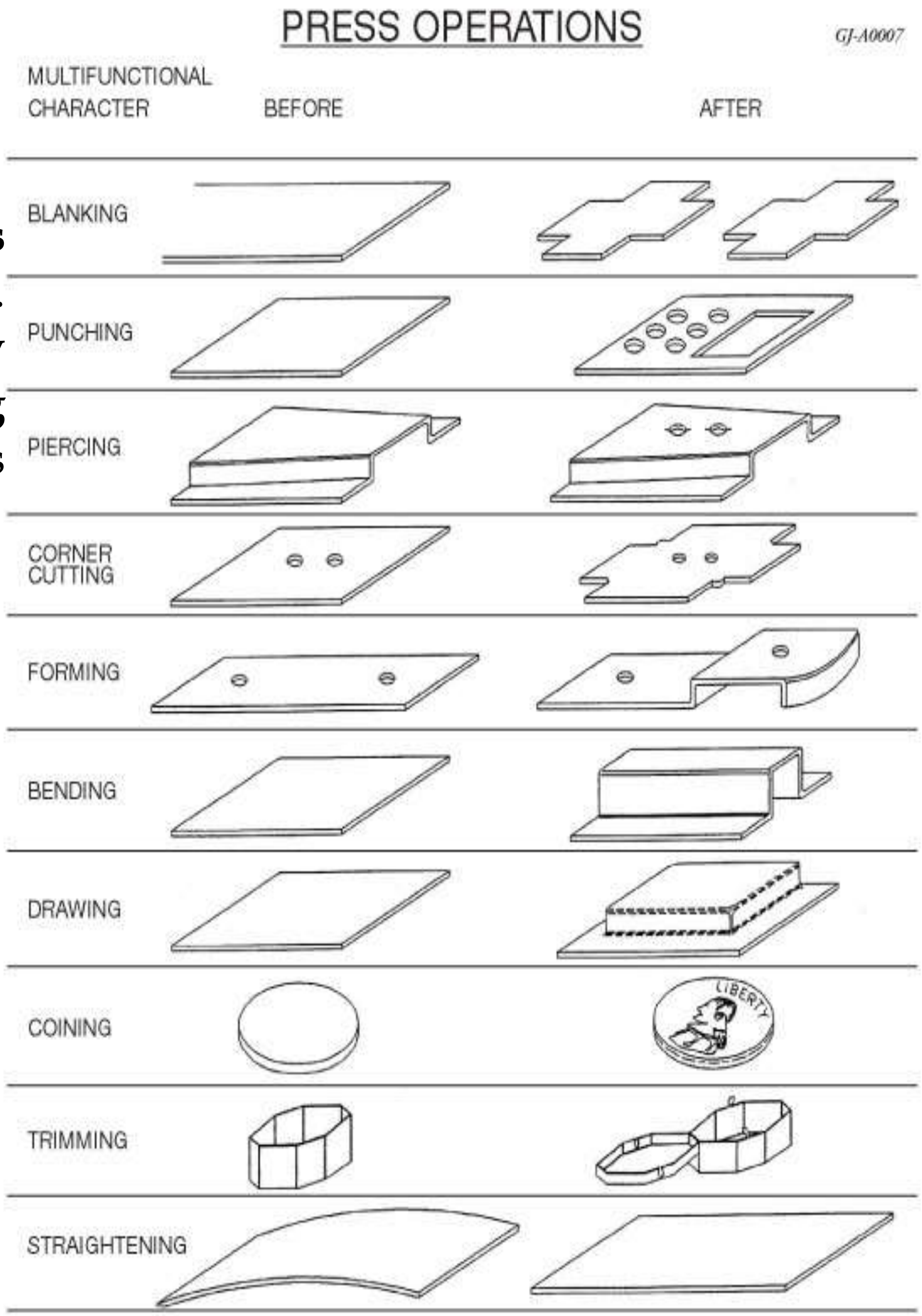
Example-3

Calculate the blank size of the given shell as shown in fig

Blank size D = 122mm

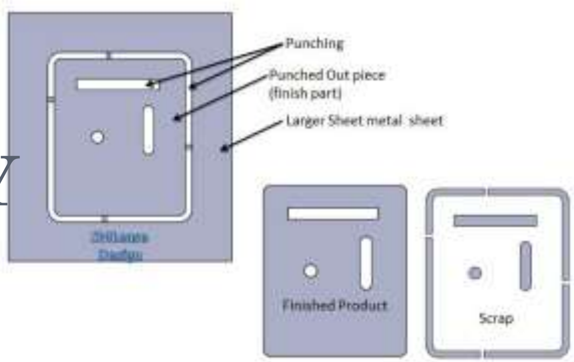
Sheet metal Process in detail

- Cutting (Shearing) Operations
- In this operation, the **work piece 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
  - Trimming
  - Notching
  - Perforating
  - Slitting
  - Lancing
  - Parting
  - Shaving
  - Fine blanking

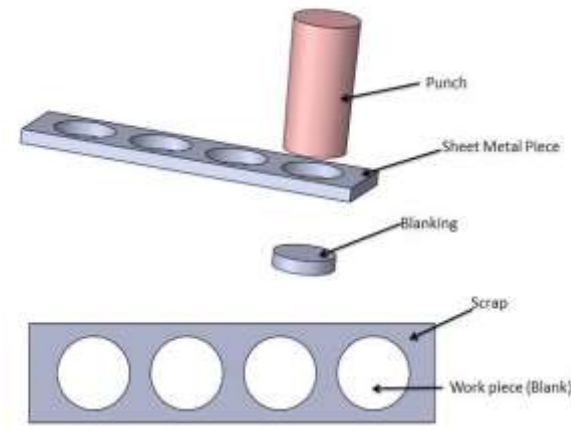


Shearing Operations

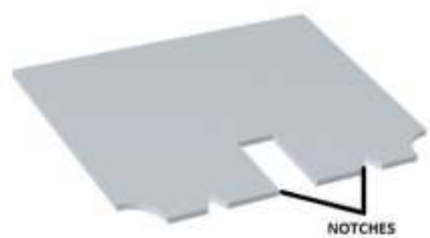
- **Punching (Piercing)** It is a **cutting operation** by which **various shaped holes** are made in sheet metal. **Punching** is similar to **blanking except** that in punching, the **hole is the desired product**, the **material punched out** to form the hole **being waste**.



- **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.



NOTCHING OPERATION

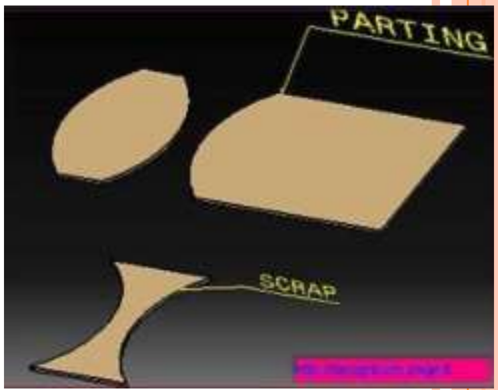
Manufacturing Technology

- **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 work piece.

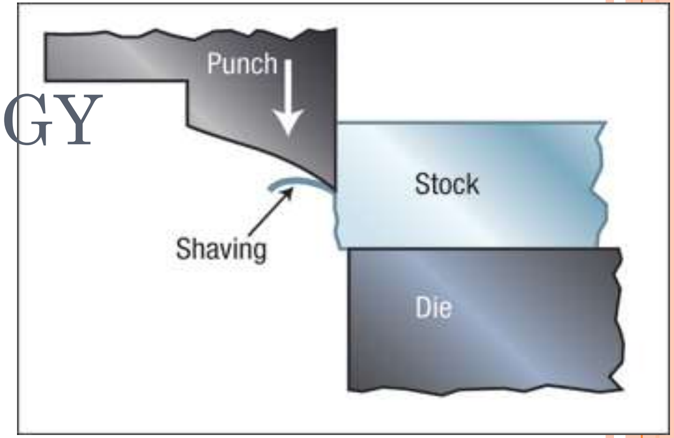
- **Lancing**: This is a **cutting operation** in which a hole is **partially cut** and then one side is **bent down to form a sort of tab**. Since **no metal is actually removed**, there will be no scrap. (Tab, Vent)

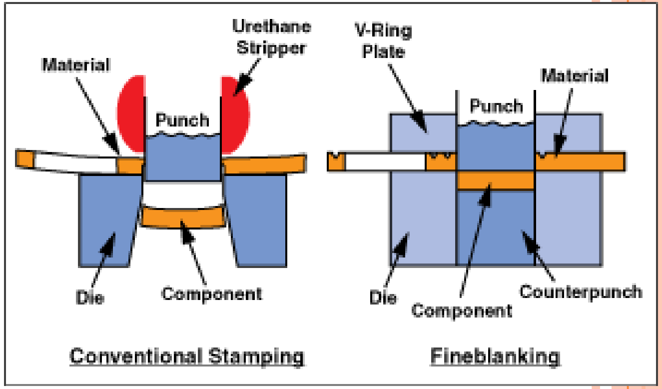
- **Parting**: Parting involves cutting a sheet metal strip by a **punch with two cutting edges** that match the opposite sides of the blank.



Manufacturing Technology

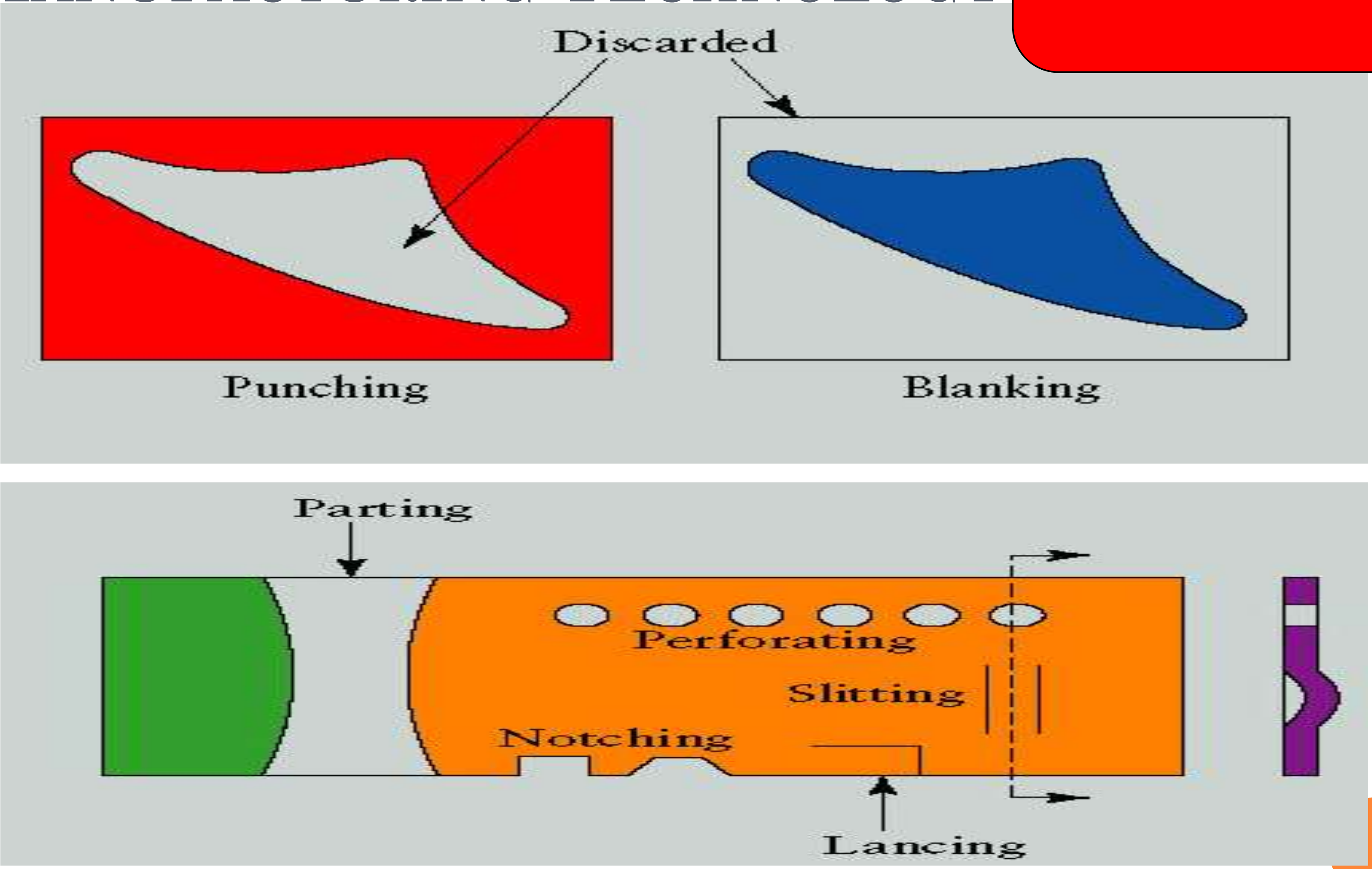
- **Shaving**: The **edge of blanked parts** is generally **rough, uneven and un-square**. Accurate dimensions of the part are obtained by **removing a thin strip of metal along the edges**.
- **Fine blanking**: Fine blanking is a operation used to **blank sheet metal parts** with **close tolerances** and smooth, straight edges in one step.
- **Trimming**: This operation consists of **cutting unwanted excess material** from the **periphery** of previously formed components.



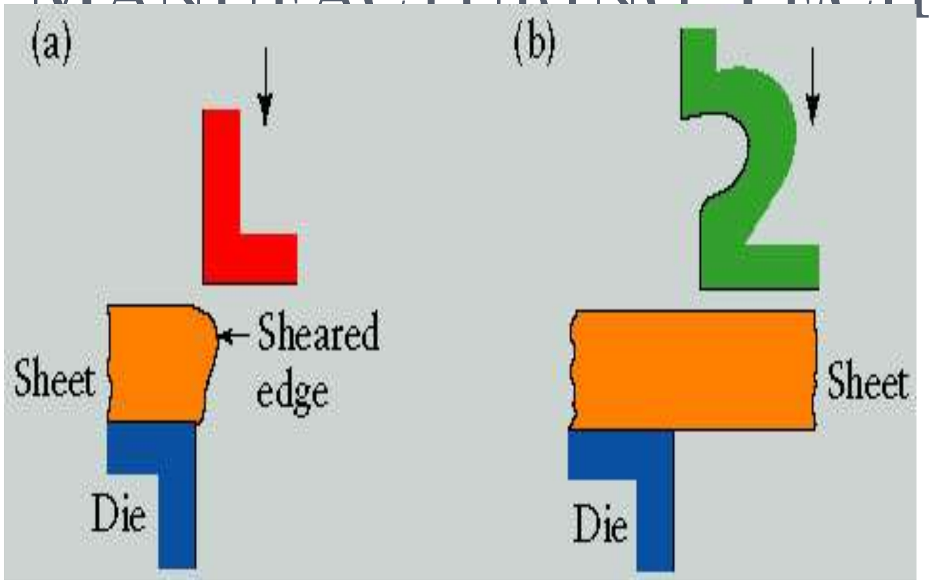


Shearing Operations

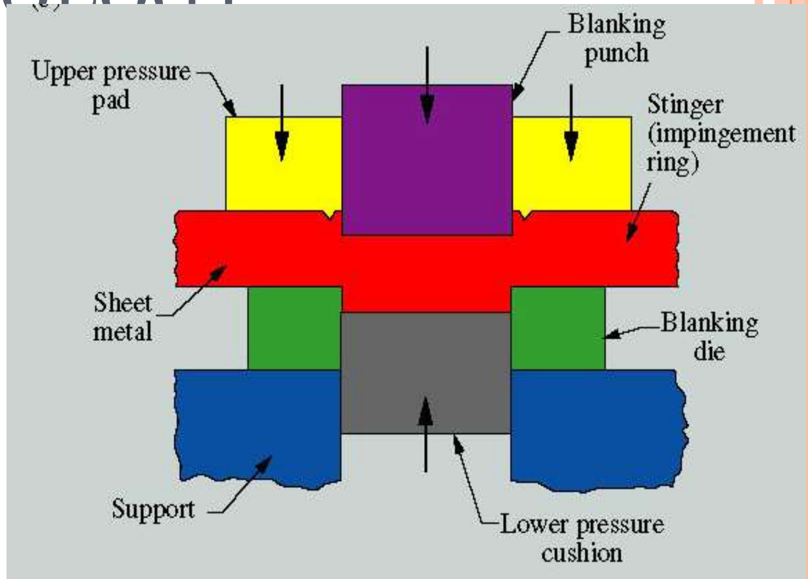
MANUFACTURING TECHNOLOGY



Shearing Operations



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



Fine blanking

Shaving

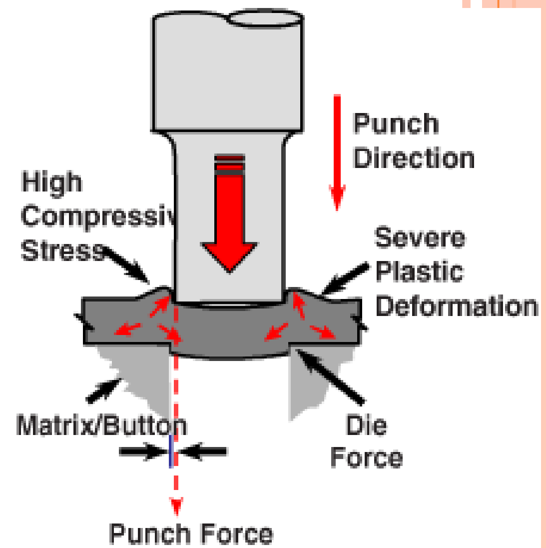
Trimming

Shearing Dies

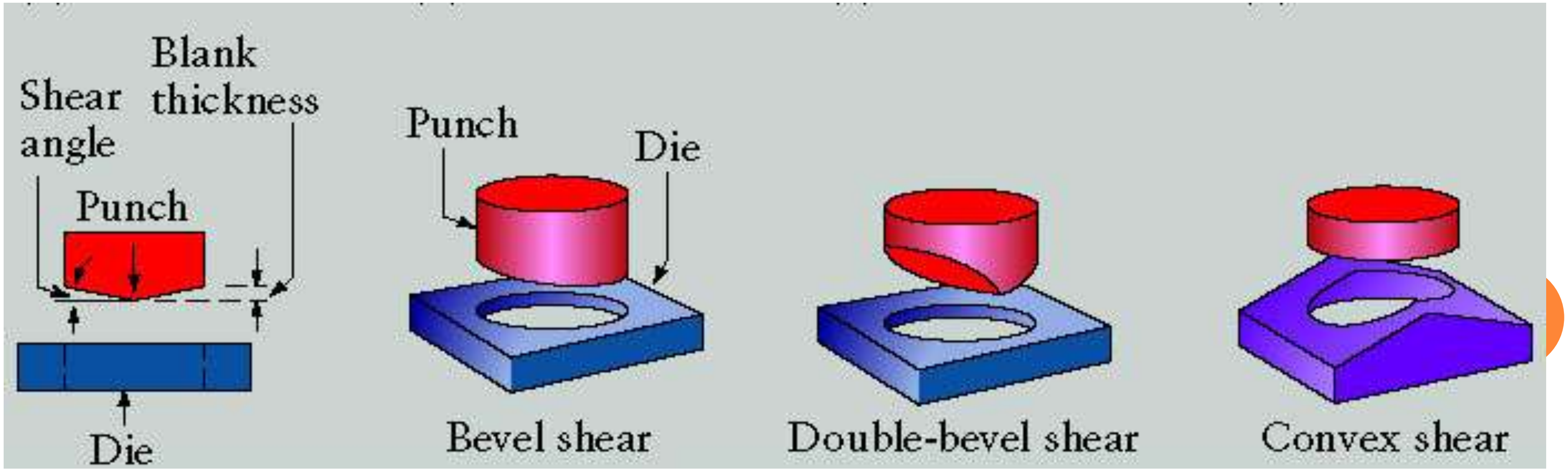
- Because the **formability of a sheared part** can be influenced by the **quality of its sheared edges**, clearance control is important.
- In practice, clearances usually **range between 2% and 8%** of the sheet's thickness; generally, the thicker the sheet, **the larger is the clearance (as much as 10%).** However, the smaller the clearance, the better is the quality of the edge.

PUNCH AND DIE SHAPES

- As the surfaces of the punch and die are flat, **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 Figure. This geometry is particularly suitable for **shearing thick blanks**, because it **reduces the total shearing force**.

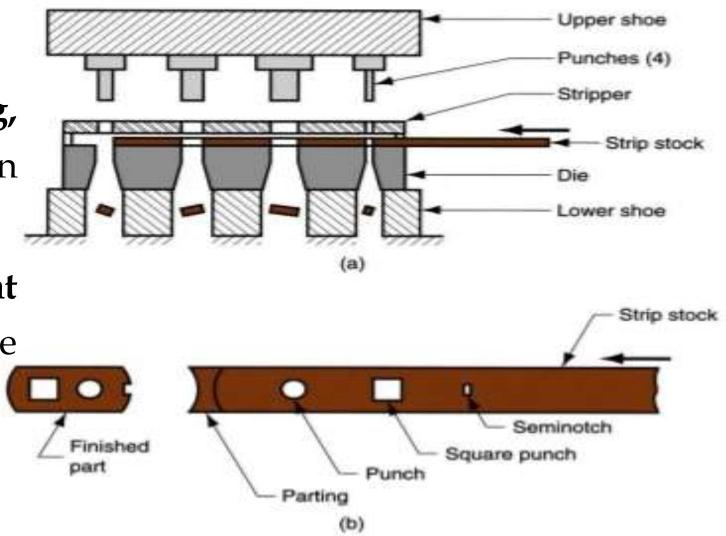


Examples of the use of shear angles on punches and dies

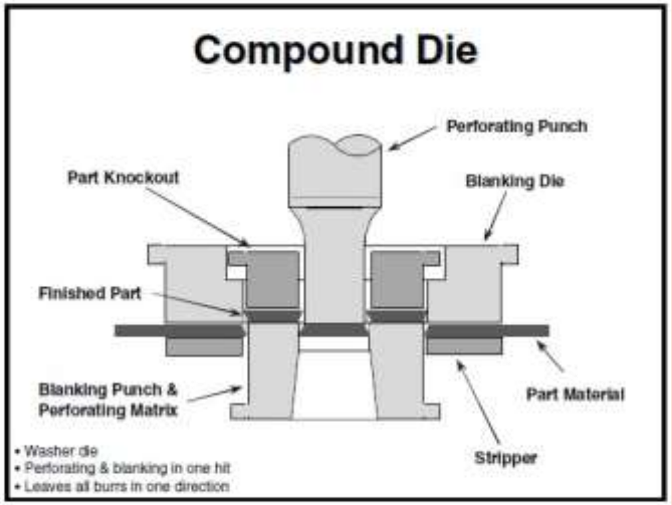


Types of Shearing Dies

- **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.

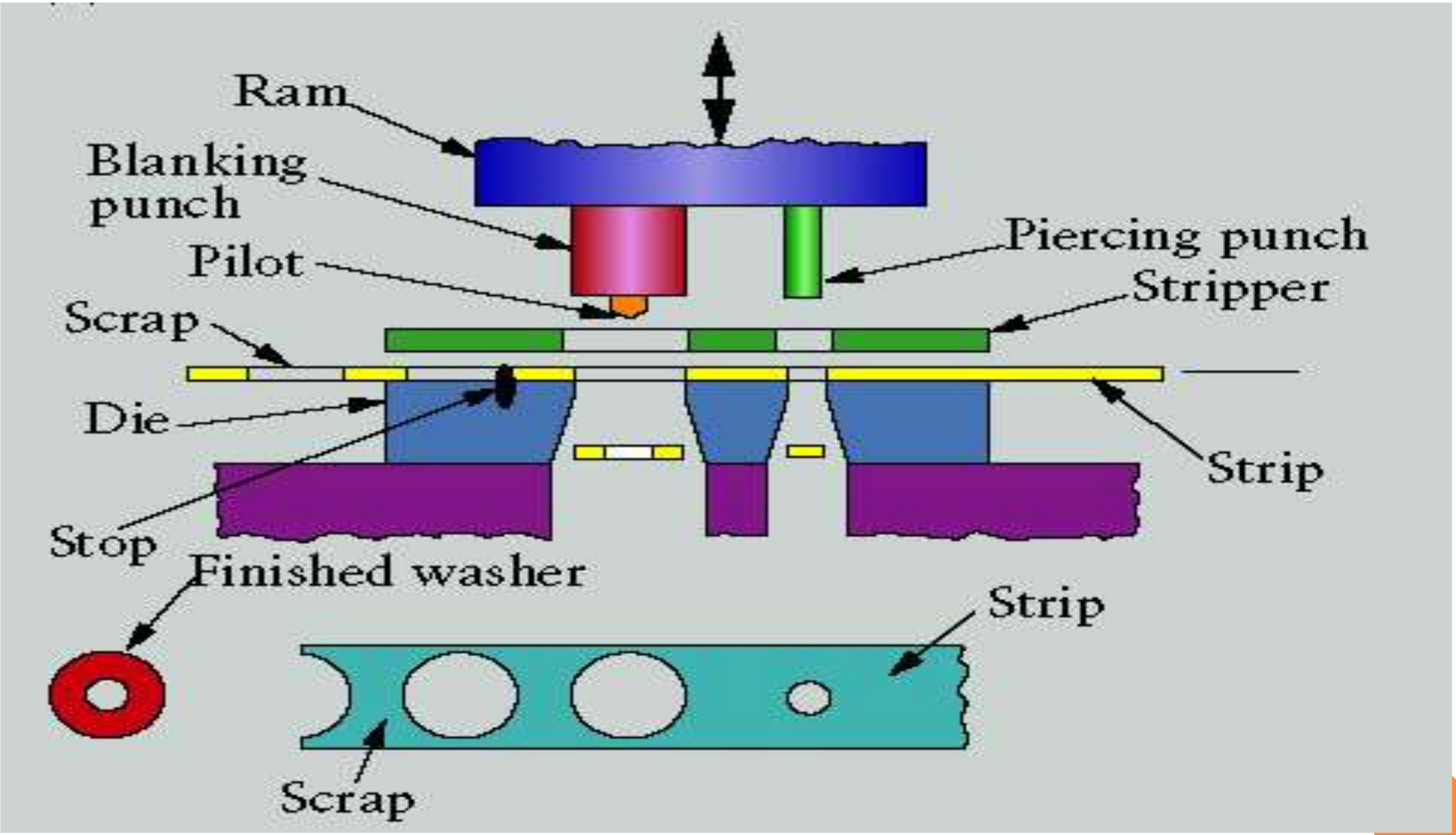


- **Compound Dies:**
  - **Several operations on the same strip may be performed in one stroke** with a compound die in one station.
  - These operations are usually limited to **relatively simple shearing** because they are **slow and the dies are more expensive** than those for individual shearing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



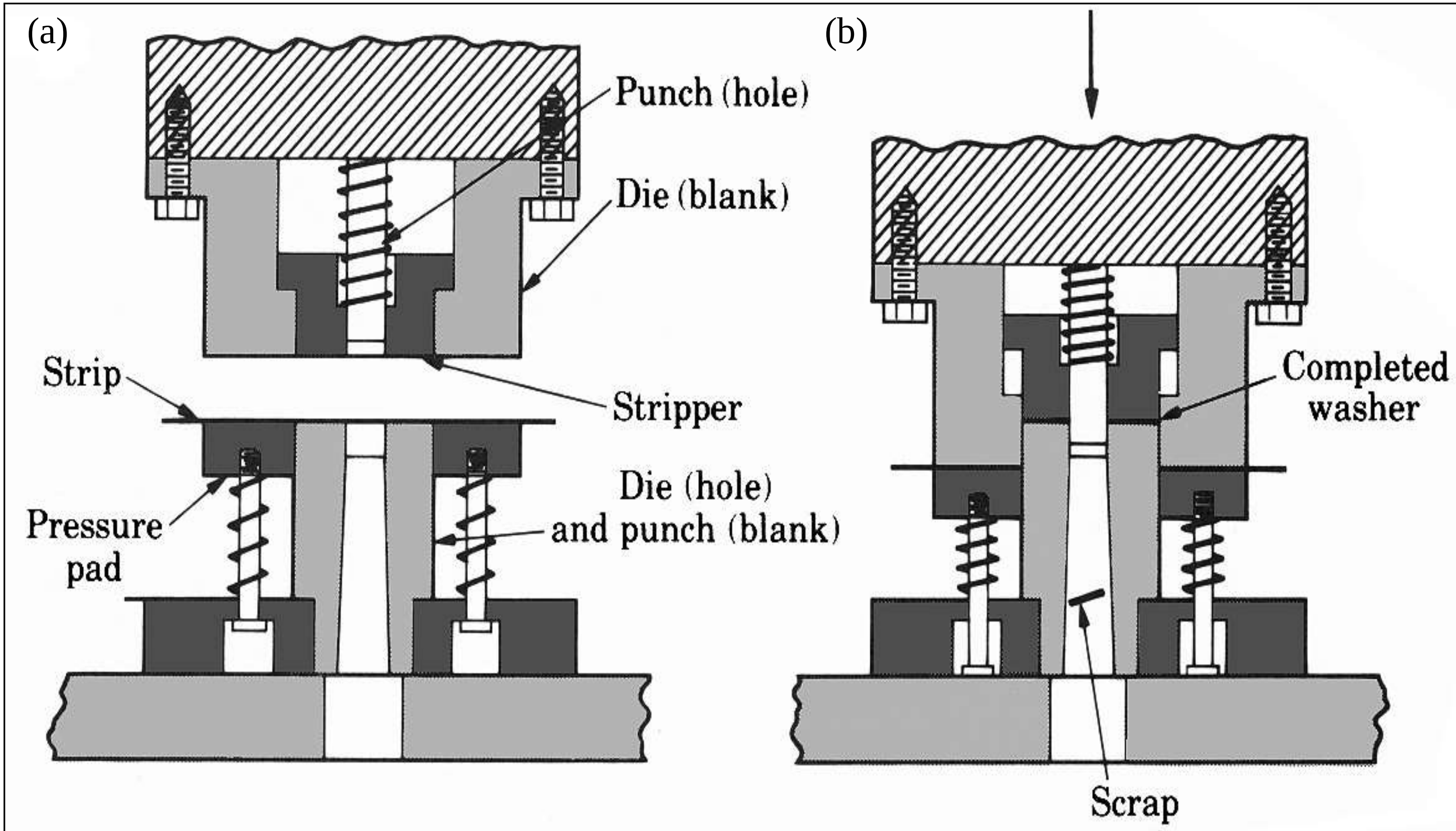
- **Transfer Dies (Combination Dies):**
  - The sheet metal undergoes **different operations at different stations**, which are arranged along a **straight line or a circular path**.
  - After each operation, the **part is transfer to the next operation** for additional operations.

- **Progressive Die**



(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.

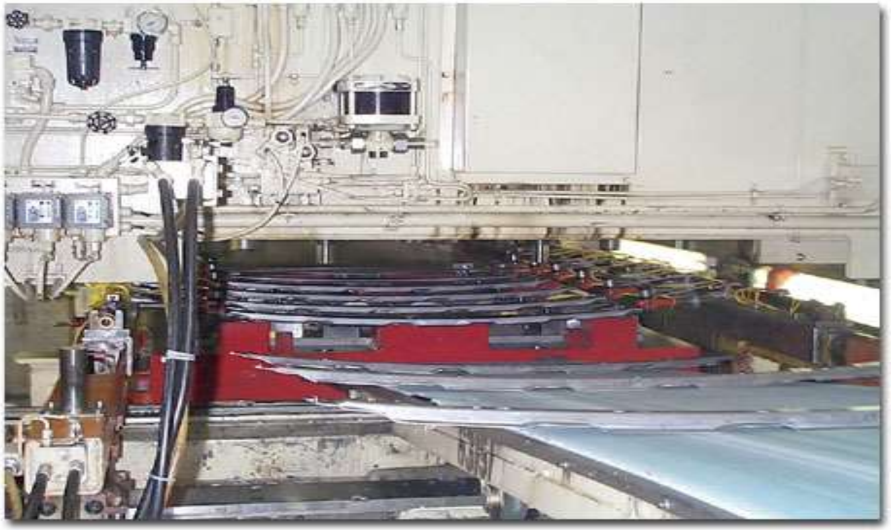
- **Compound Die**



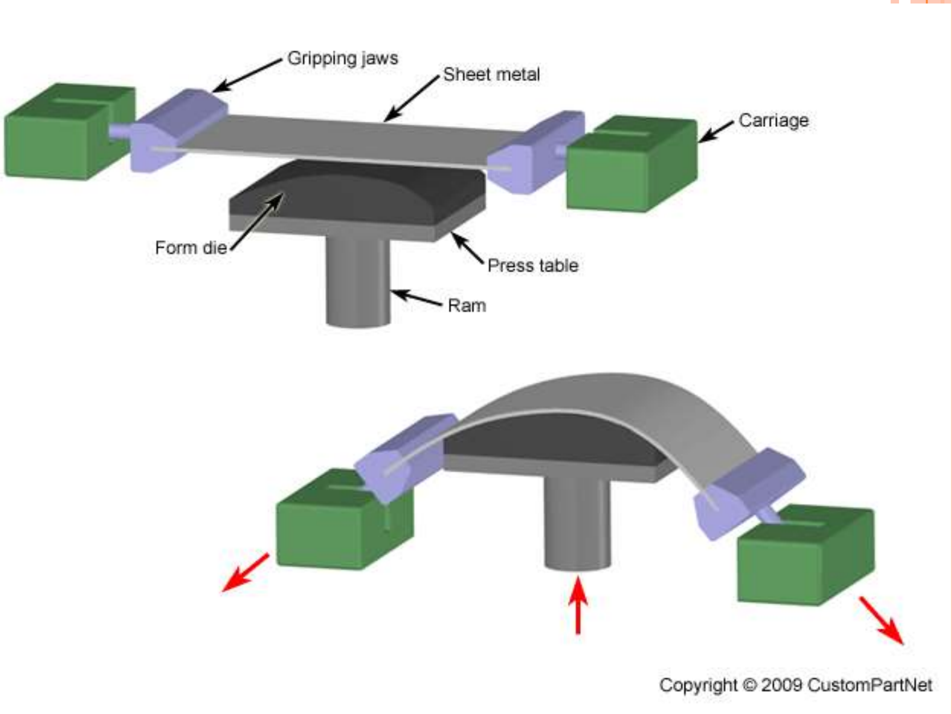
Schematic illustrations: (a) before and (b) after blanking a common washer in a compound die.
Note the separate movements of the die (for blanking) and the punch (for punching the hole in the washer).

MANUFACT

- **Transfer Dies**



FORMING OPERATIONS

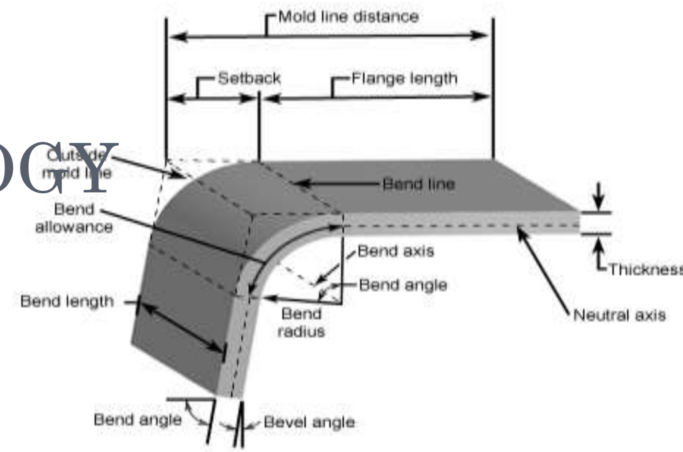


Manufacturing Technology

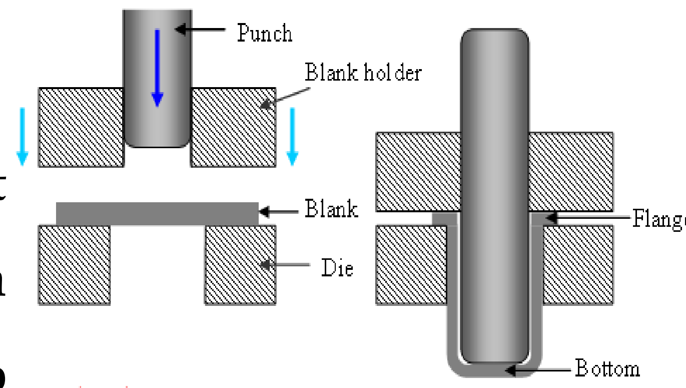
Forming Operations

- 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 work piece is changed** to get the desired product. The forming operations include
  - **Bending**
  - **Drawing**
  - **Squeezing**

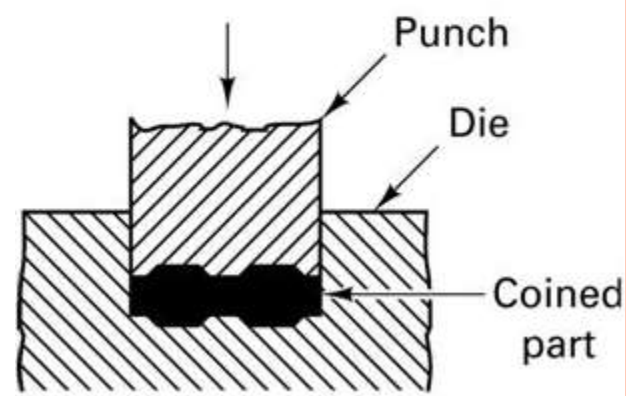
- **Bending**: In this operation, the material in the **form of flat sheet or strip,** is **uniformly strained around a linear axis** which lies in the neutral plane and **perpendicular to the lengthwise direction** of the sheet or metal



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



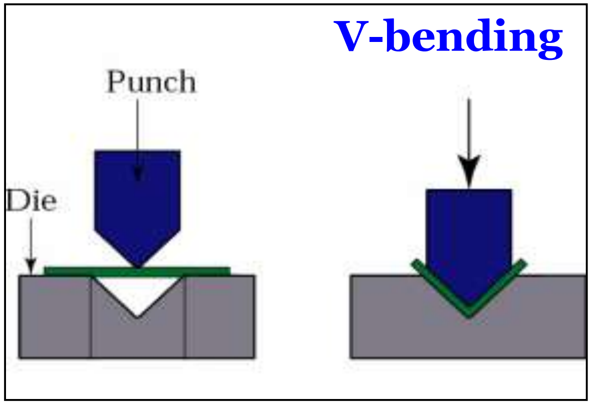
- **Squeezing**: Under this operation, the metal is caused to **flow to all portions of a die cavity** under the action of **compressive forces**.

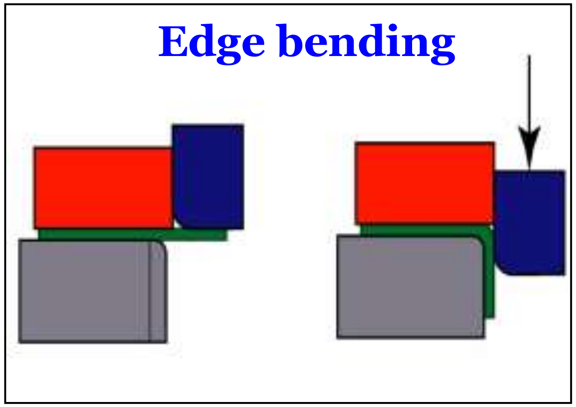


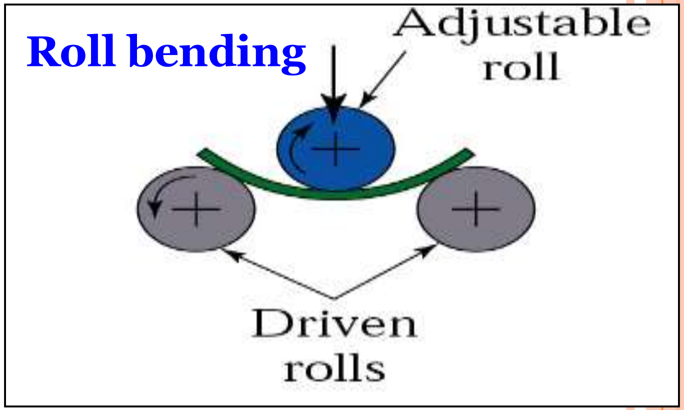
Types of Bending operations

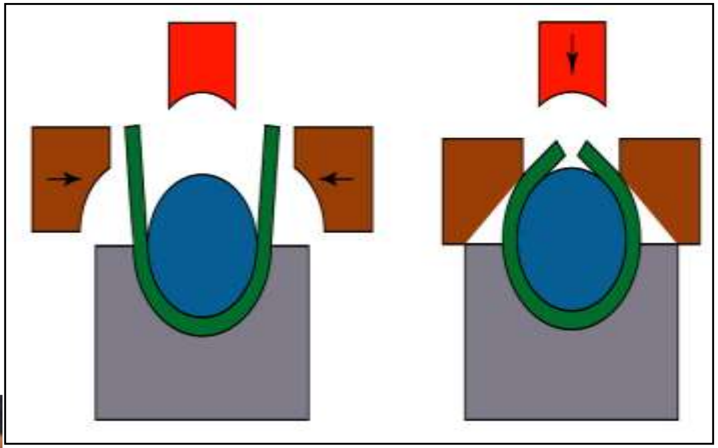
- V-bending
- Edge bending
- Roll bending
- Air bending
- Flanging
- Dimpling
- Tube forming
- Stretch forming
- Press break forming
- Beading
- Roll forming
- Bulging

Bending operations

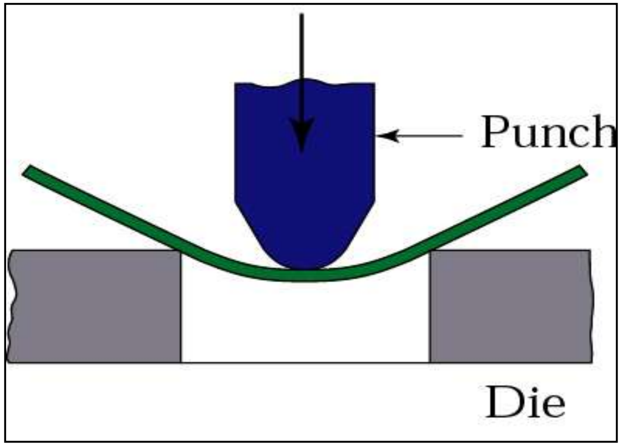








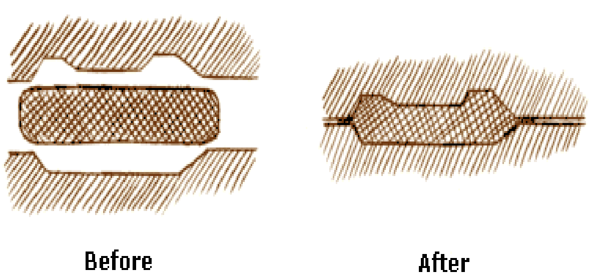
Bending in 4-slide machine



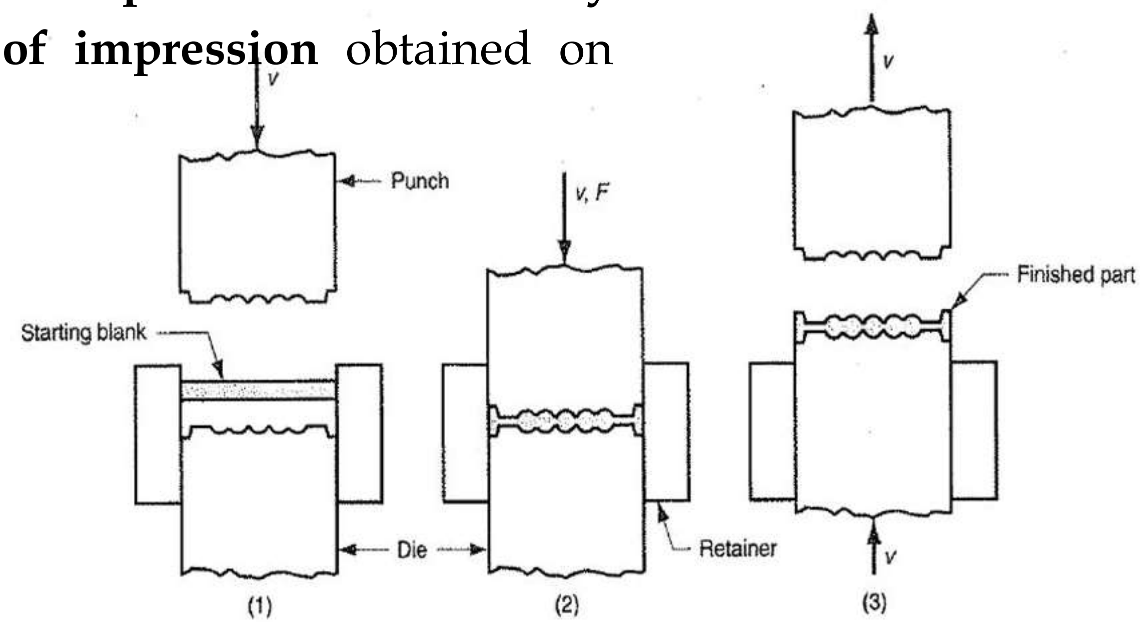
Air bending

Coining

- It is a **cold working** sizing operation. It is used for the **production of metals and coins**. The coining processes **consists of die and punch**. By using the punch and die, the **impression and images are created** on the metal.
- The **pressure** involved in **coining process is about 1600Mpa**. The **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. The **type of impression** obtained on **both sides will be different**.

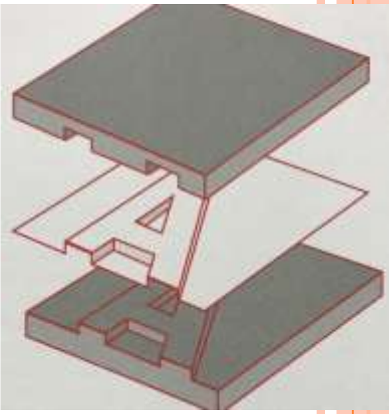


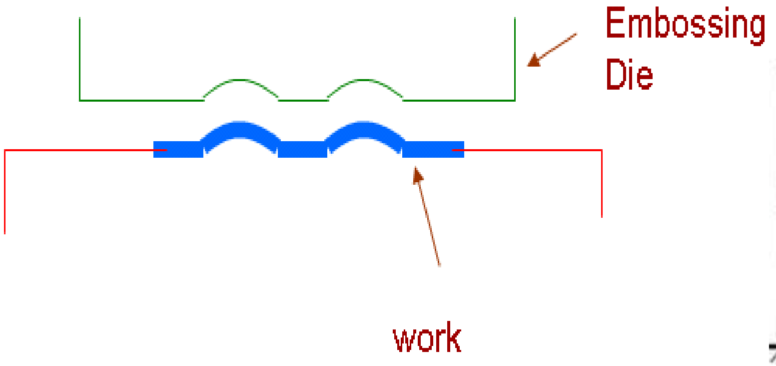
COINING

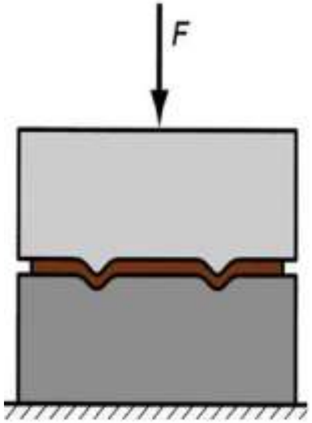


Embossing

- This is the process of **making raised or projected design on the surface** of the metal with its **corresponding relief on the other side**.
- This operation **includes drawing and bending**.
- It **uses a die set** which consists of **die and punch with desired shape**.
- This operation requires **less force compared with coining process**. It is very useful for **producing nameplates tags** and designs on the metal.

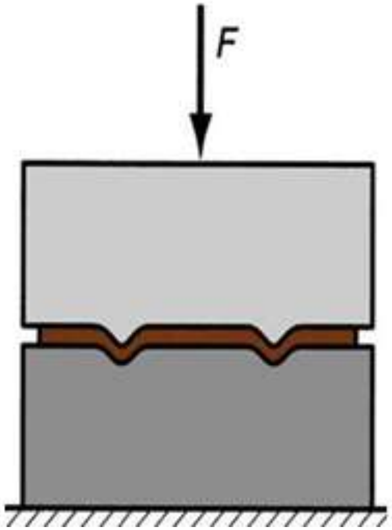


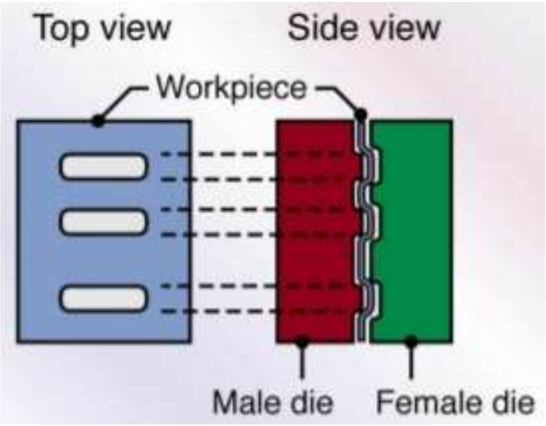




Difference between Coining and Embossing

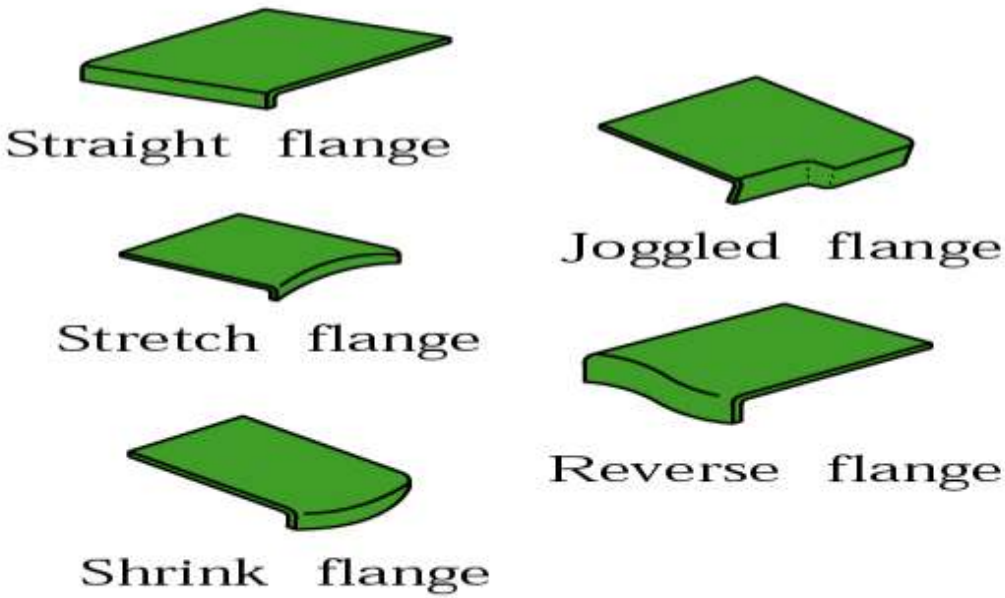
- The same design is created on both sides of work piece in **Embossing (One side depressed and the other side raised**).

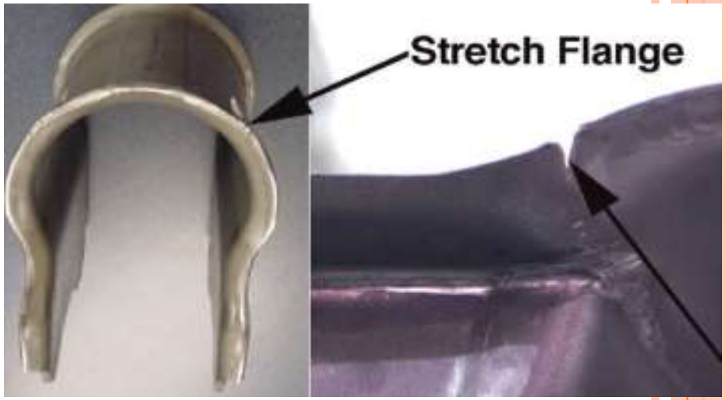




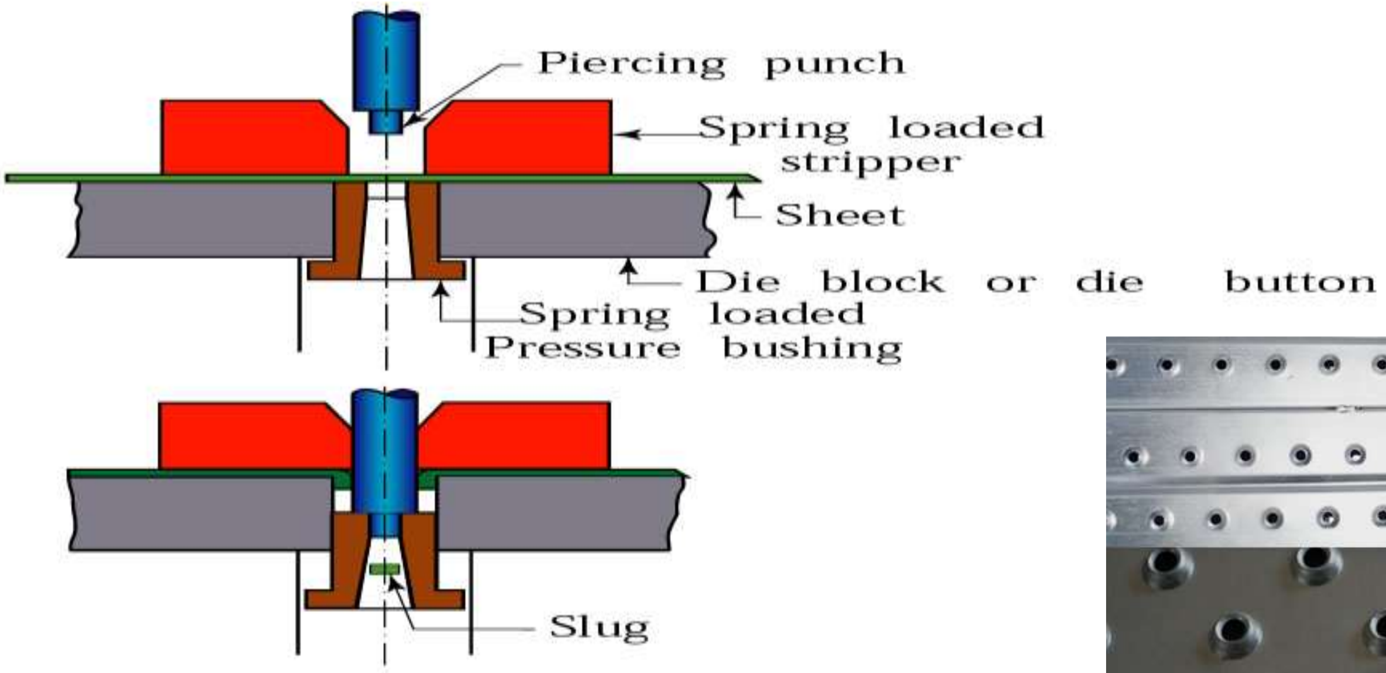
- While in **Coining operation**, a **different design is created** on **each side of work piece**.
- Force required for **coining process is more** than embossing process.
- Production of important articles such as **medals, coins, tokens** etc.

- **Flanging**
  - Flanging is a process of **bending the edges of sheet metals to 90º**
    - **Shrink flanging** – subjected to **compressive hoop stress**.
    - **Stretch flanging** –subjected to **tensile stresses**



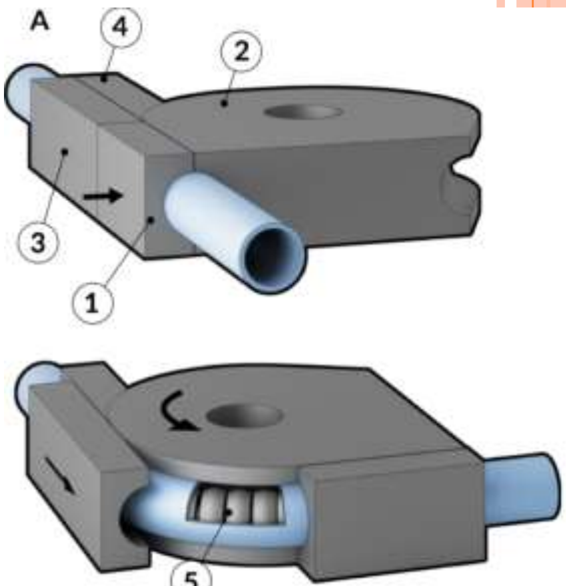


- **Dimpling**:
  - First hole is **punched and expanded** into a flange
  - Flanges can be produced by **piercing with shaped punch**
  - When **bend angle < 90 degrees** as in fitting conical ends its called **flanging**



Tube Forming or 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**.



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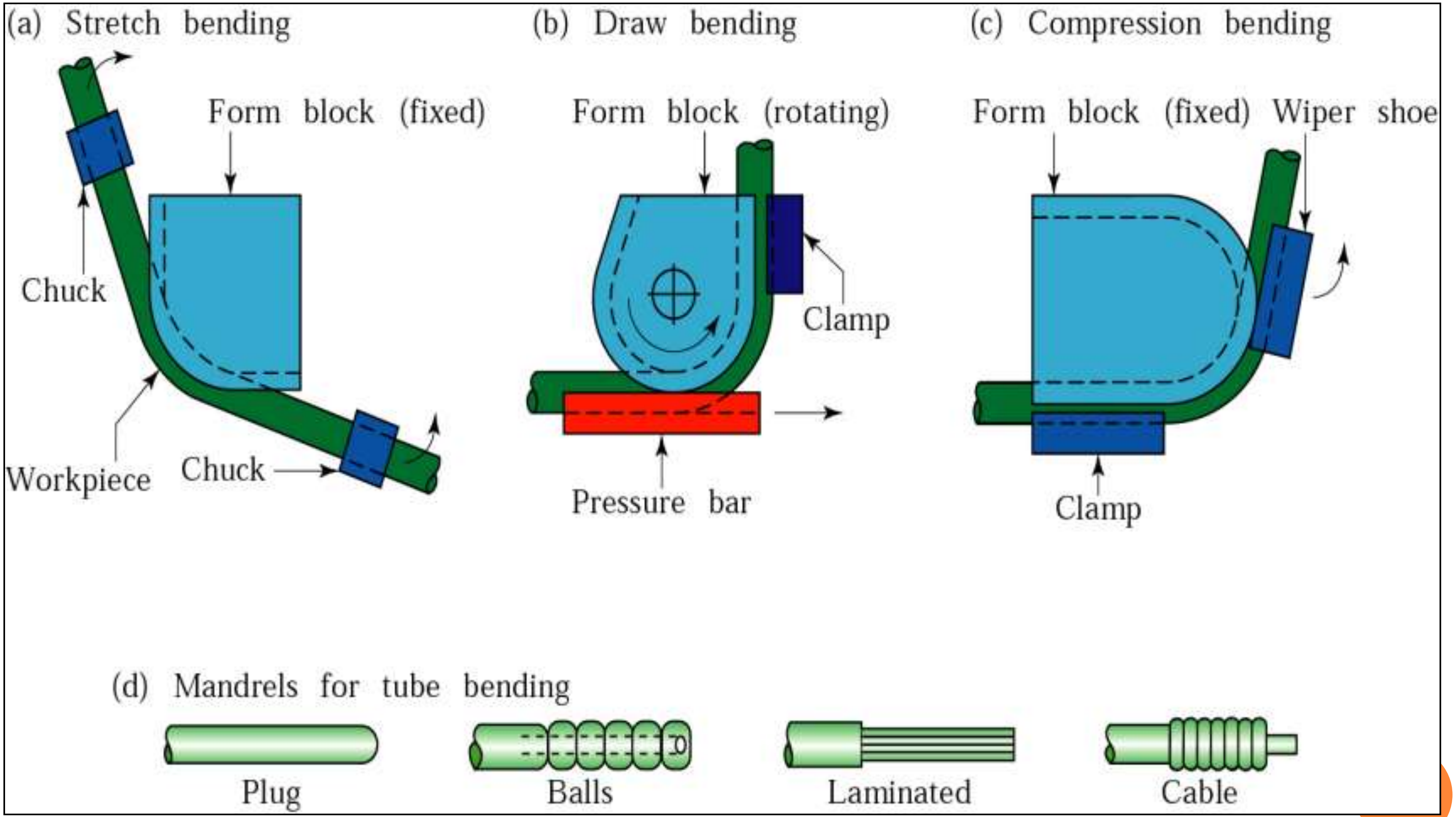
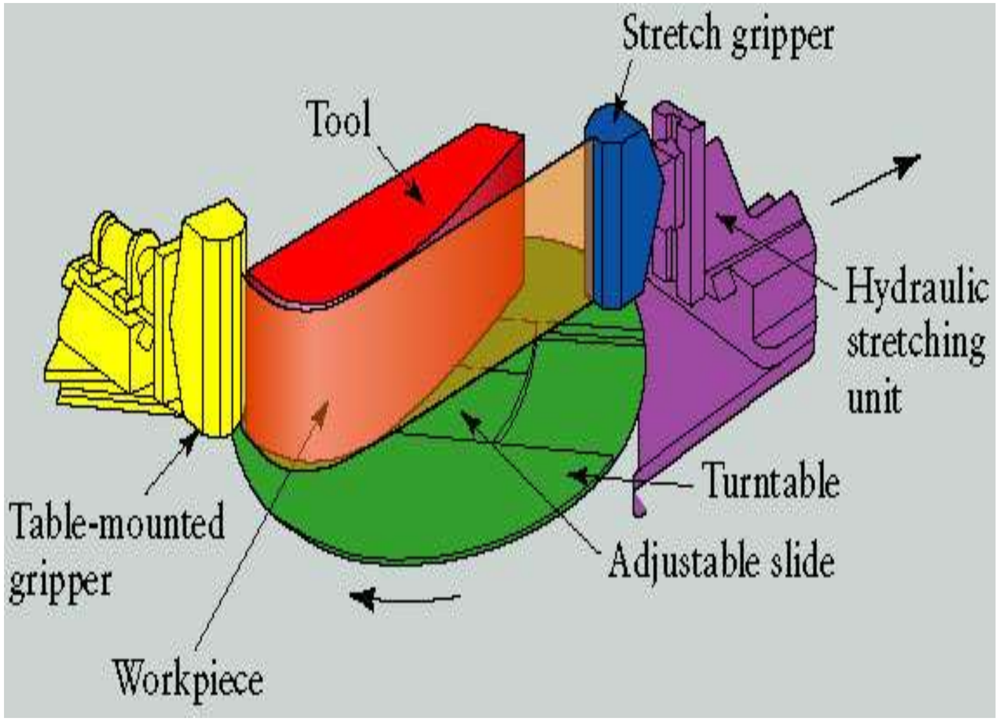
Tube Forming



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

Stretch Forming

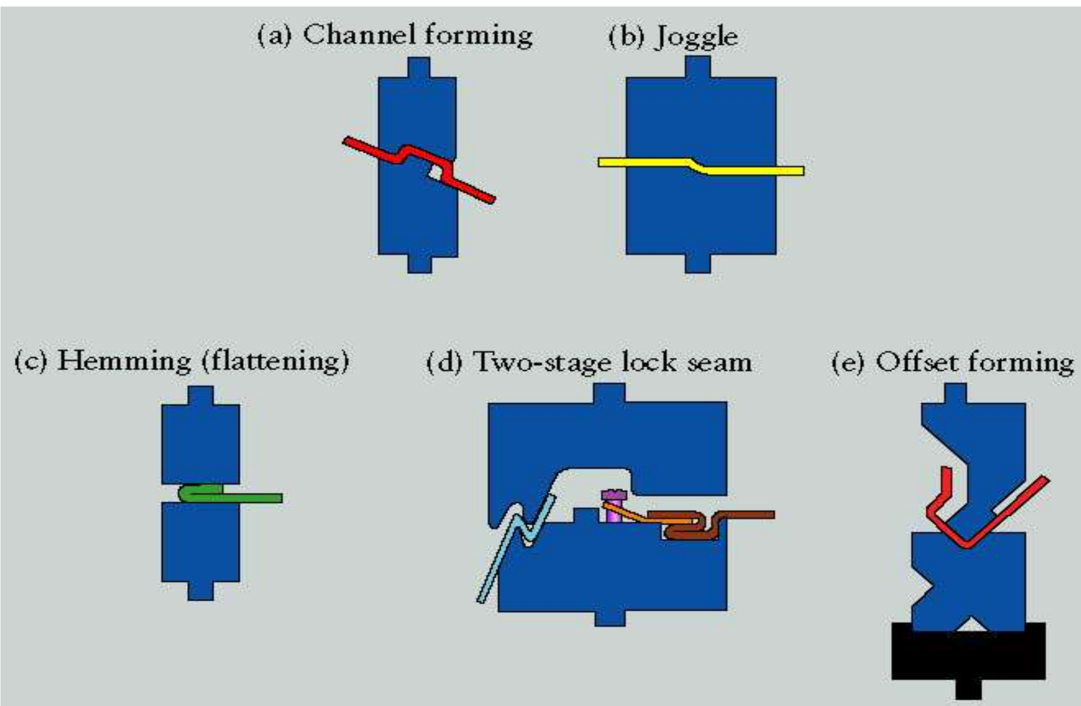
- The **sheet metal is clamped** around **its edges and stretched** over a **die** or **form block**, which moves **upward, downward or sideways**, depending on the particular machine. **Stretch forming** is used primarily to make **aircraft-wing skin panel, automobile door panels and window frames**.



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

Press break forming

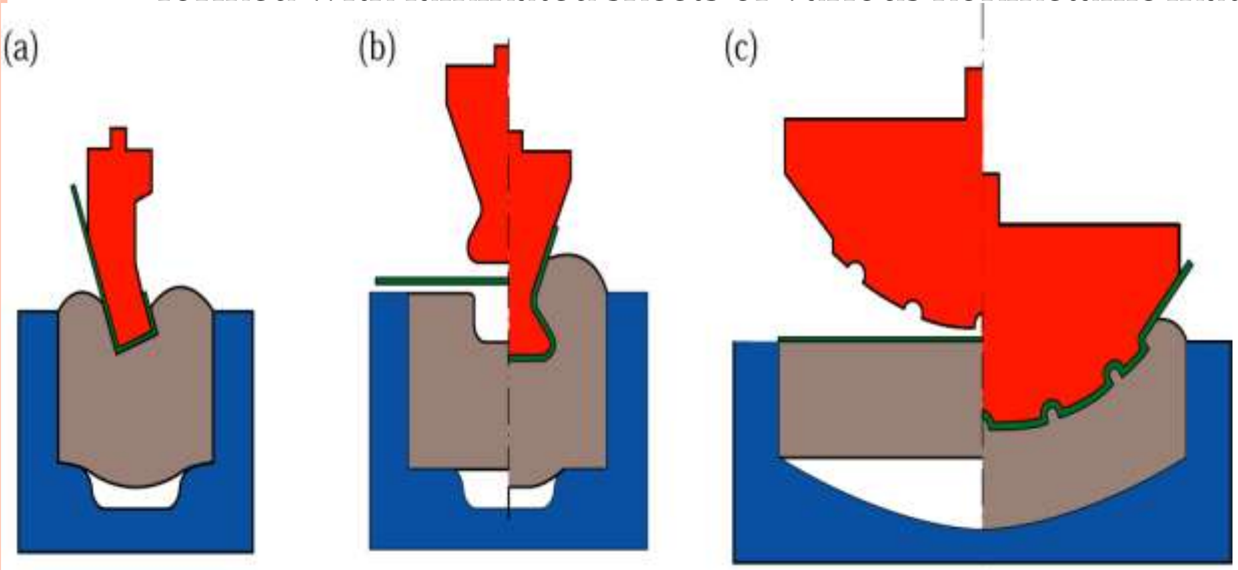
- **Sheet metal or plate** can be bent easily with simple **fixtures using a press**. Long and relatively narrow pieces are usually **bent in a press break**. This machine utilizes **long dies in a mechanical or hydraulic press** and is suitable for small production runs. The tooling is simple and adaptable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



Schematic illustrations of various bending operations in a press brake

Rubber Forming

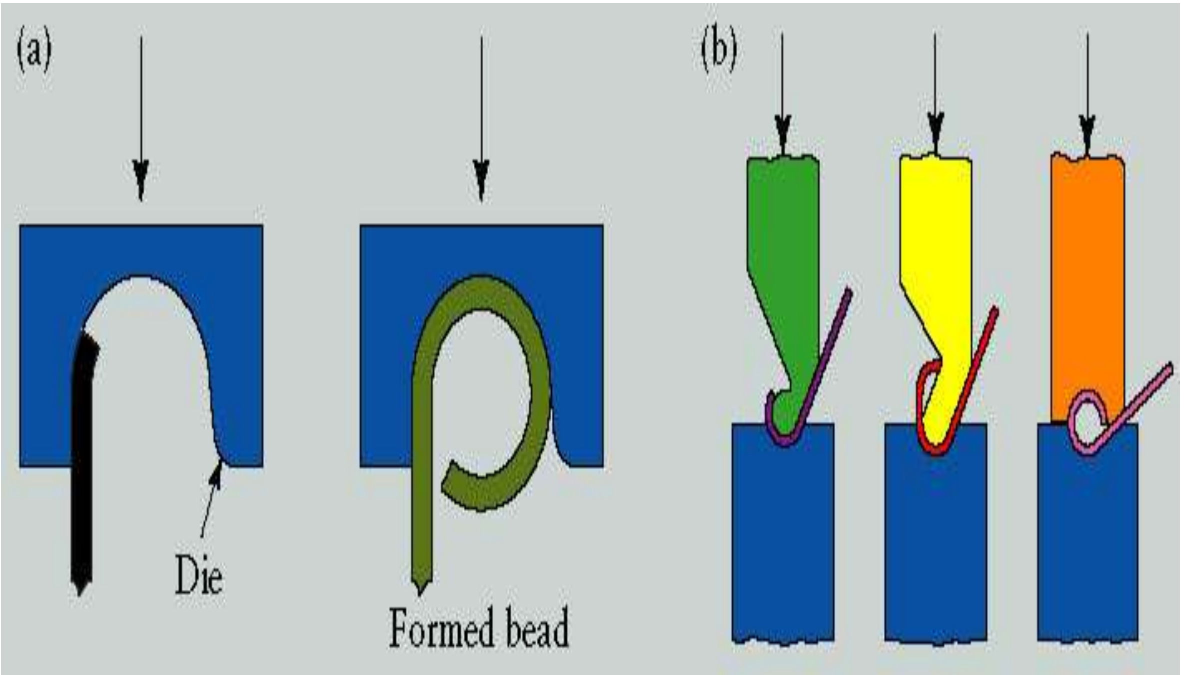
- One of the **dies in a set is made** of **flexible material**, such as a **rubber or polyurethane membrane**. Polyurethanes are used widely because of their **resistance to abrasion, long fatigue life and resistance to damage by burrs or sharp edges of the sheet blank**.
- In **bending and embossing 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.

Beading

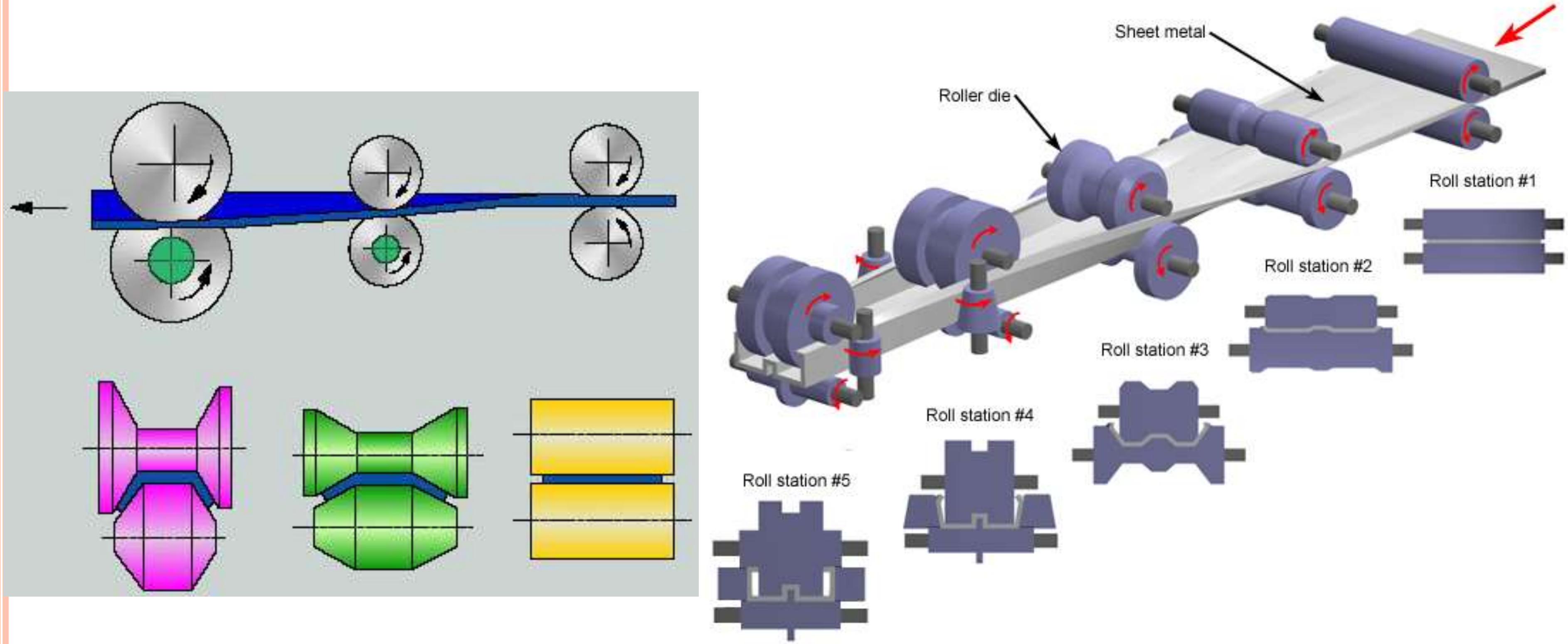
- In beading, the **edge of the sheet metal is bent** into the **cavity of a die**. The **bead gives stiffness to the part by increasing the moment on inertia** of the edges. Also, it improves the **appearance of the part** and **eliminates** exposed **sharp edges.**



(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

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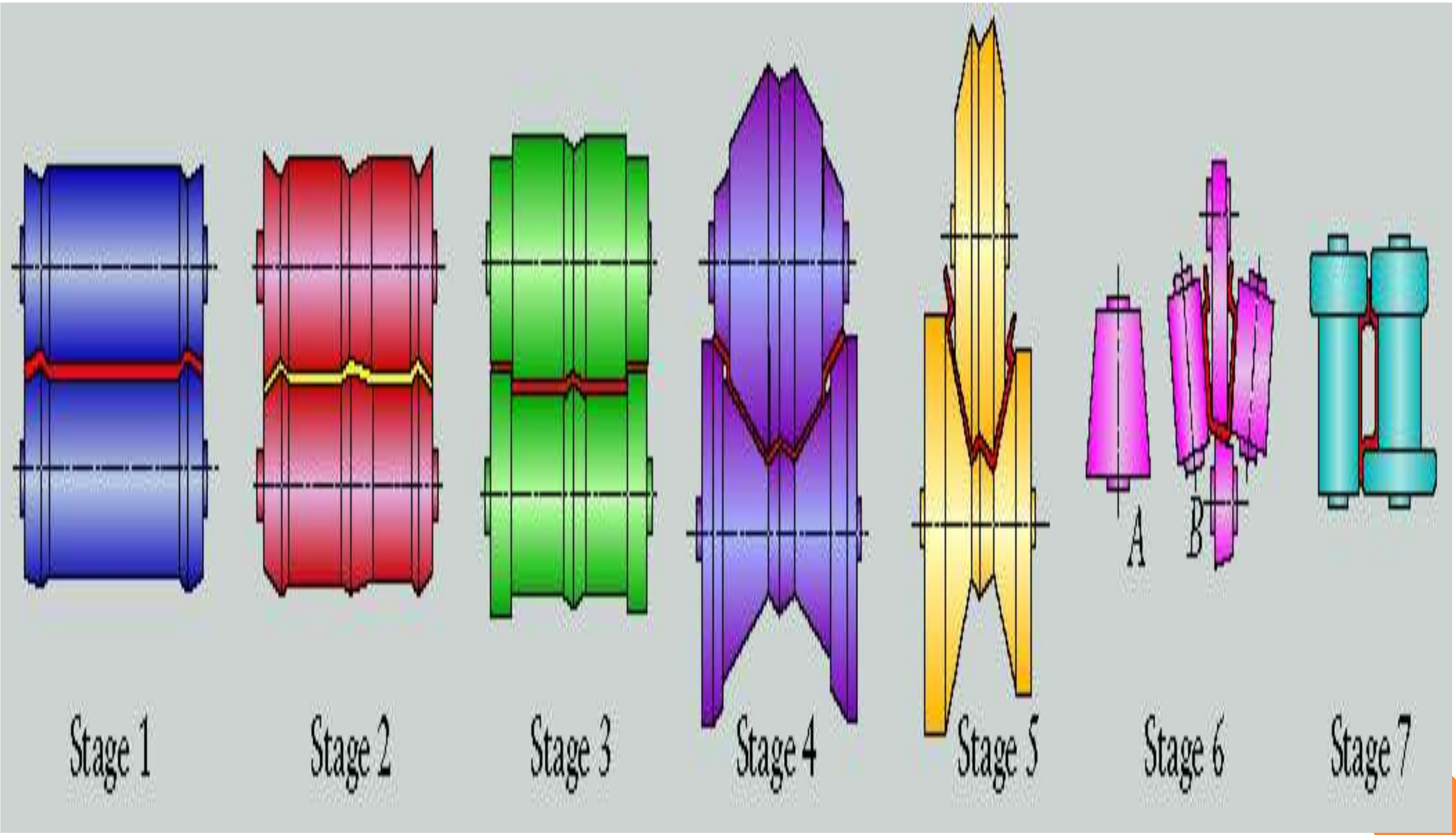
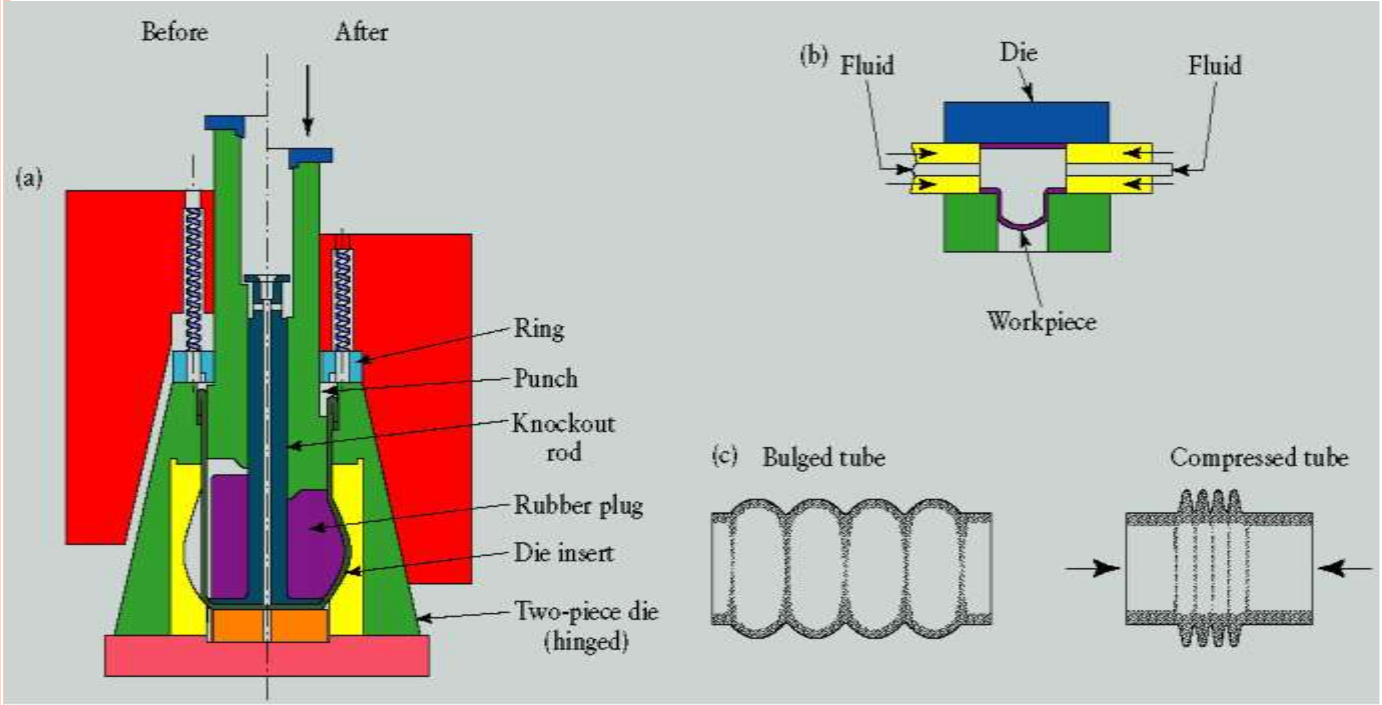
Stages in roll forming



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

Bulging

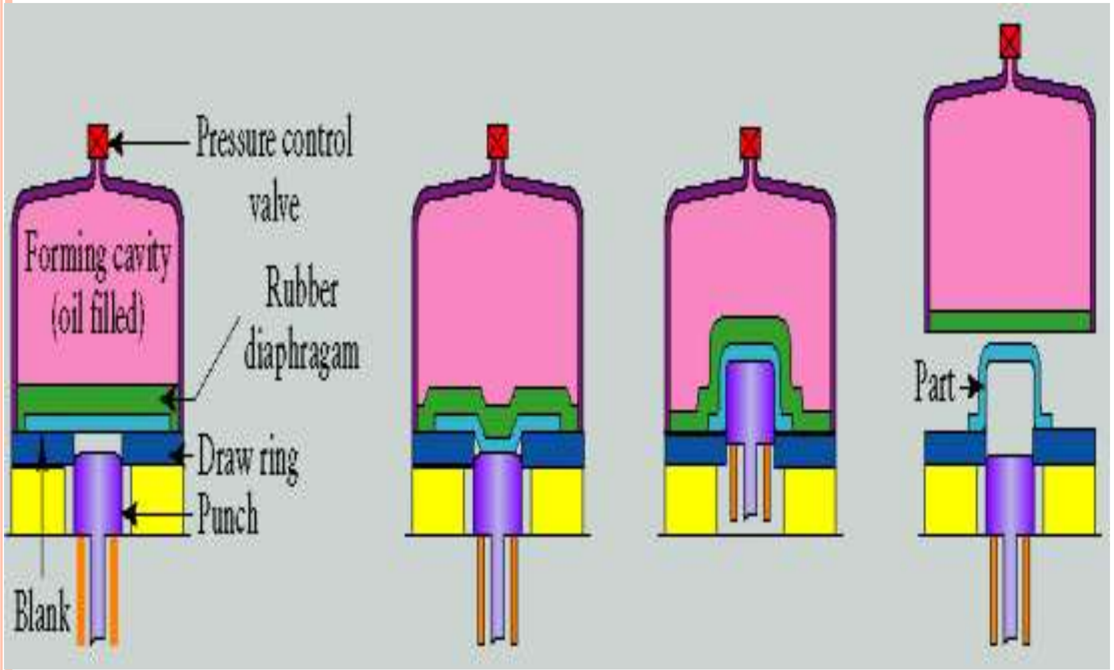
- The basic forming process of bulging involves **placing tabular, conical or curvilinear part into a split-female die** and **expanding it** with, say, a **polyurethane plug**.
- The punch is then retracted, the plug returns to its original shape and the part is removed by opening the dies.



(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.

Hydro forming Process

- In **hydro forming or fluid forming** process, the pressure over the rubber **membrane is controlled throughout the forming cycle**, with maximum **pressure reaching 100 MPa.** This procedure allows **close control of the part** during forming to **prevent wrinkling or tearing**.



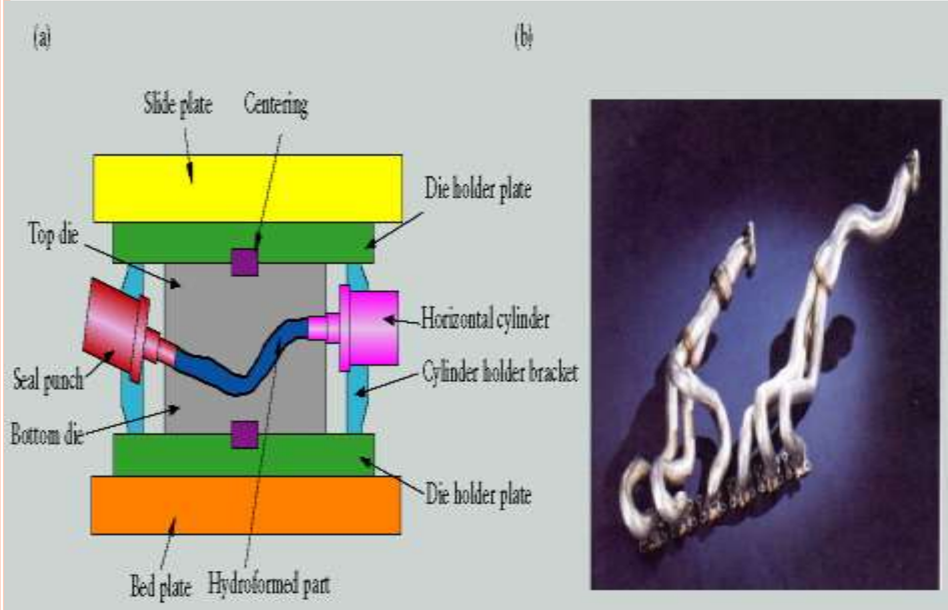
Advantages:

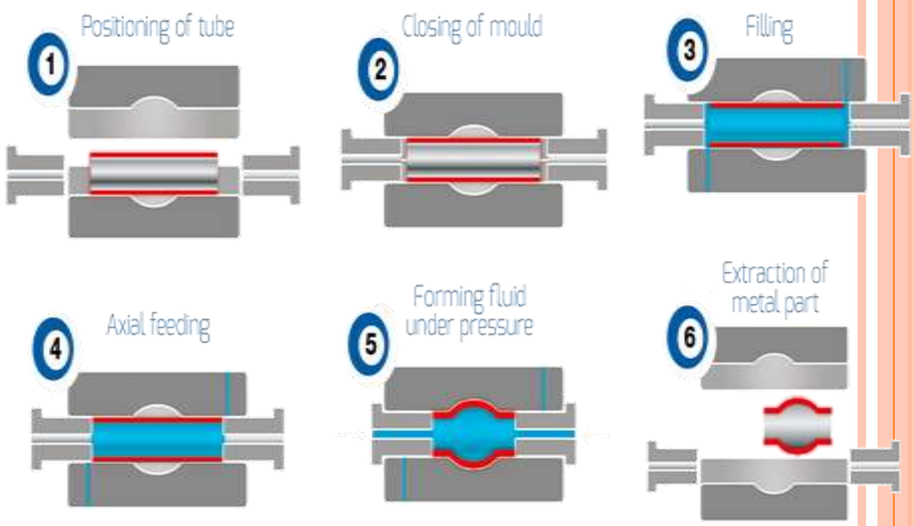
- Low tooling cost
- Flexibility and ease of operation
- Low die wear
- No damage to the surface of the sheet and
- Capability to form complex shapes.

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-Hydro forming Process

- In **tube hydro forming, 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-hydro formed parts include automotive exhaust and structural** components.

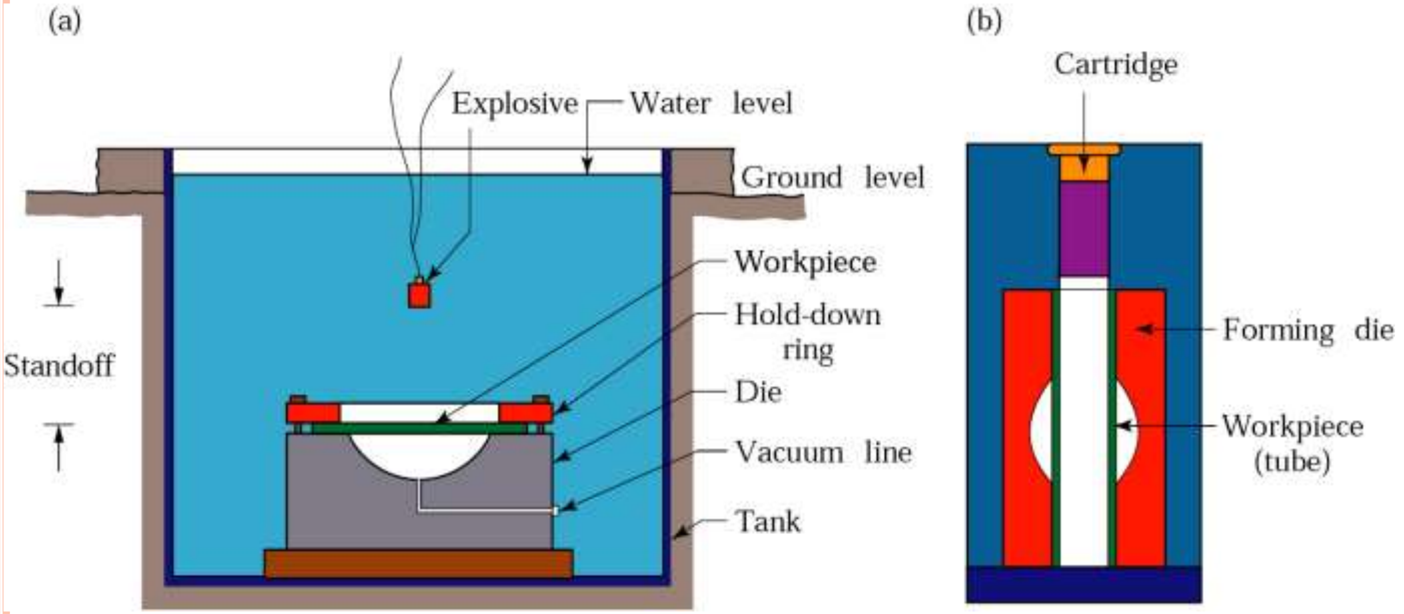




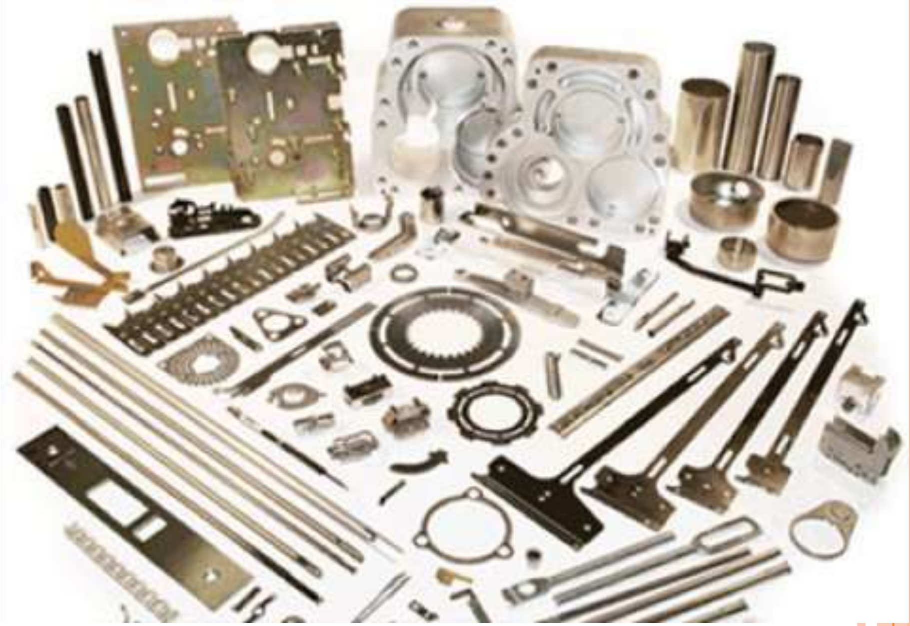
(a) Schematic illustration of the tube-hydroforming process. (b) Example of tube-hydroformed parts. Automotive exhaust and structural components, bicycle frames, and hydraulic and pneumatic fittings are produced through tube hydroforming.

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.**



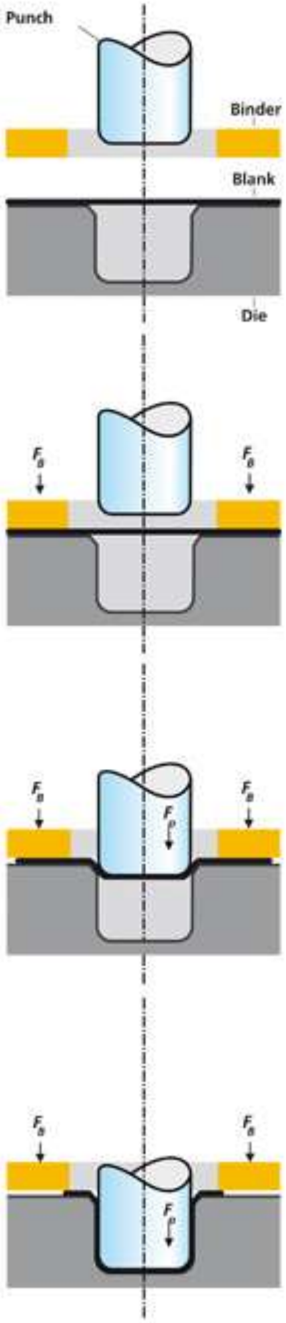
(a) explosive forming process. (b) confined method of explosive bulging of tubes.



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 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



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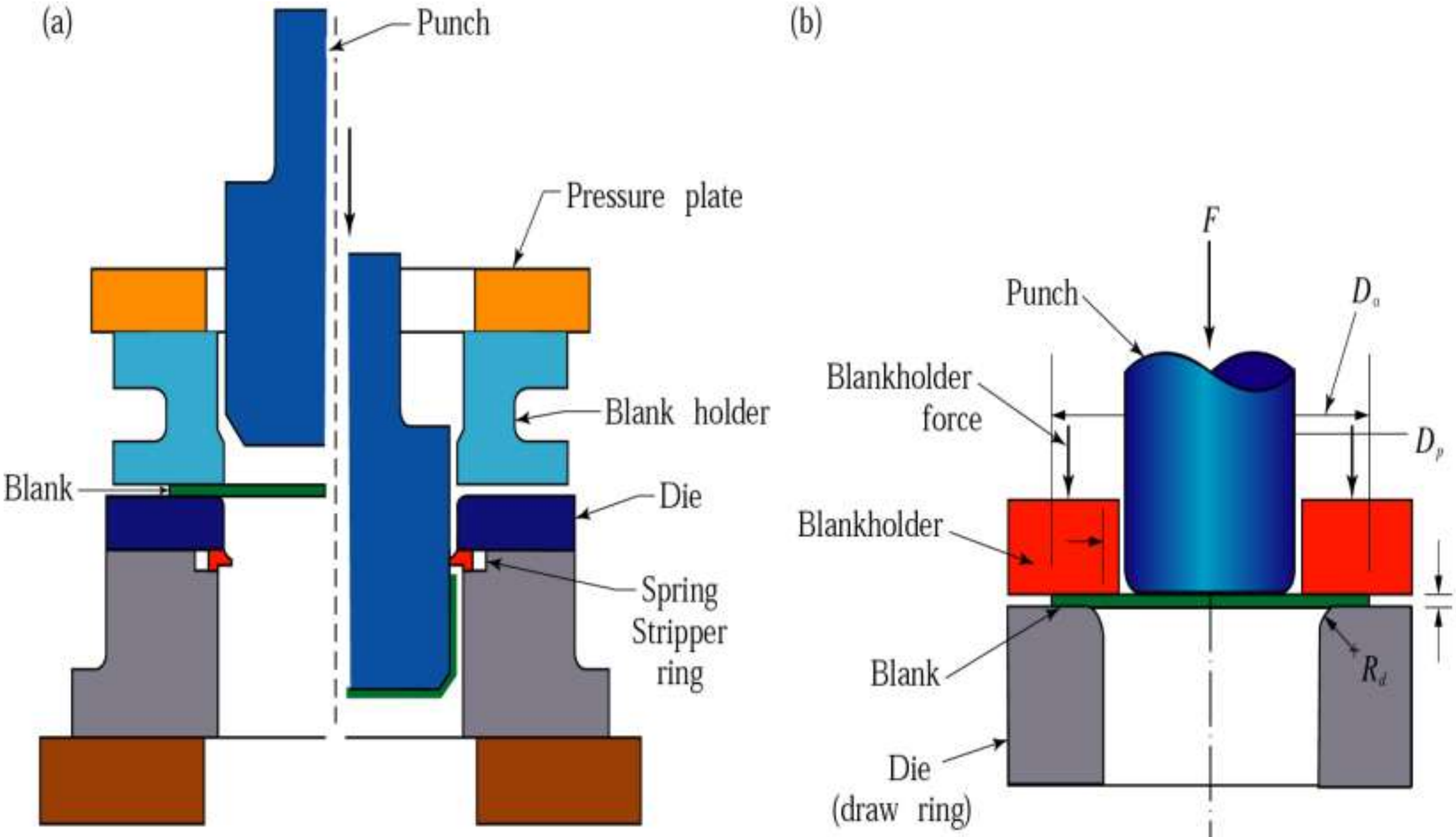
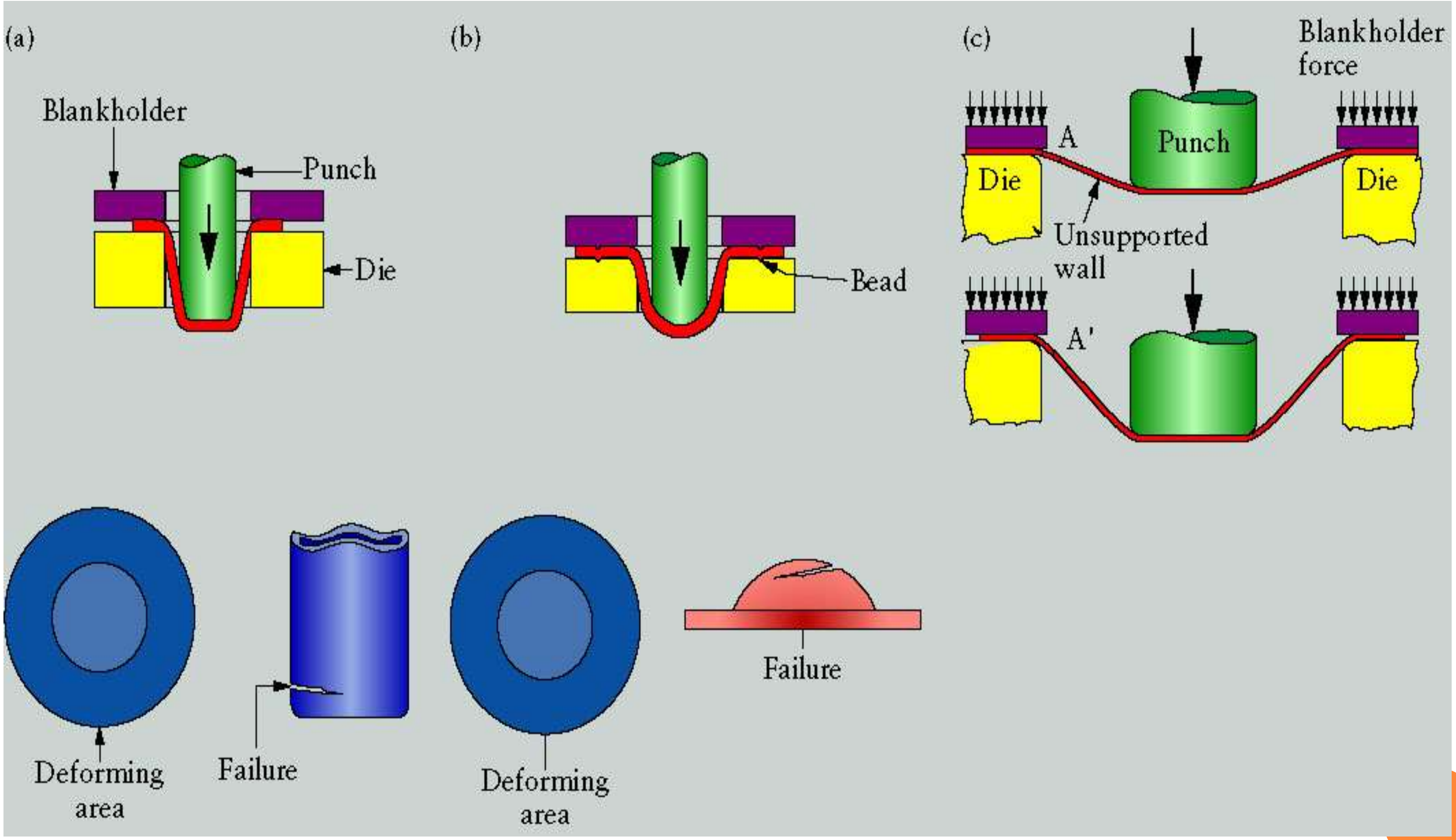
Deep Drawing



(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.

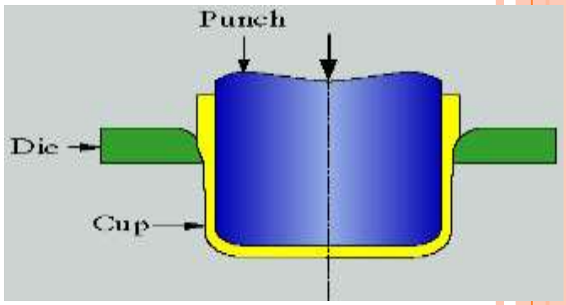
Examples of drawing operations

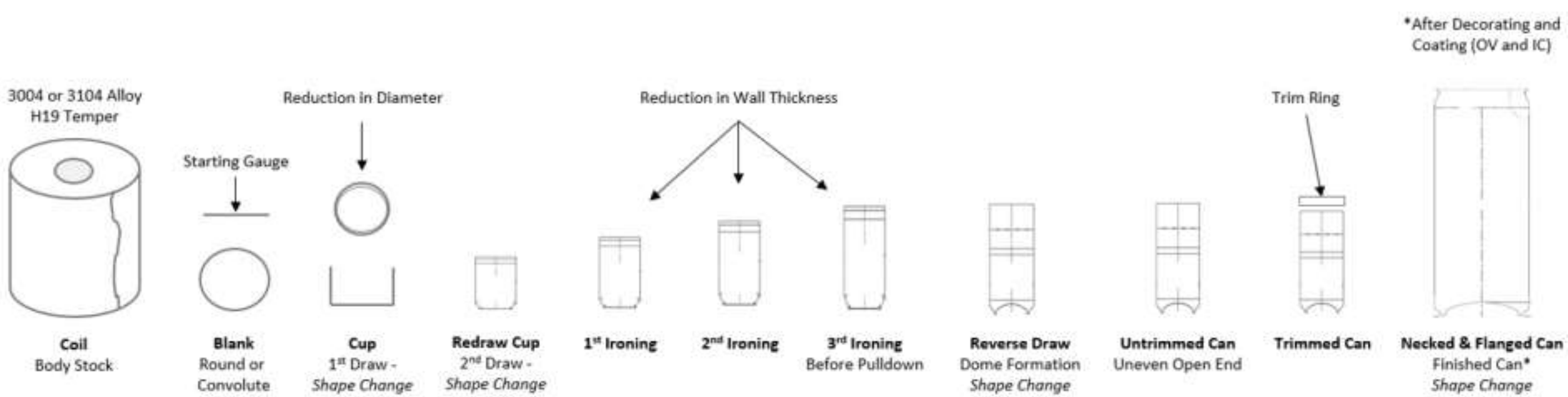


(a) pure drawing and (b) pure stretching. The bead prevents the sheet metal from flowing freely into the die cavity. (c) Possibility of wrinkling in the unsupported region of a sheet in drawing.

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**.

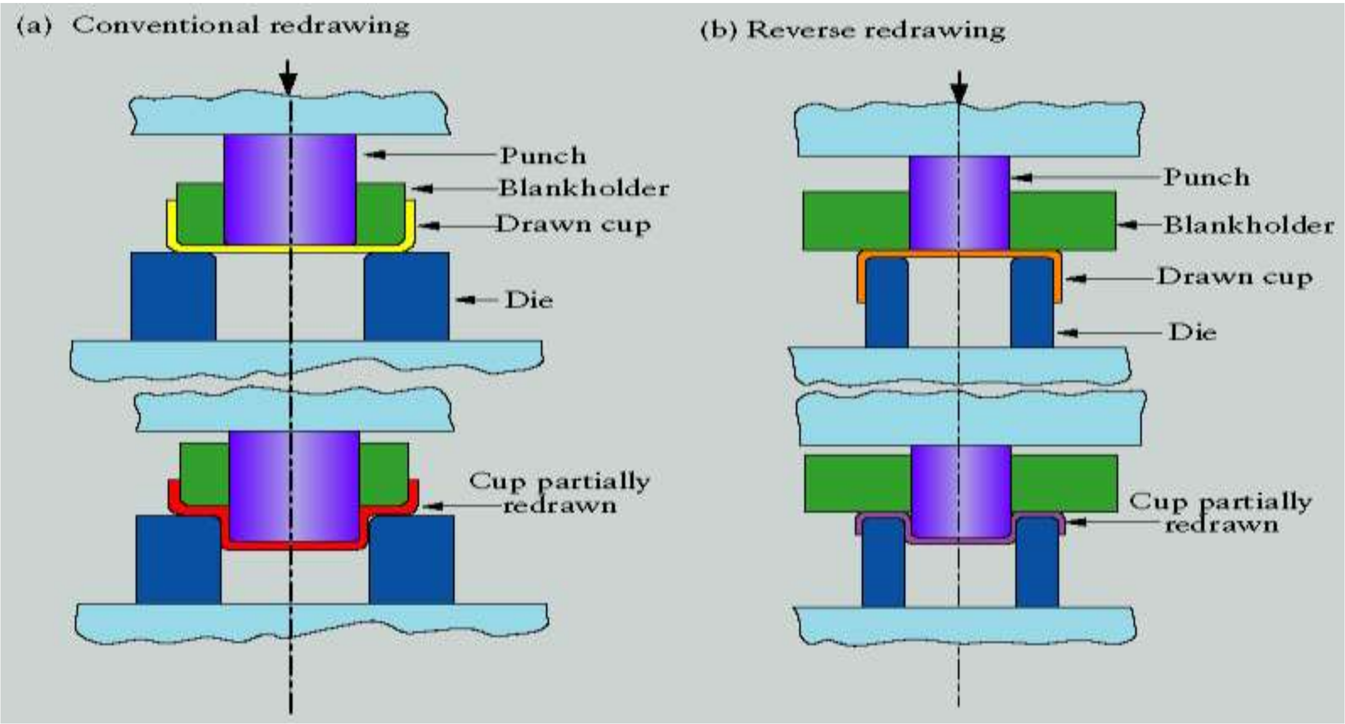




Schematic illustration of the ironing process. Note that the cup wall is thinner than its bottom. All beverage cans without seams (known as two-piece cans) are ironed, generally in three steps, after being deep drawn into a cup. (Cans with separate tops and bottoms are known as three-piece cans.)

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 s**oftening. 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.

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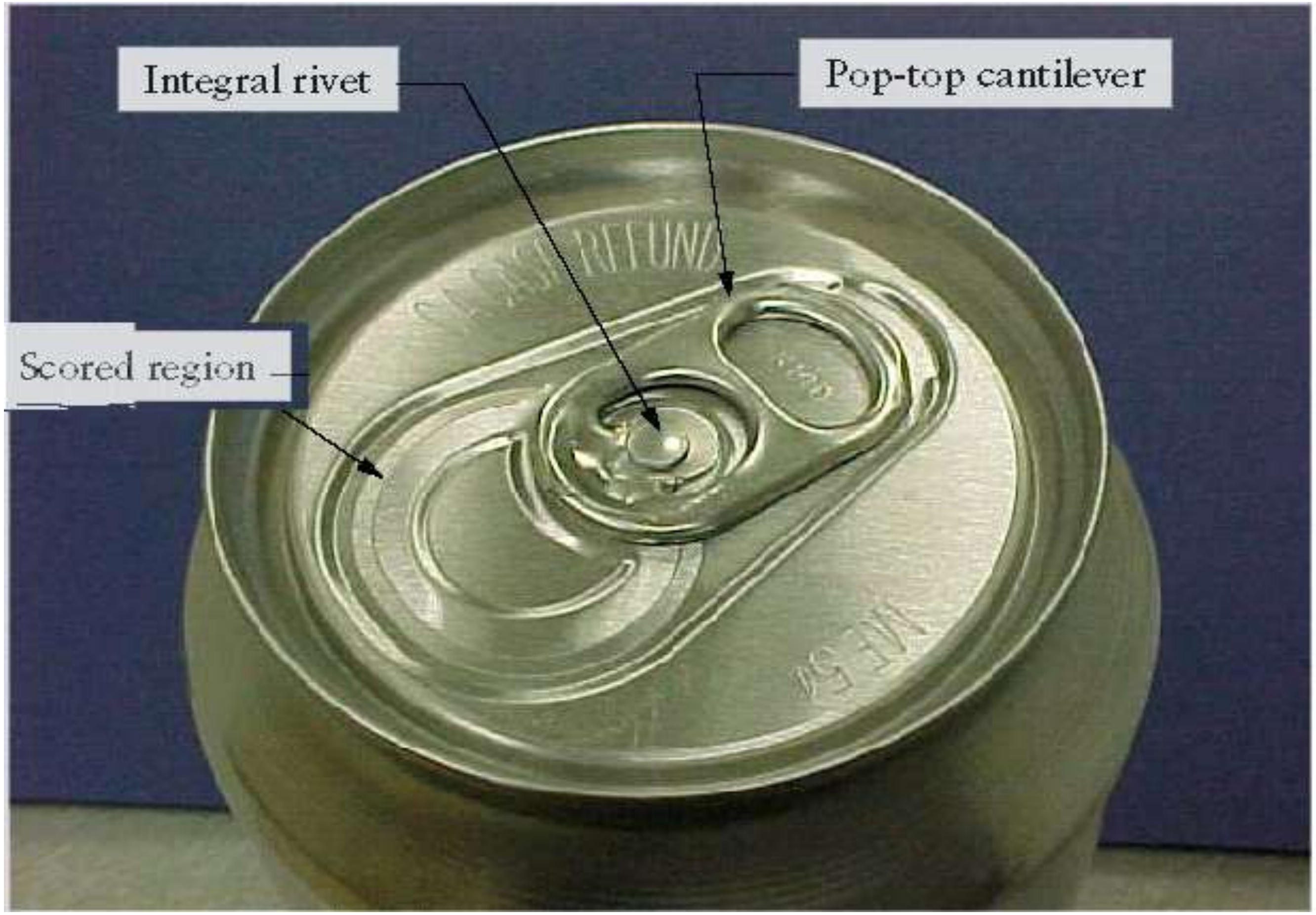
Metal-Forming Process for Aluminum Beverage Can



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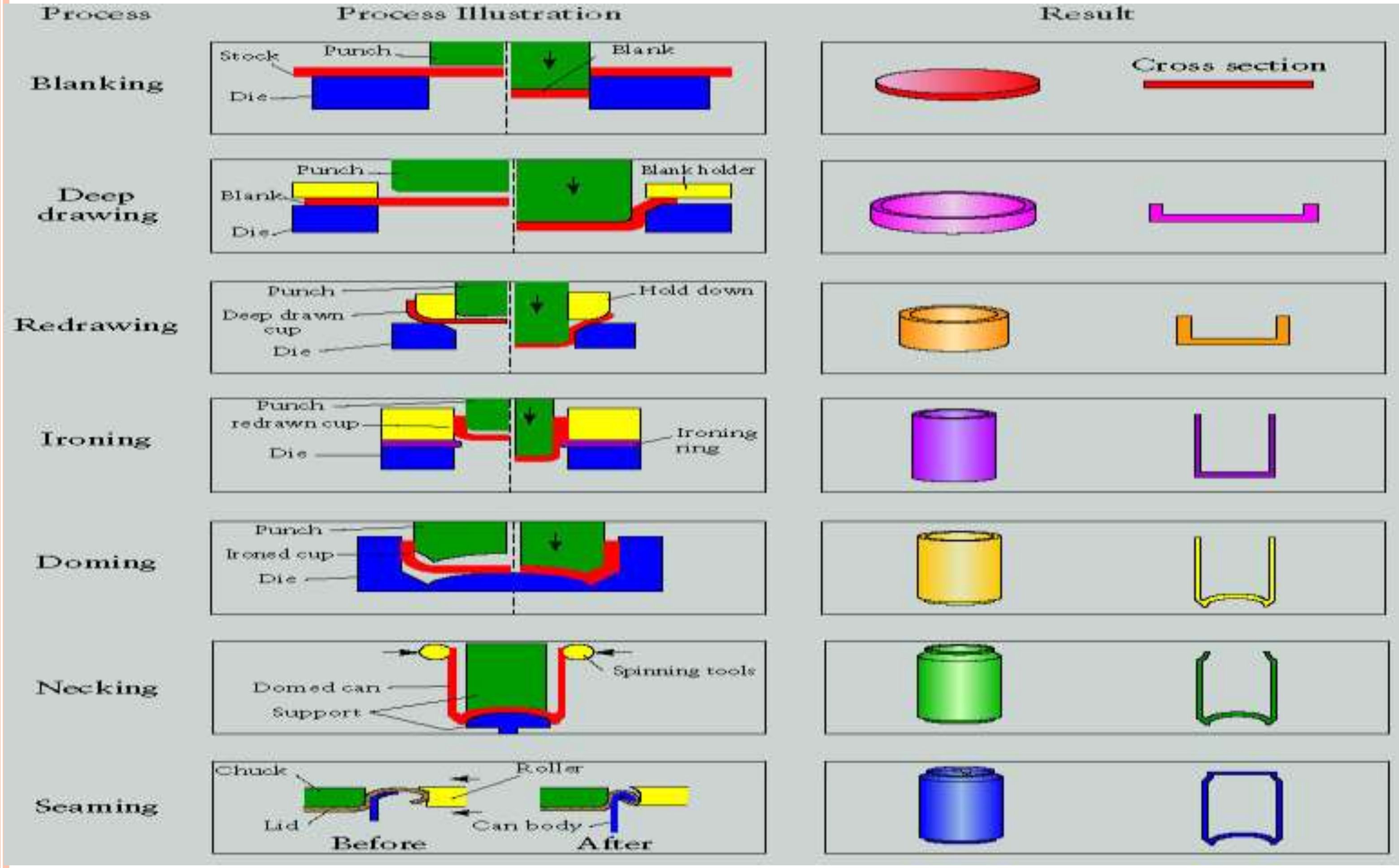
Steps in Manufacturing an Aluminium Can



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

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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

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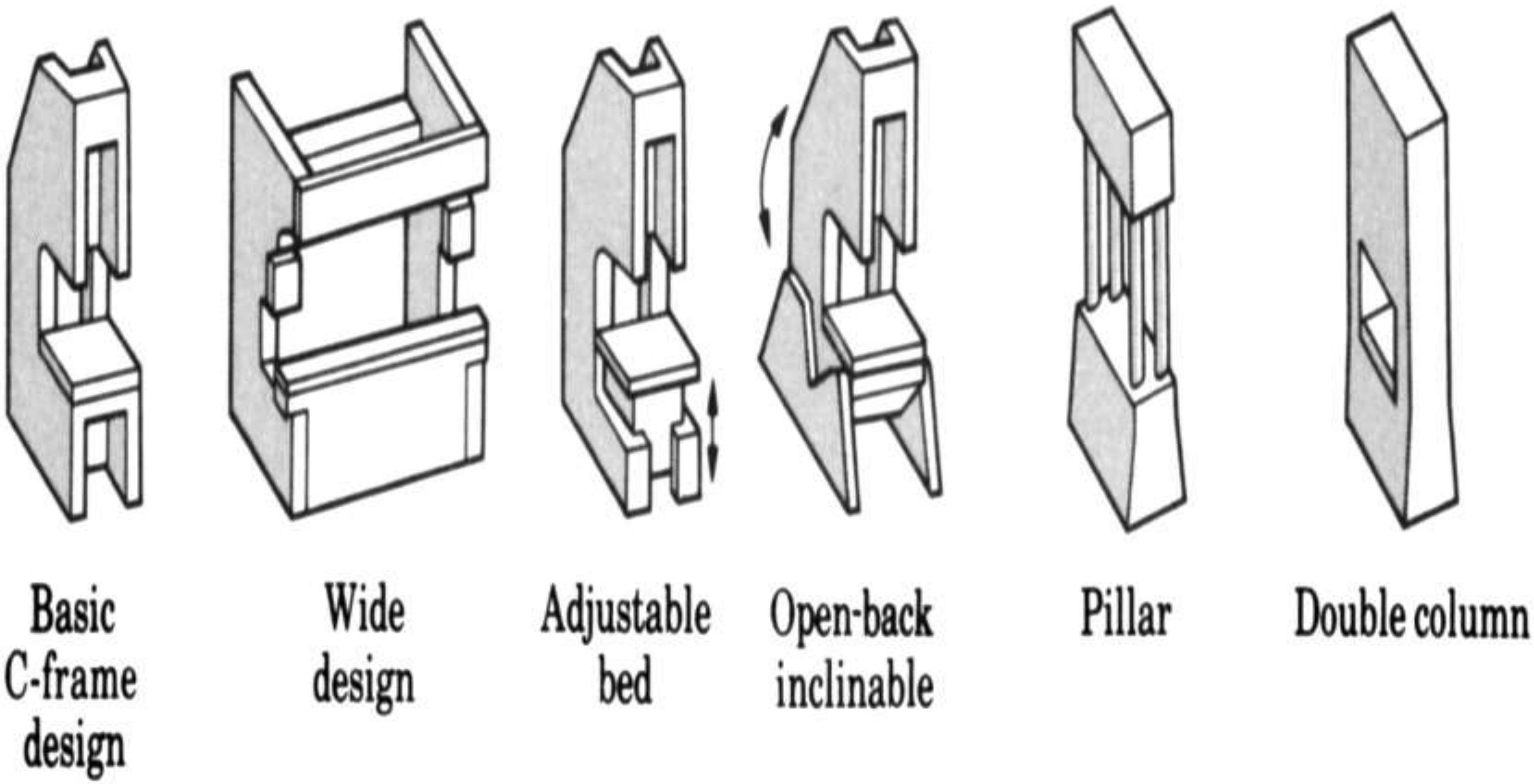
TYPES OF PRESS FRAMES



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

Sheet and Plate Metal Products

- Sheet and plate metal parts for consumer and industrial products such as
  - Automobiles and trucks
  - Airplanes
  - Railway cars and locomotives
  - Farm and construction equipment
  - Small and large appliances
  - Office furniture
  - Computers and office equipment

Advantages of Sheet Metal Parts

- High strength
- Good dimensional accuracy
- Good surface finish
- Relatively low cost
- For large quantities, economical mass production operations are available

Tools and Accessories

- Marking and measuring tools
- Steel Rule
  - It is used to set out dimensions.
- Try Square
  - Try square is used for making and testing angles of 90degree
- Scriber
  - It used to scribe or mark lines on metal work pieces.
- Divider
  - This is used for marking circles, arcs, laying out perpendicular lines, bisecting lines, etc

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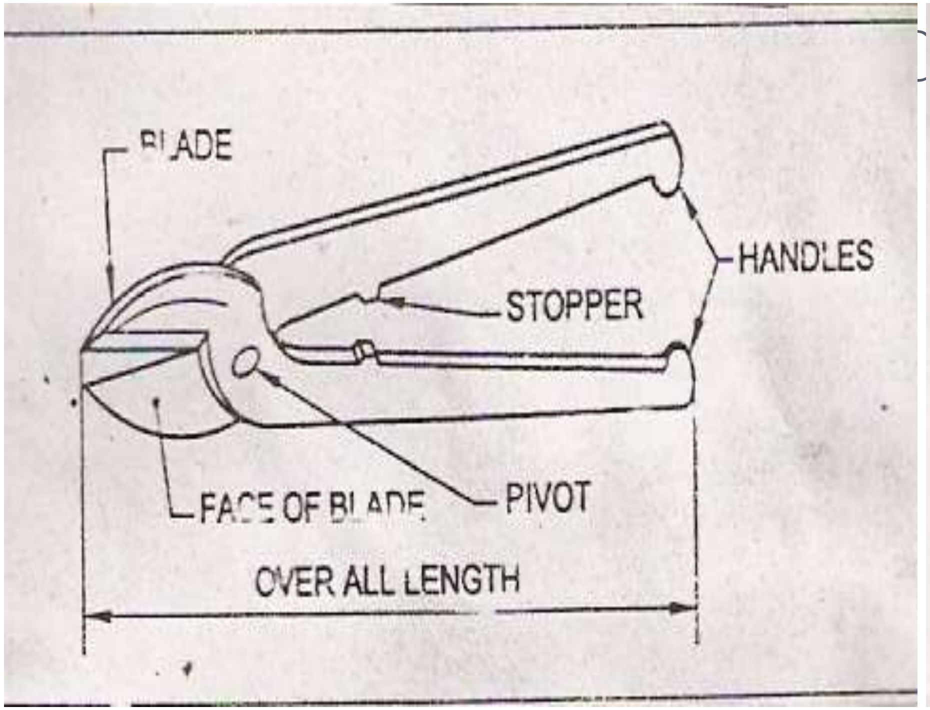
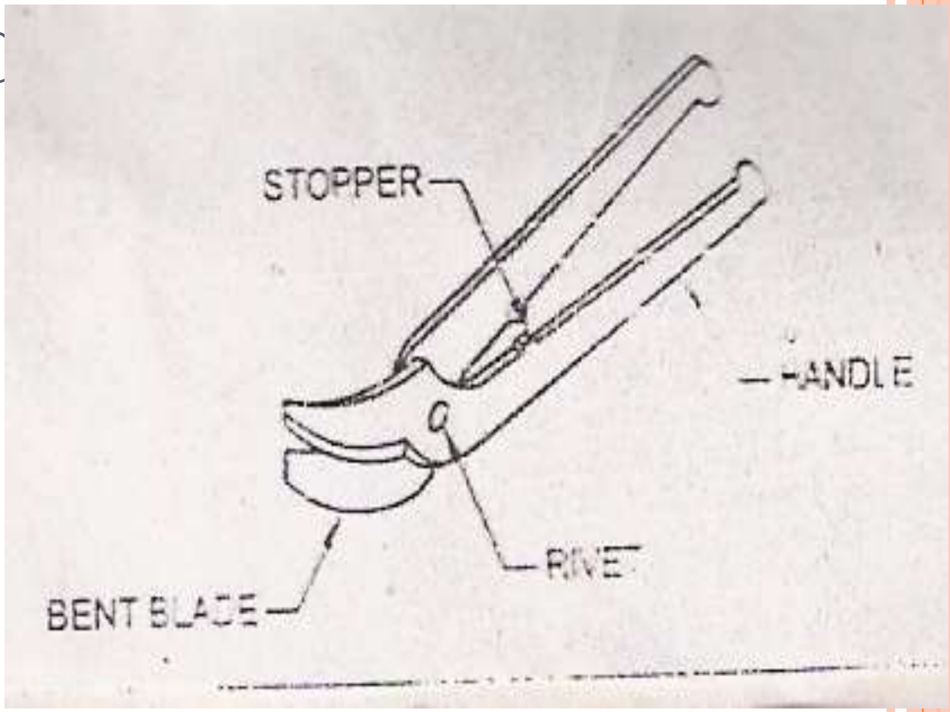
- Marking and measuring tools



Straight snip



Curved snip

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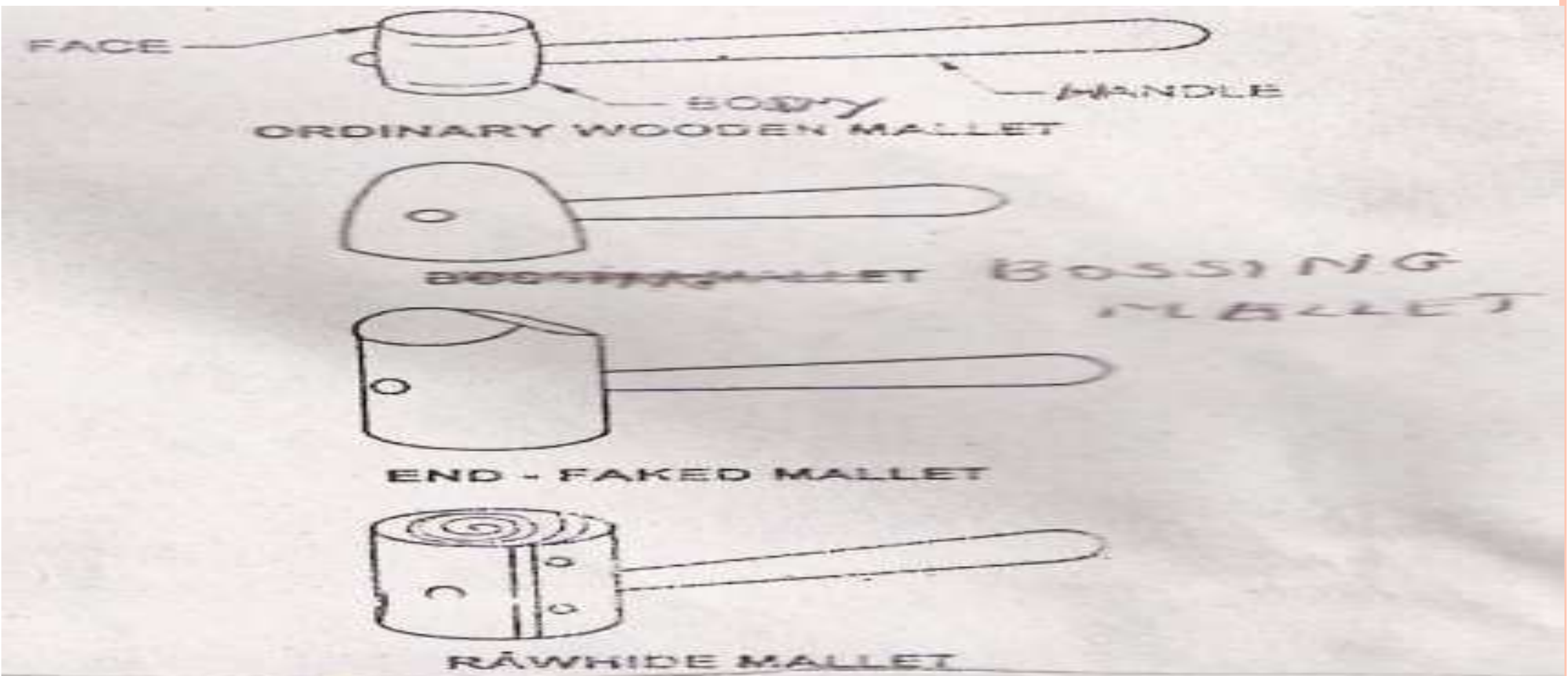

Types of Mallets

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