Sheet-Metal Forming Processes

Extrusion and Drawing of Metals

Definitions

Extrusion is defined as the process of shaping material, such as aluminum, by forcing it to flow through a shaped opening in a die. Extruded material emerges as an elongated piece with the same profile as the die opening.

- **Drawing** is defined as the process of shaping material, such as aluminum, by pulling the material through a shaped opening in a die (draw die).

  This process of drawing is not to be confused with the drawing process related to the forming of sheet metals

Extruded items

- Railings for sliding doors
- Window frames
- Tubing having various cross-sections
- Aluminum ladders
- Numerous structural and architectural shapes

Drawing Products

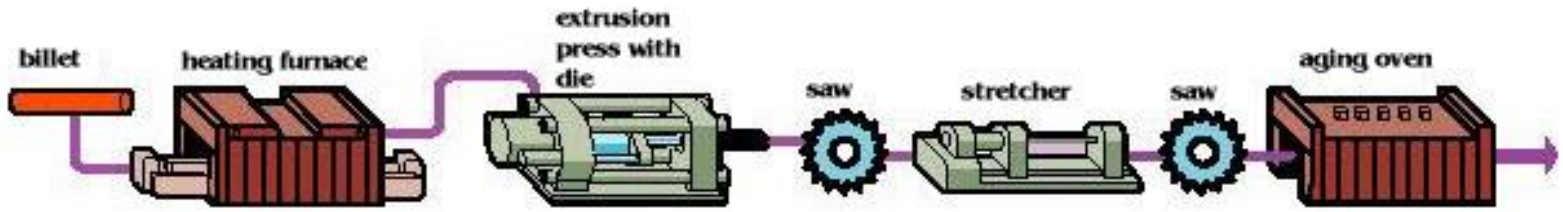
- Rods and wires:

Including :

- Rods for shafts
- Machine and structural components
- Electrical wiring
- Cables
- Tension-loaded structural members
- Welding electrodes
- Springs
- Paper clips
- Spokes for bicycle wheels
- Stringed musical instruments

Types of Extruding Process

Direct (forward) extrusion
Indirect (reverse, inverted, or backwards) extrusion
Hydrostatic extrusion

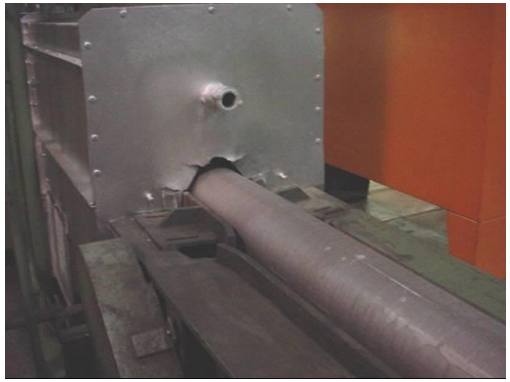


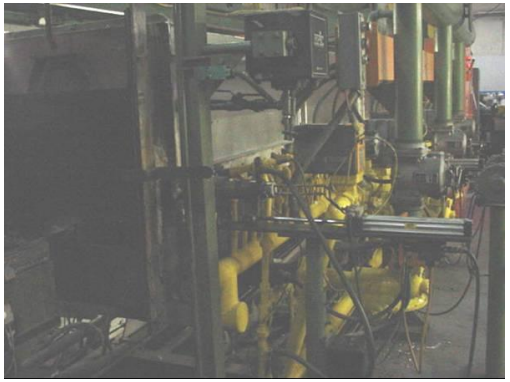
Properties

Log table

- Extrusion process actually increases the properties of metals, because it allows the creation of a final end product that is stronger and more resilient than components that must be assembled. It allows for the fabrication of products to various specifications and sizes, while being flexible enough to allow for design alterations.

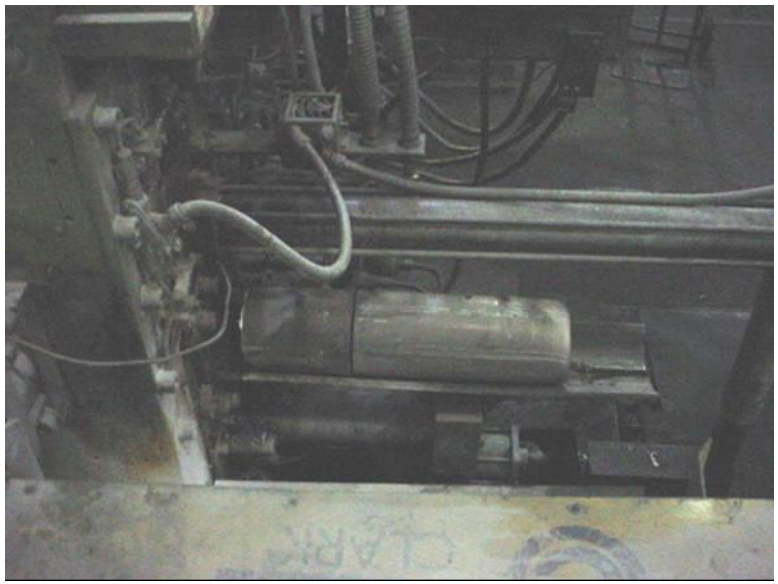
Furnace





- The extrusion process starts with the furnace, where aluminum billets are heated to the necessary point of malleability. The aluminum or aluminum alloy is heated to temperatures ranging 750 to 900 degrees Fahrenheit, at which temperatures it acts as a malleable solid.

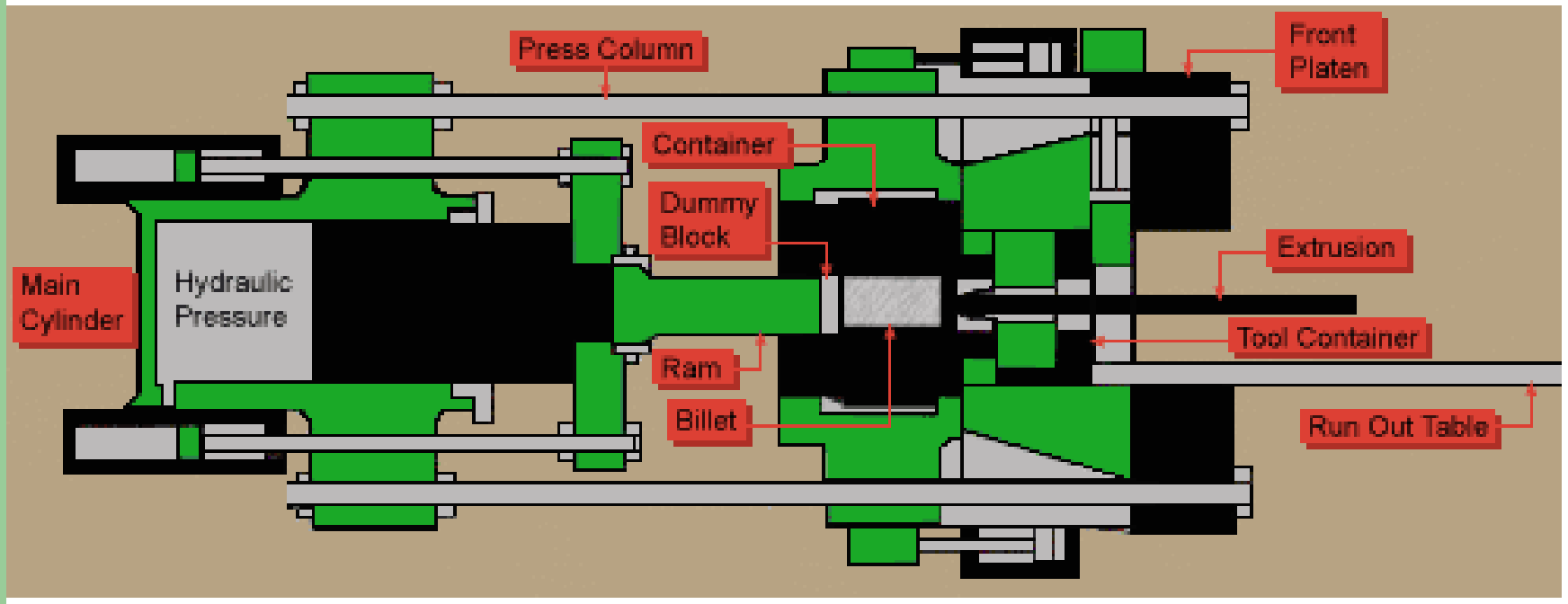
Metals



- **Common metals used in extraction process:**
- Aluminum
- Copper
- Steels
- Stainless steels
- Magnesium
- Lead

- **Other metal alloys can be extruded with various levels of difficulty**

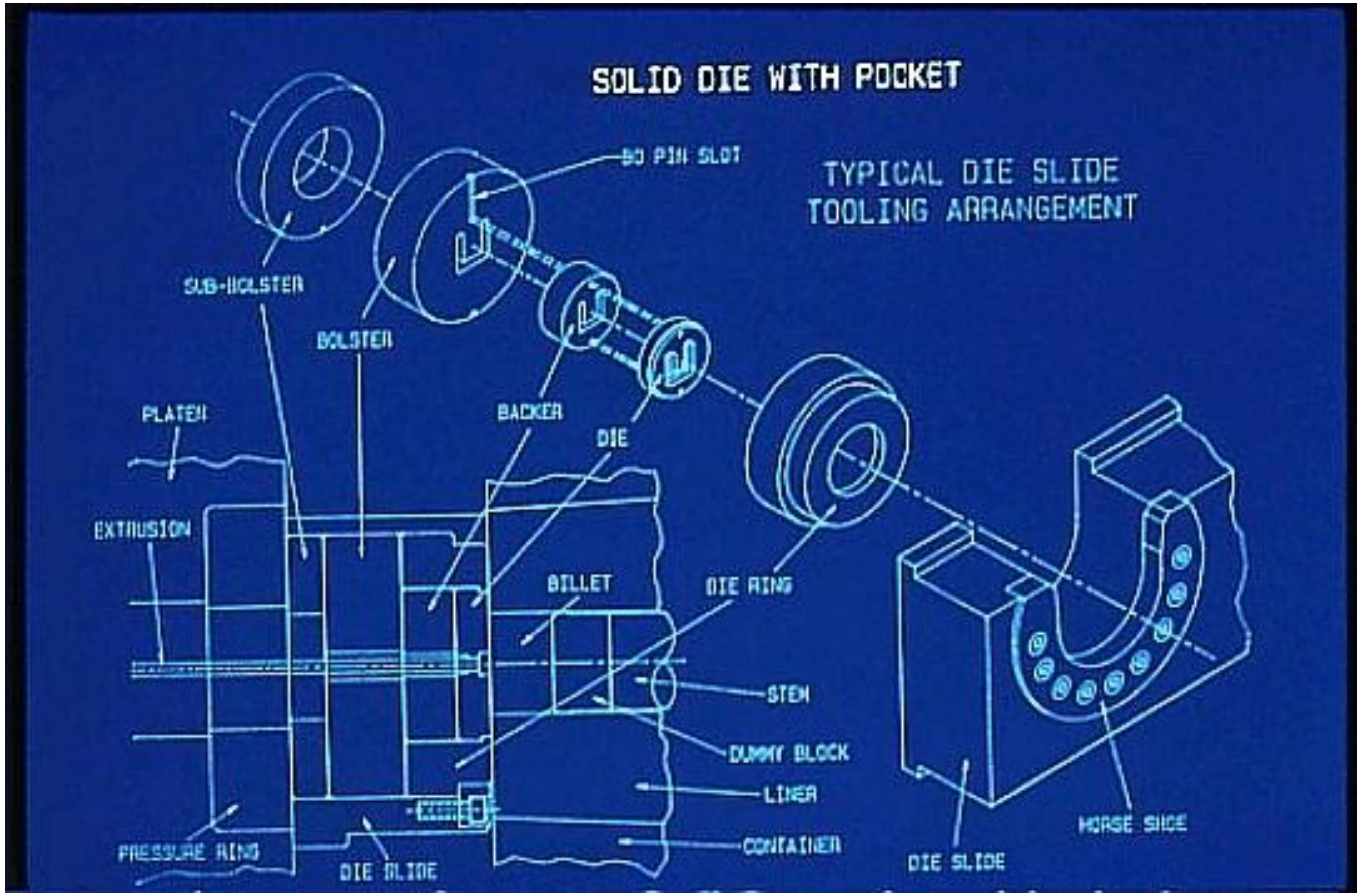
Typical Horizontal Hydraulic Extrusion Press



Typical Horizontal Hydraulic Extrusion Press

- At this point, aluminum is a soft solid that can be pressed through dies, using scaleable amounts of pressure - a process called extrusion.
- An extrusion press utilizes a hydraulic ram that applies between 100 to 15,000 tons or more of pressure.
- The extrusion press container chamber, which holds the billet, is made of steel.

Die Slide, Tooling Assembly



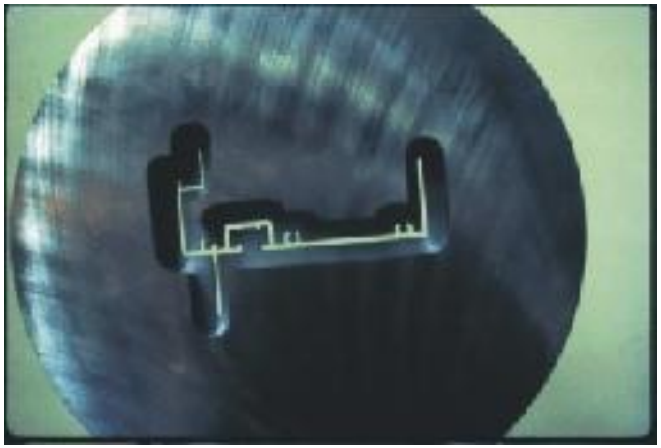
Profile

- The aperture in the die represents the final product. The aluminum is pressed through the chamber and through the die to create the final, shaped profile.

Photos showing a new length of extrudate, just emerging from the press (left) and the production of a profile in progress (right).

Dies

- *A solid die, as shown here, produces shapes without any enclosed voids and/or semihollow conditions*



- This process allows designers and engineers freedom to create products in complex and intricate shapes, since the end product can be extruded as a final piece instead of requiring multiple ones that must be assembled.

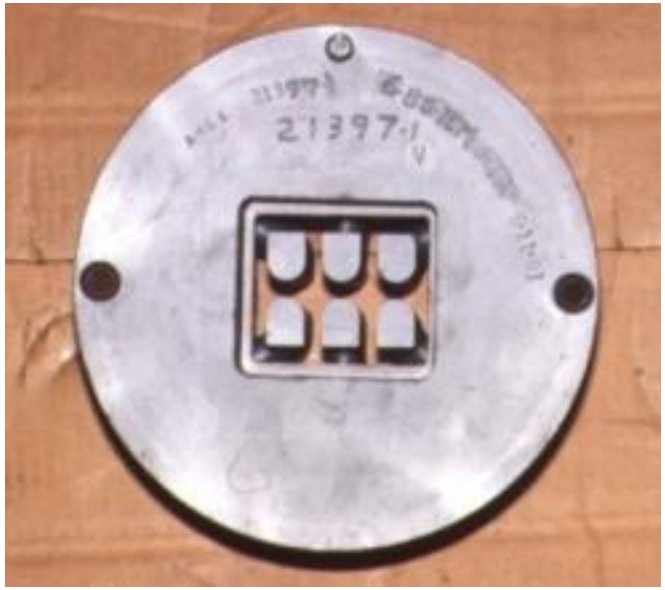
Dies Continued

- The extrusion process also creates a natural finish - a thin layer of aluminum oxide - that forms on the surface of the metal as a result of the process. This naturally resilient and attractive finish can be improved with additional beautifying and weather-resistant finishes.

- *A semihollow die also produces shapes without enclosed voids; however, unlike a solid die, it produces shapes with a tongue ratio of 3:1 or greater.*

Dies Continued

- Complex shapes may emerge from the extrusion press as slowly as one foot per minute. Simpler shapes can emerge as quickly as 200 feet per minute.



- *A hollow die produces shapes with one or more enclosed voids. The die shown here, when used together with a mandrel and other support tooling, produces a profile with six voids.*

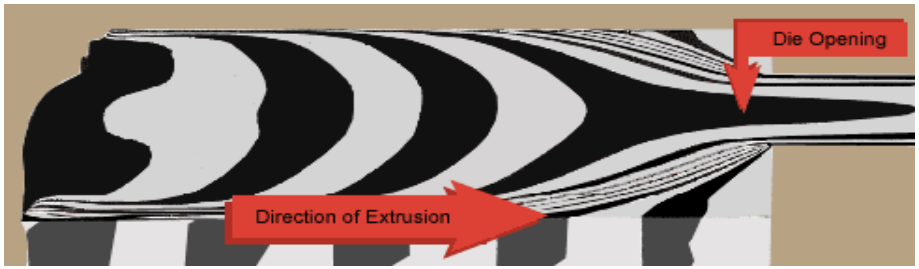
Extrusion Principles

The force required for extrusion depends on:

- The strength of the billet material
- The extrusion ratio A_o/A_f
- Friction between the billet and the chamber and die surface

The geometric variables in extrusion are:

- The die angle
- The ratio of the cross-sectional area of the billet to that of the extruded product, A_o/A_f
- The temperature of the billet
- The speed at which the ram travels
- The type of lubrication



Flow through a die

Benifits

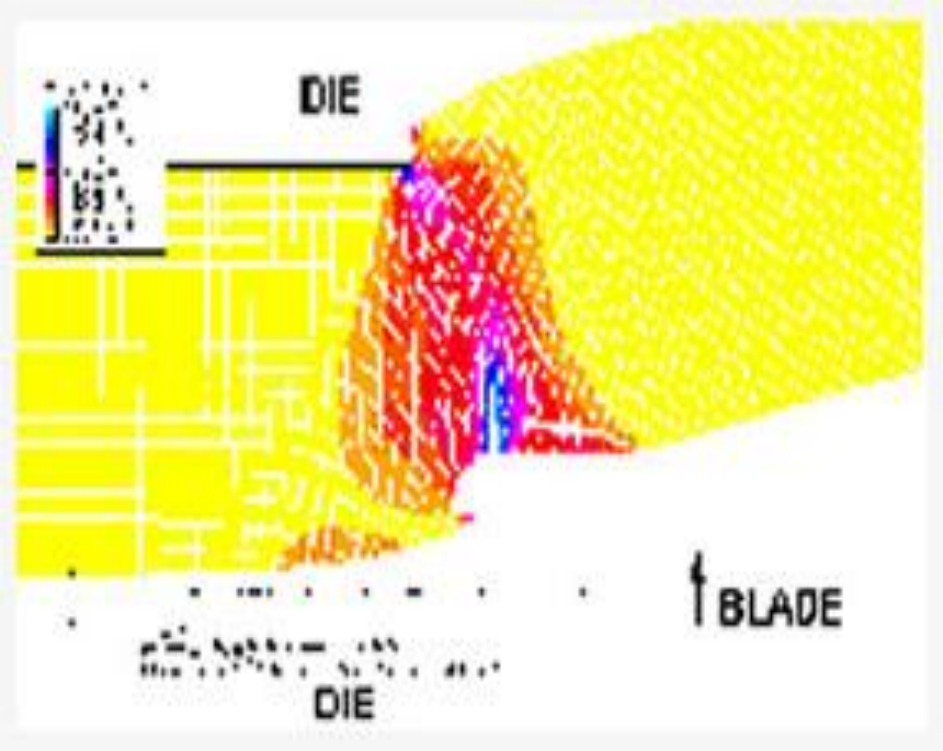
- A benefit to extrusions and Drawing process would be that large deformations can take place without fracture, because the material is under high triaxial compression during the process.
- Since the die geometry remains constant throughout the process extruded products have a constant cross-section

Characteristics of Sheet-Metal Forming Processes

- Drawing - shallow or deep parts with relatively simply shapes.
- Explosive – Large sheets with relatively simple shapes.
- Magnetic Pulse – Shallow forming, bulging, and embossing operations on relatively low-strength sheets
- Peen – Shallow contours on large sheets
- Roll – Long parts with constant simple or relatively complex cross sections.
- Rubber – Drawing and embossing of simple or relatively complex shapes.
- Spinning – Small or large axis-symmetric parts, good surface finish.
- Stamping – includes punching, blanking, embossing, bending, flanging, and coining.
- Stretch – Large parts with shallow contours.
- Superplastic – Complex shapes, fine detail and close dimensional tolerances.

Shearing

- Punch Force
  F = 0.7TL(UTS)
- Die Cutting
- Fine blanking
- Slitting
- Steel Rules
- Nibbling



COMPARISON OF :

F_1 = Cutting Force

F_2 = Vee-ring force

F_3 = Counter force

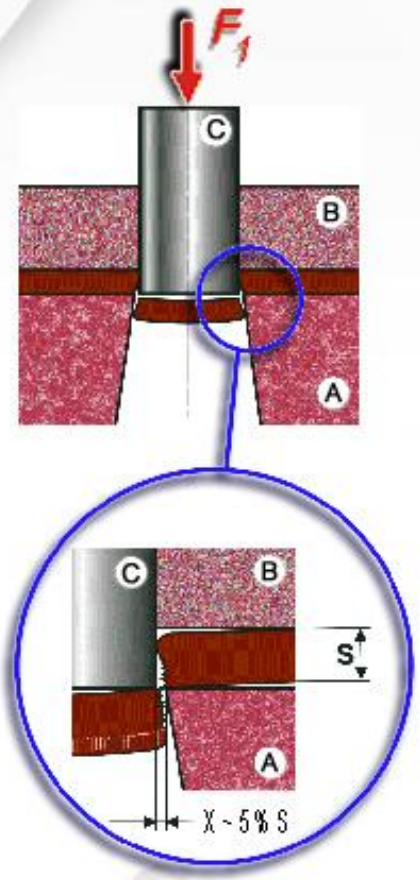
(A) = Die plate

(B) = Guide plate

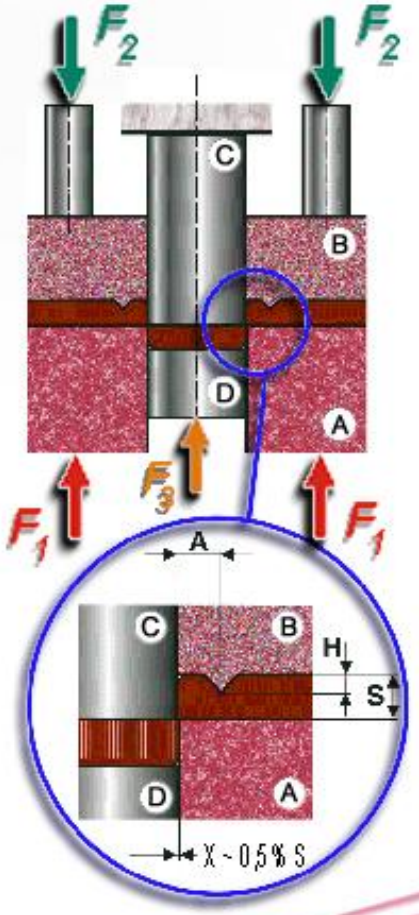
(C) = Punch

(D) = Ejector

CONVENTIONAL BLANKING



FINE BLANKING



UTIL INDUSTRIES

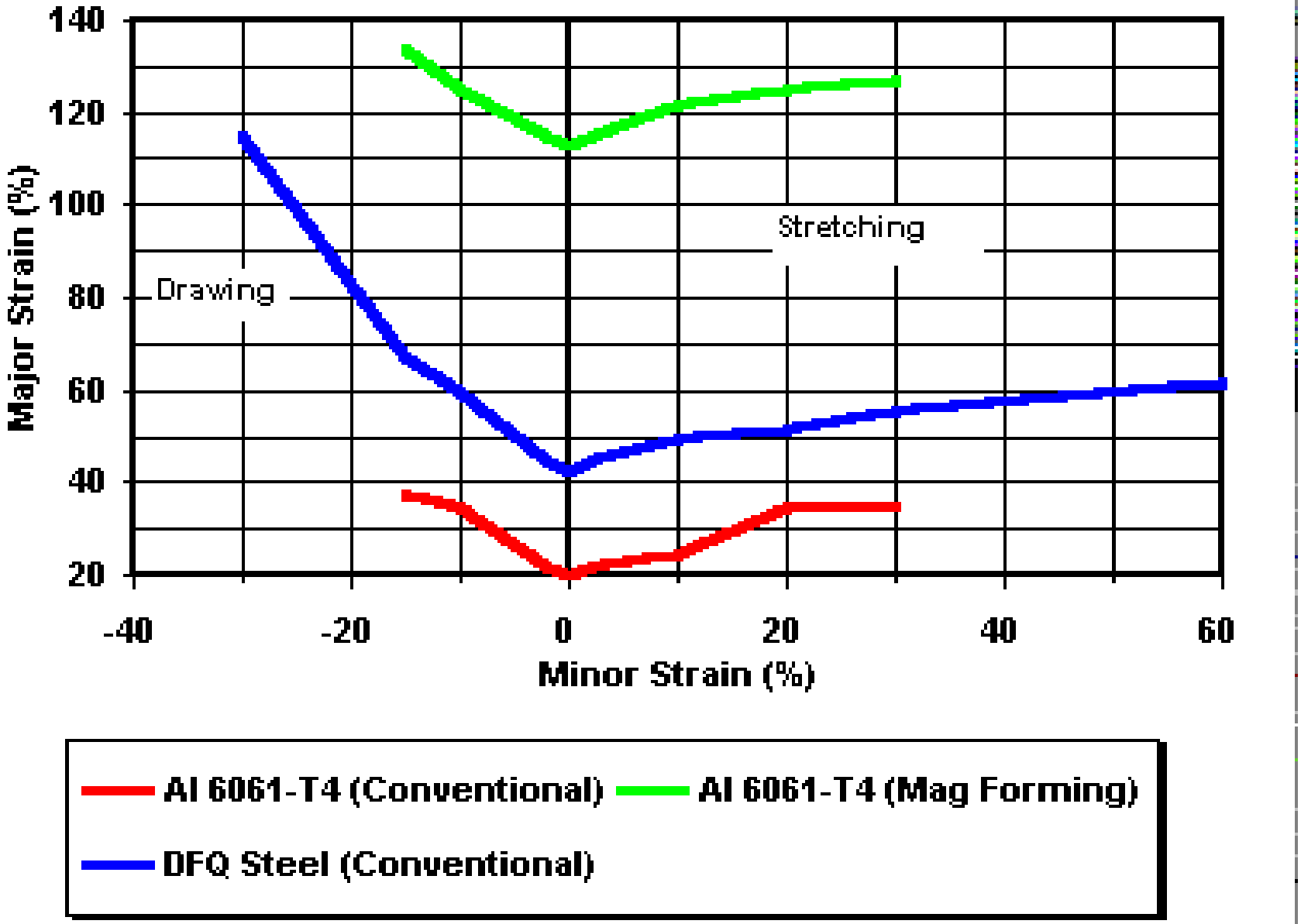
Miscellaneous cutting methods

- Laser-beam cutting
- Water-jet cutting
- Friction sawing
- Flame cutting
- Cutting with band saw

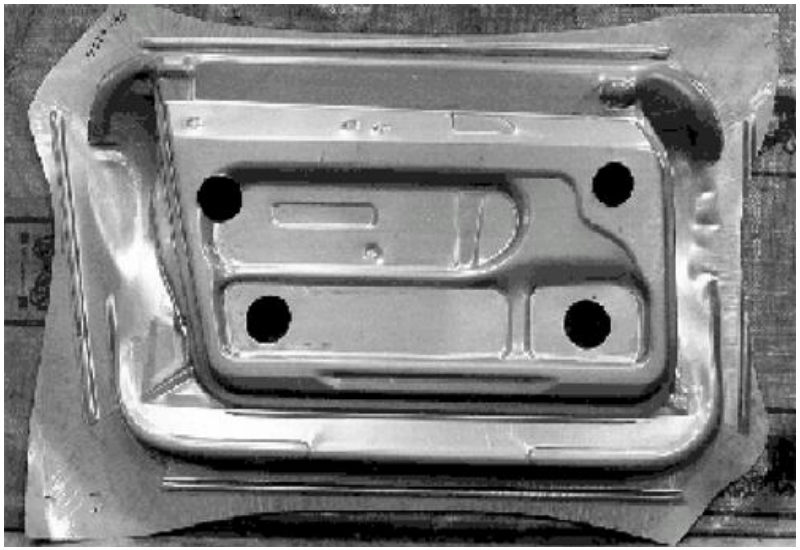

CUTTING
Laser

Characteristics of Metals

- Elongation
- Yield-Point Elongation
- Anisotropy (planar)
- Anisotropy (normal)
- Residual Stresses
- Springback
- Wrinkling
- Quality of sheared edges
- Surface condition of sheet

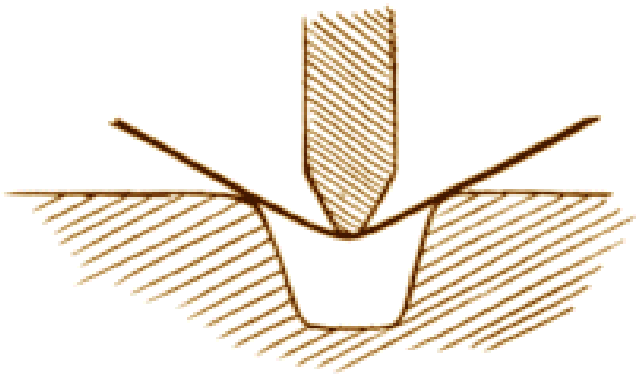

140
120
100
80
60
40
20
Major Strain (%)
Drawing
Stretching
-40
-20
0
20
40
60
Minor Strain (%)
Al 6061-T4 (Conventional)
Al 6061-T4 (Mag Forming)
DFQ Steel (Conventional)

Examples of sheet metal parts

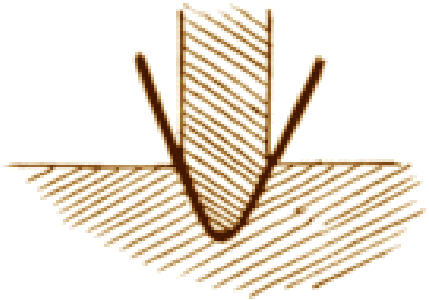


Bending

- Beyond yield strength but below the ultimate tensile strength
- Placed on die and bent using a simple punch.

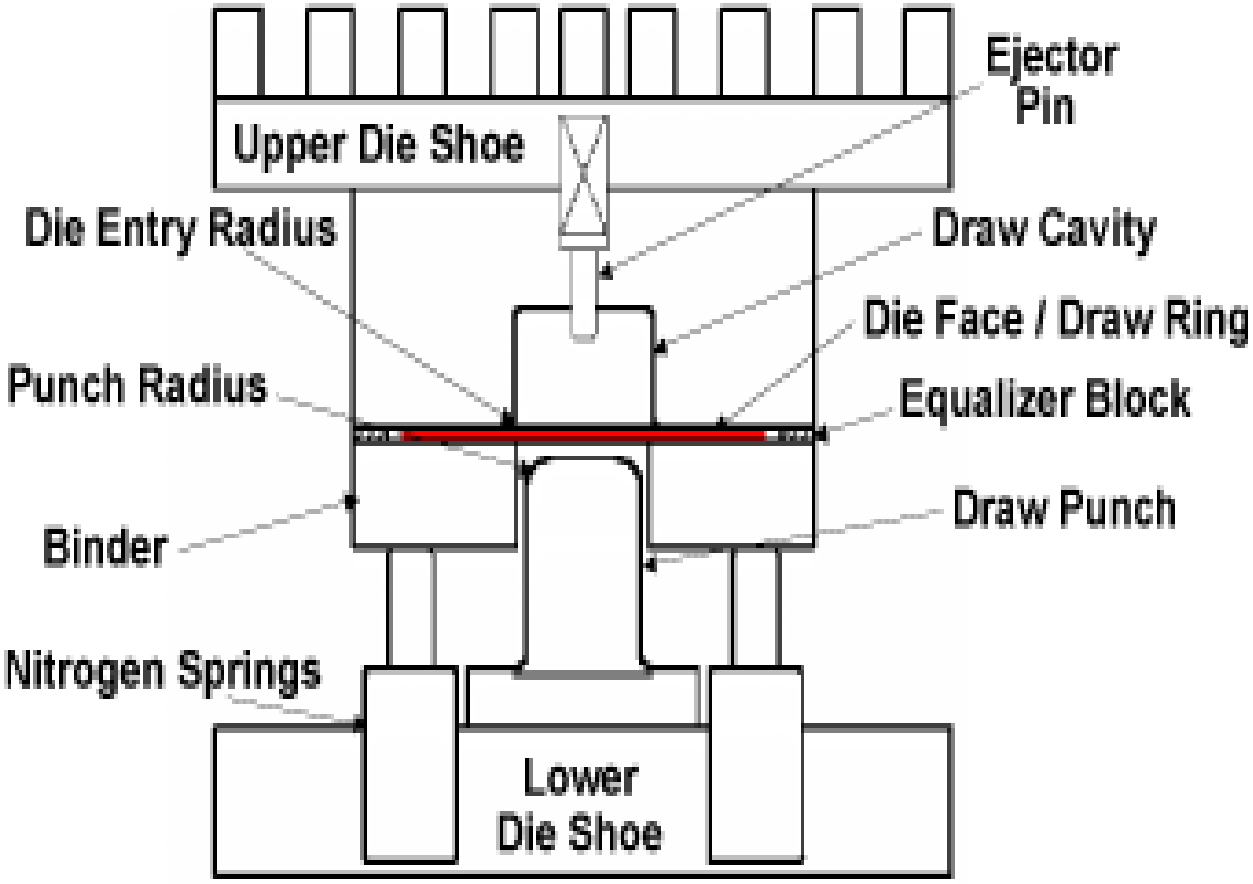


Air-Bending

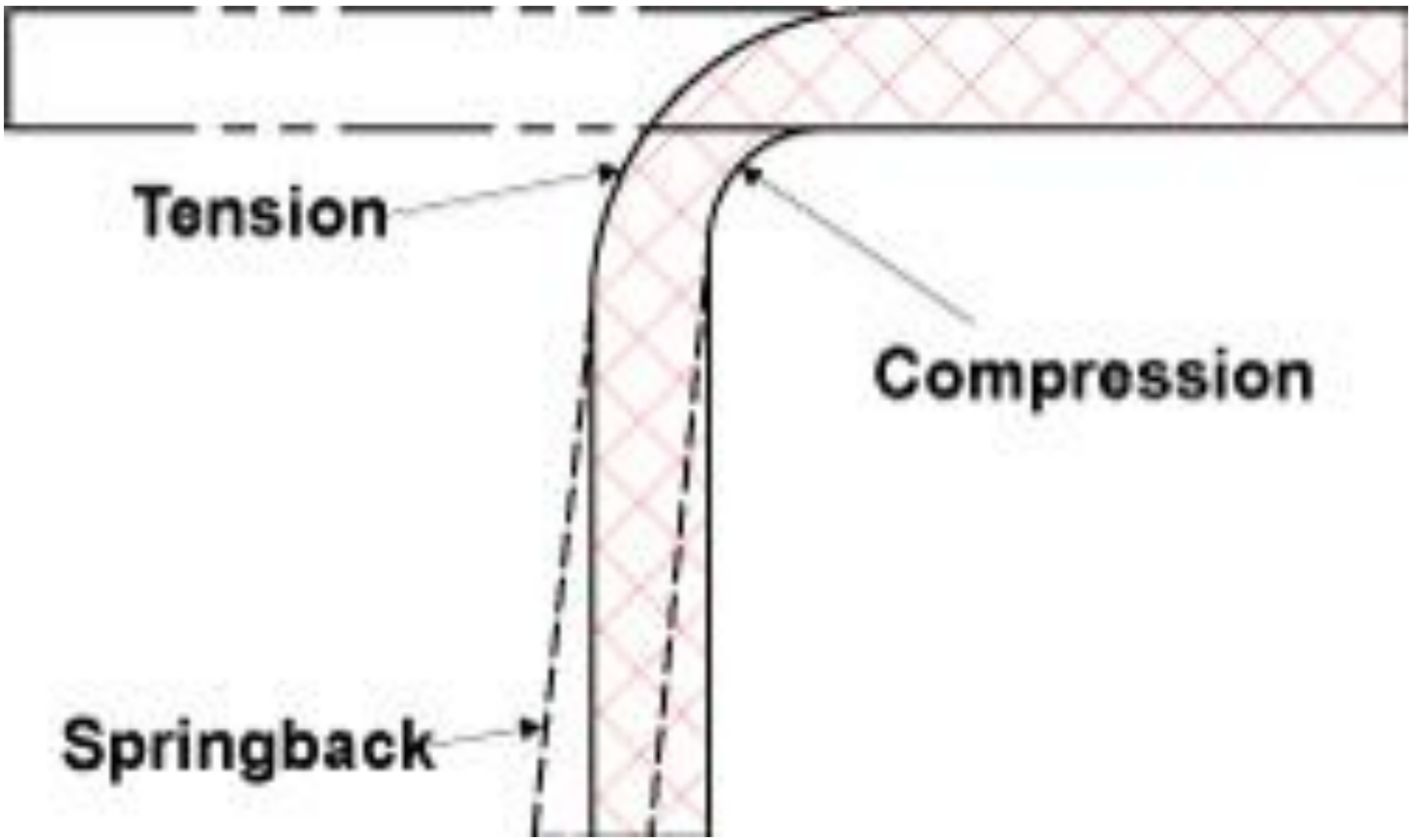


Bottoming

Bending Mechanism



Spring-back



Press Brake Forming

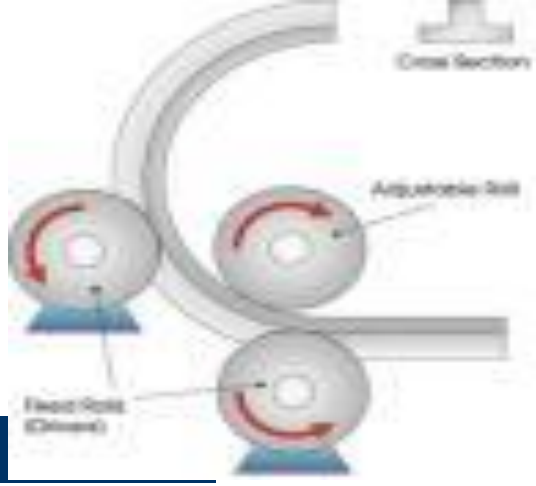
- Two- Stage Lock Seam
- Channel forming
- Joggle
- Hemming
- Off- Set forming

Clips for eyeglass cases!

Four- Slide Machine

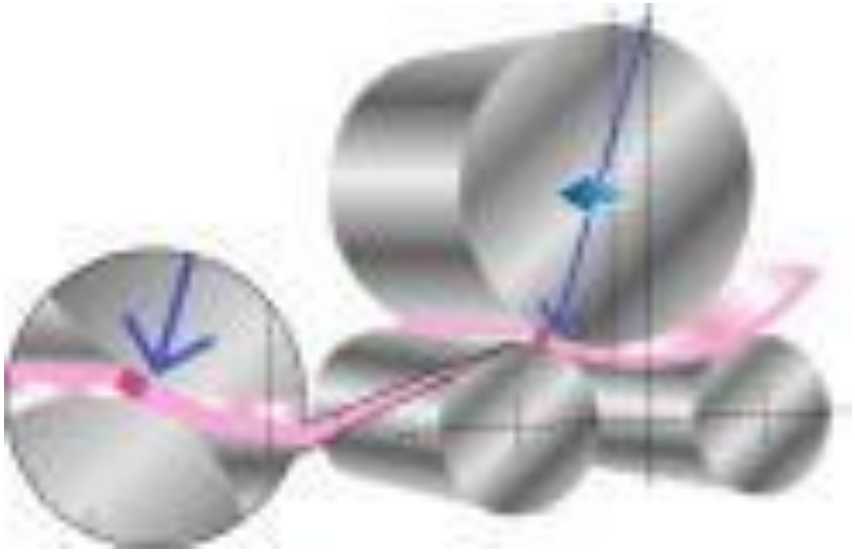
- Rapid production 60-240 parts/min
- Opposite directions
- Small parts
- Bend > 90˚

PICTURE
FRAMES



Roll Bending/ Forming

- Used for bending boilers, cylindrical pressure vessels, and any other curved structure
- Flexible adjustments

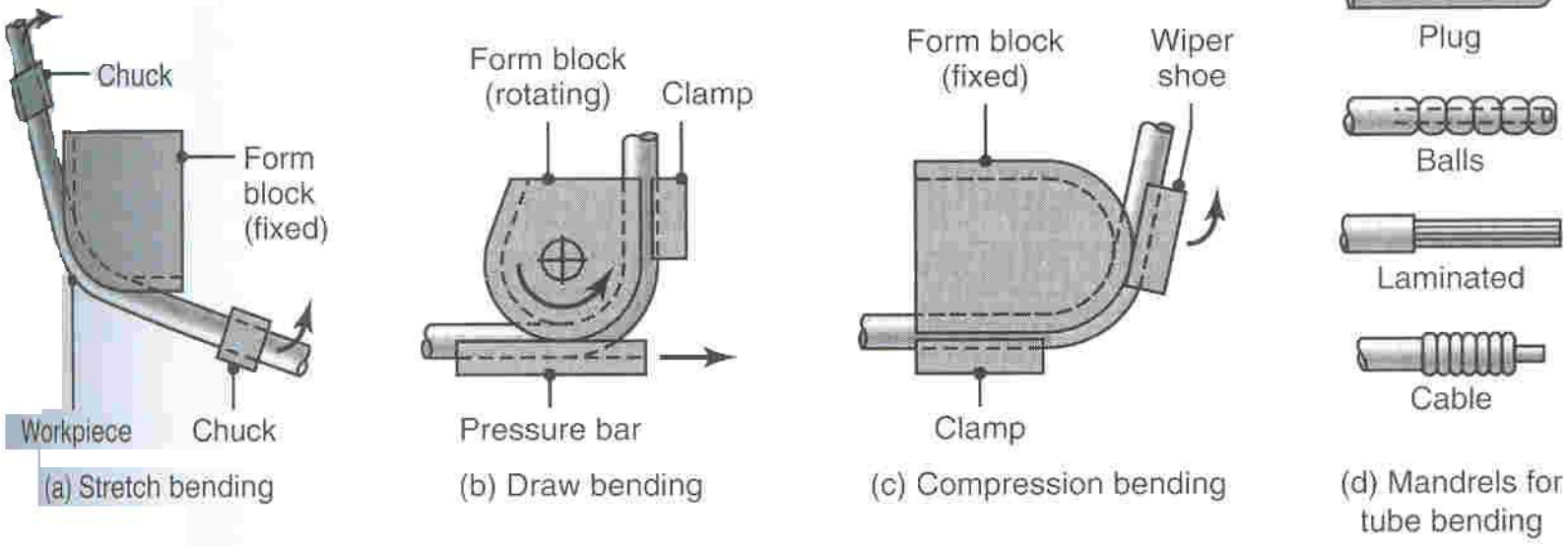


Tube Bending and Forming

- Work-piece
- Pressure Bar
- Clamp

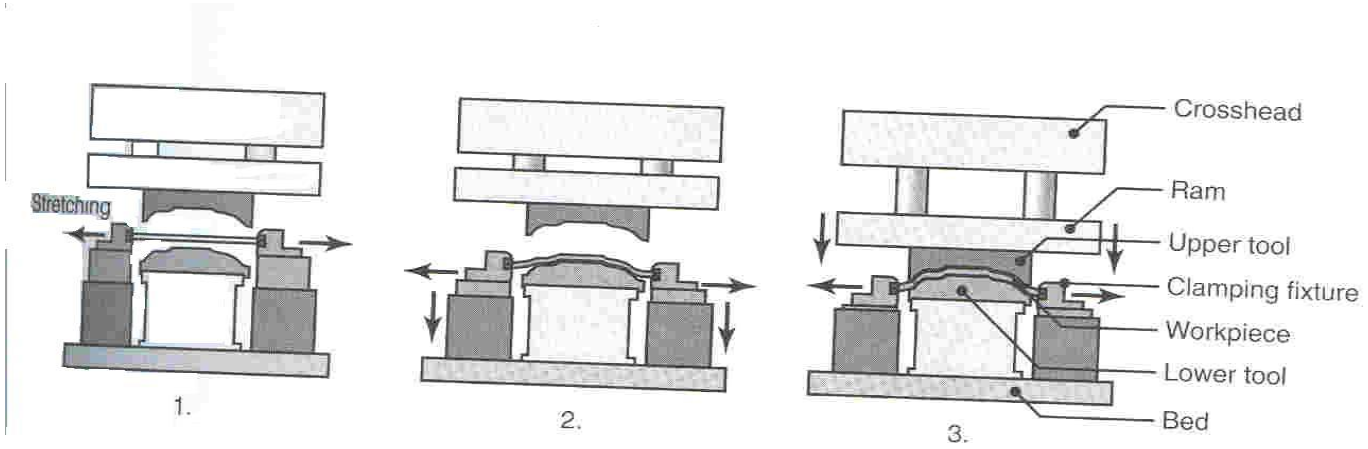
*** Internal filling is sometimes necessary to prevent collapse.**

Tube Bending and Forming



Stretch Forming

- Metal stretched across male die and clamped on edges
- Commonly used to mold aircraft wing-skin panels.
- Low volume production

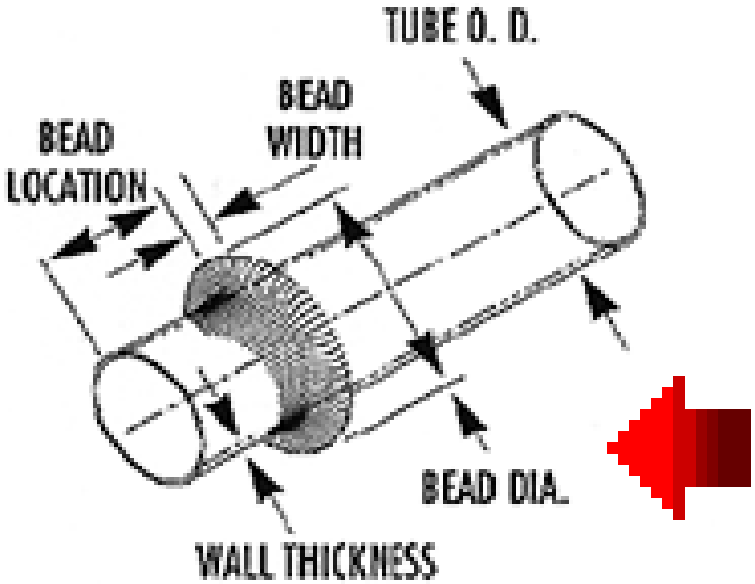


Rubber Forming?

- Thin strip of rubber placed on punch.
- Advantages
  - Resistance to abrasion
  - Resistance to cutting or tearing
  - Long fatigue life

Additional Operations

Flanging- edge bending of sheet metal



Bulging- tubular expansion

Beading- sheet metal bent into cavity

Deep Drawing

Relatively complex 3 dimensional shapes can be made out of sheet metal!

Start Over

Blanking

Seaming

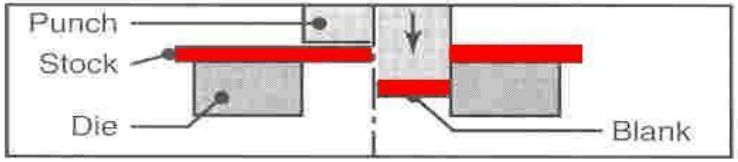
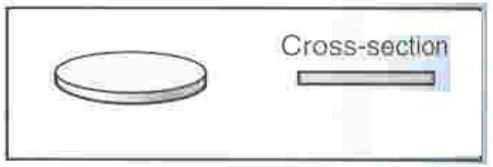
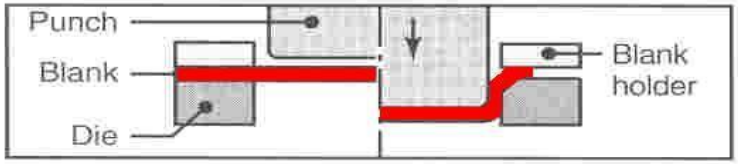
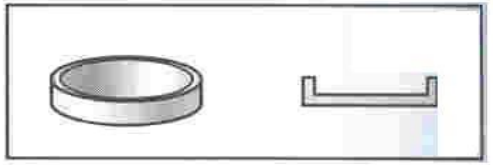
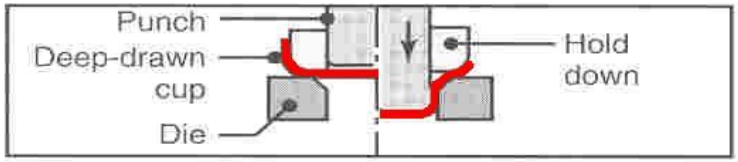
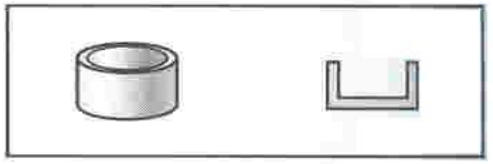
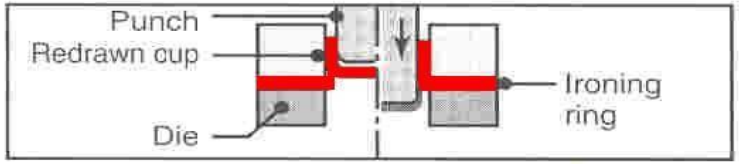
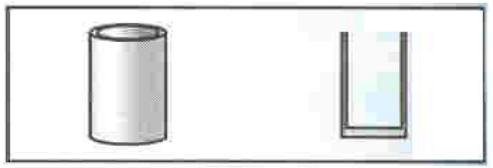
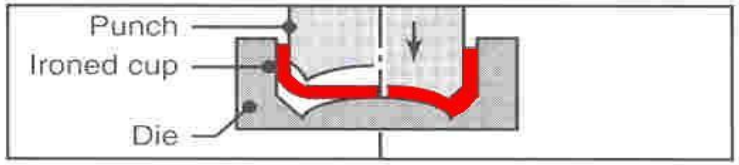
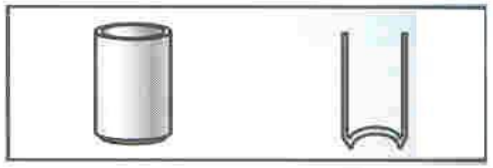
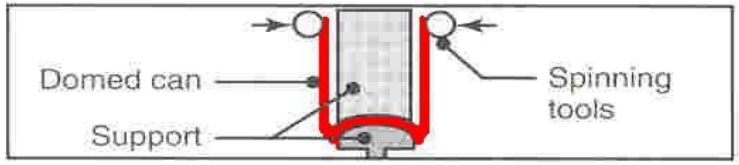
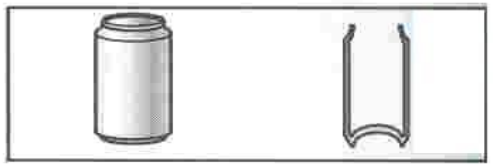
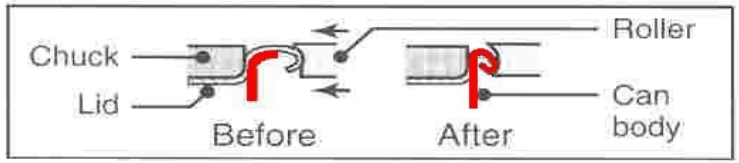
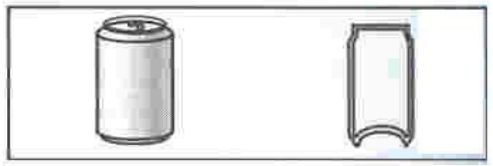
Deep Drawing

Necking

Redrawing

Doming

Ironing

Process	Process illustration	Result
1. Blanking		
2. Deep drawing		
3. Redrawing		
4. Ironing		
5. Doming		
6. Necking		
7. Seaming		

Examples of Deep Drawing

Spinning and Forming

What is Spinning?

- Spinning is the process of forming sheet metals or tubing into contoured and hollow circular shapes.

Advantages

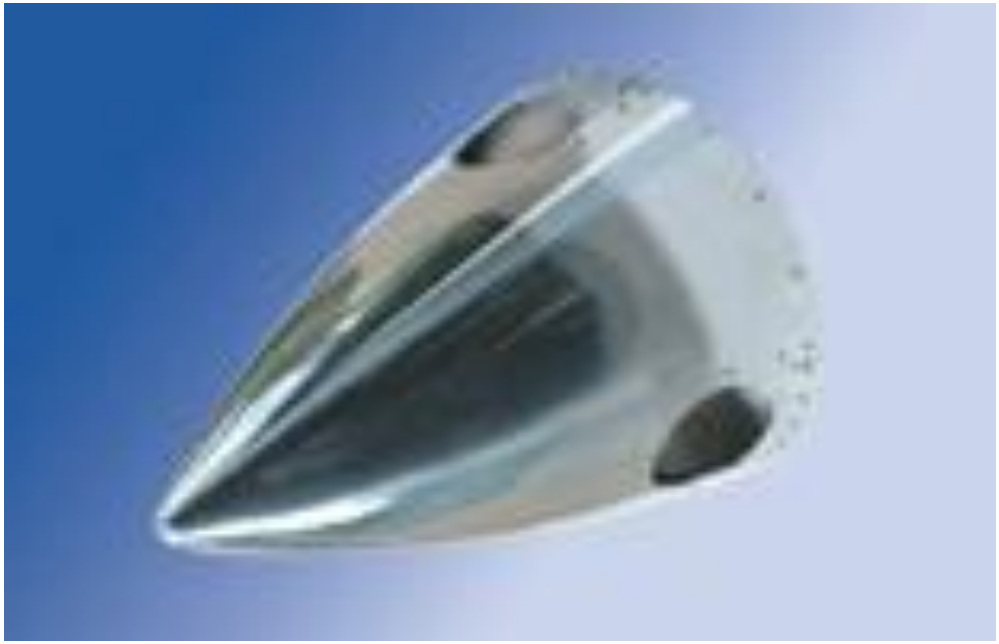
- Low cost
- High work rate

Types

- Conventional
- Sheer
- Tube

Conventional Spinning

- Great for conical shapes



Conventional- Mandrel

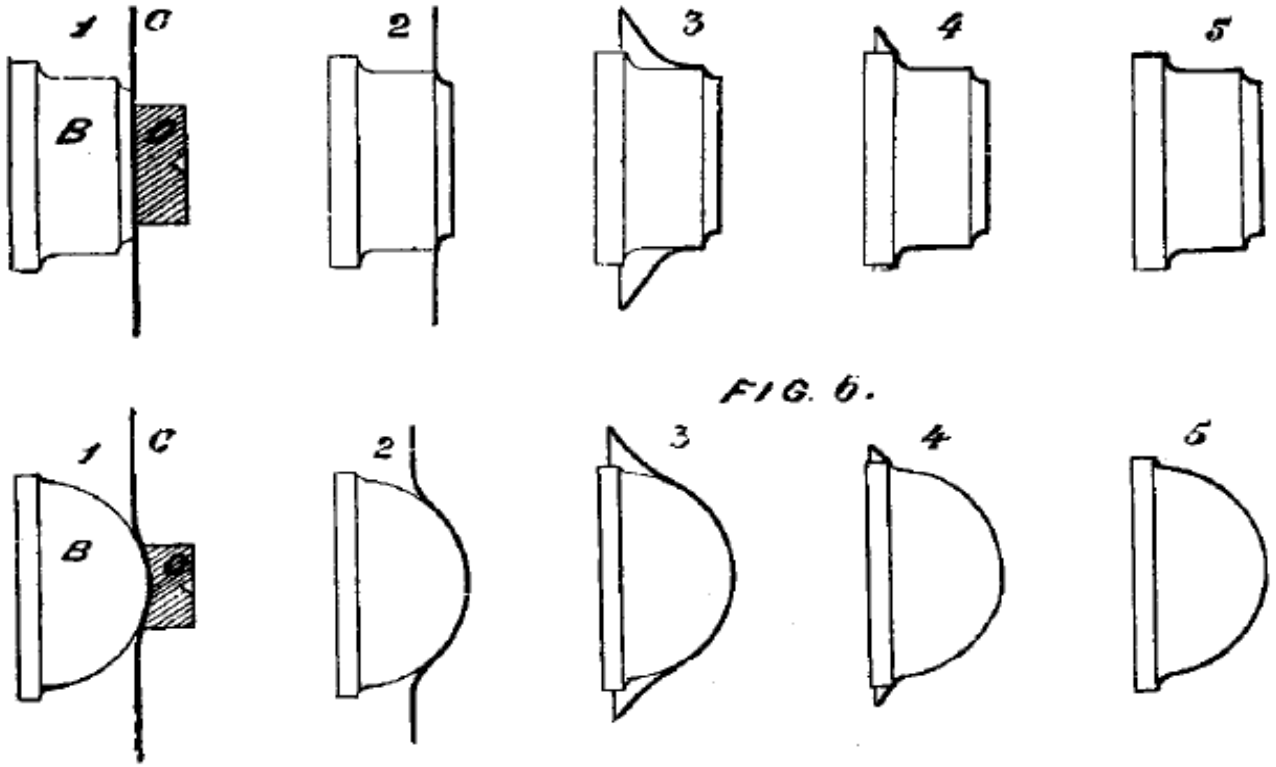


FIG. 6.

Conventional- Tools

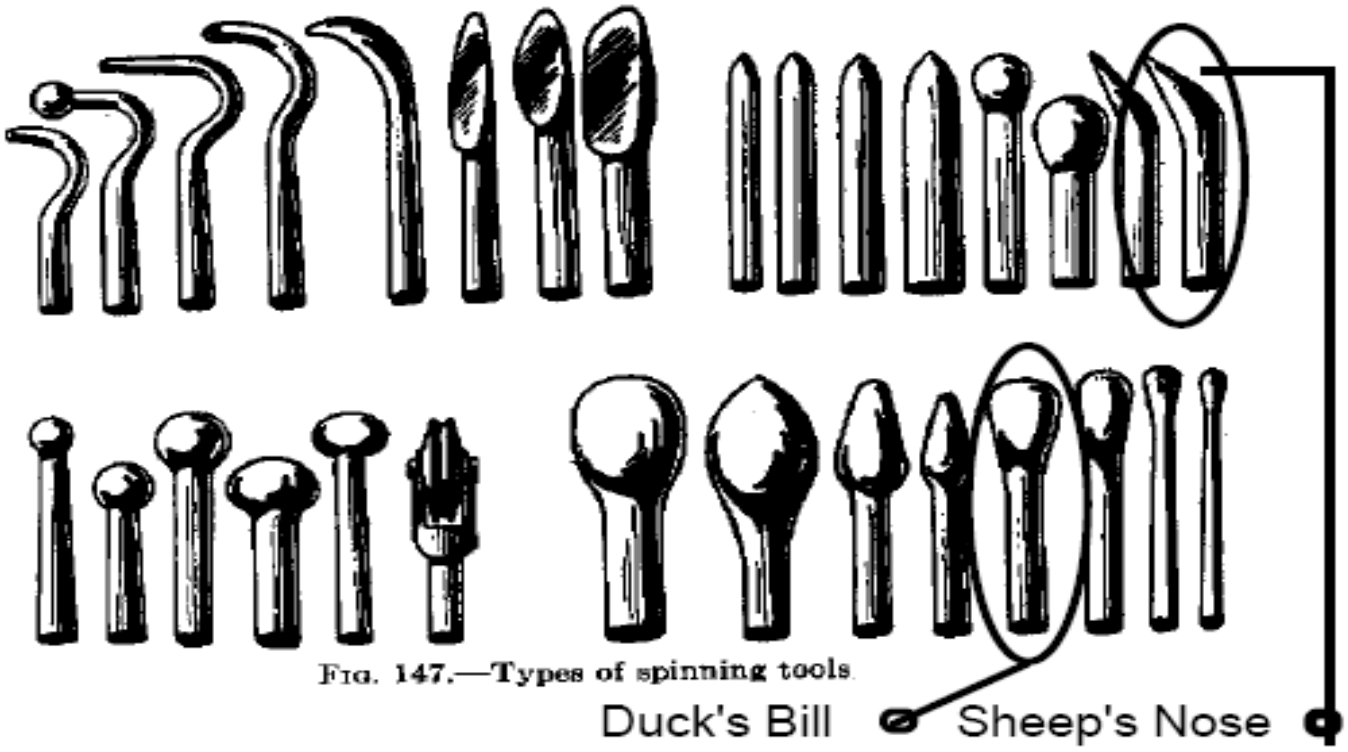
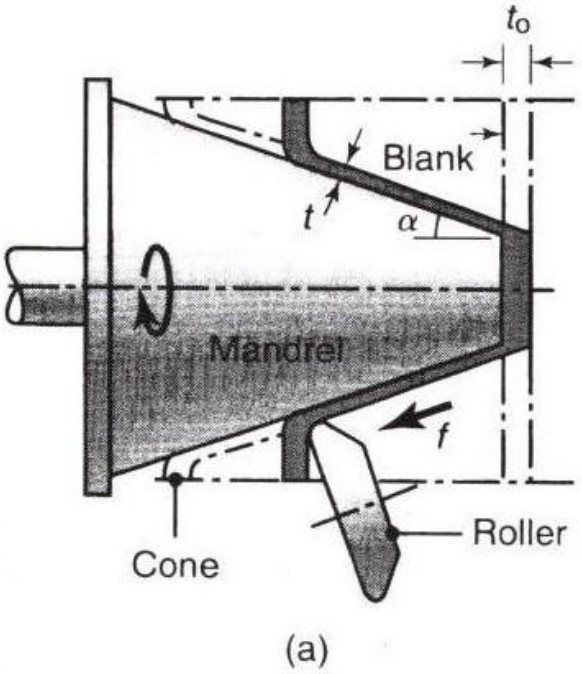


Fig. 147.—Types of spinning tools

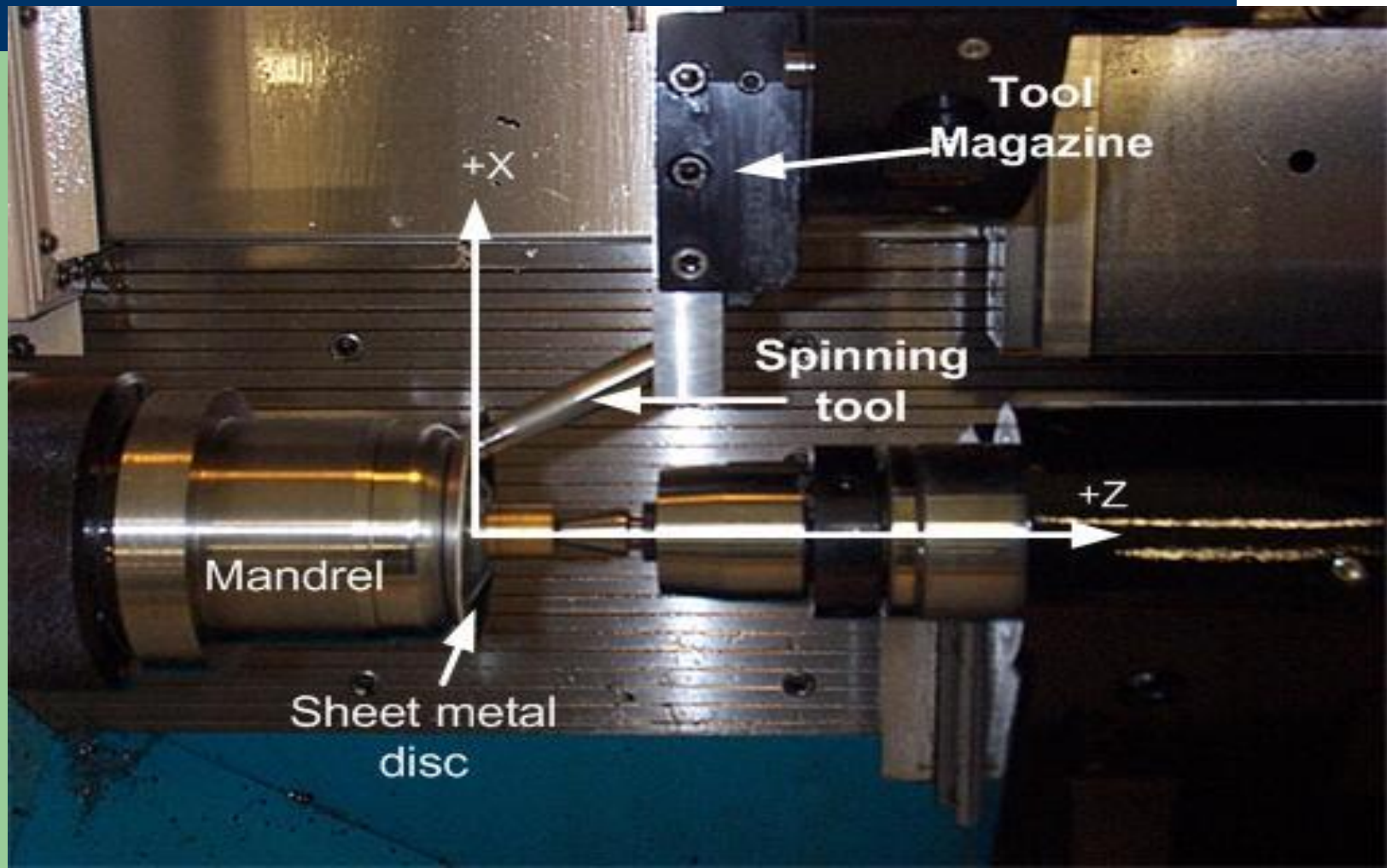
Sheer Spinning

- Uses rollers
- Faster than conventional

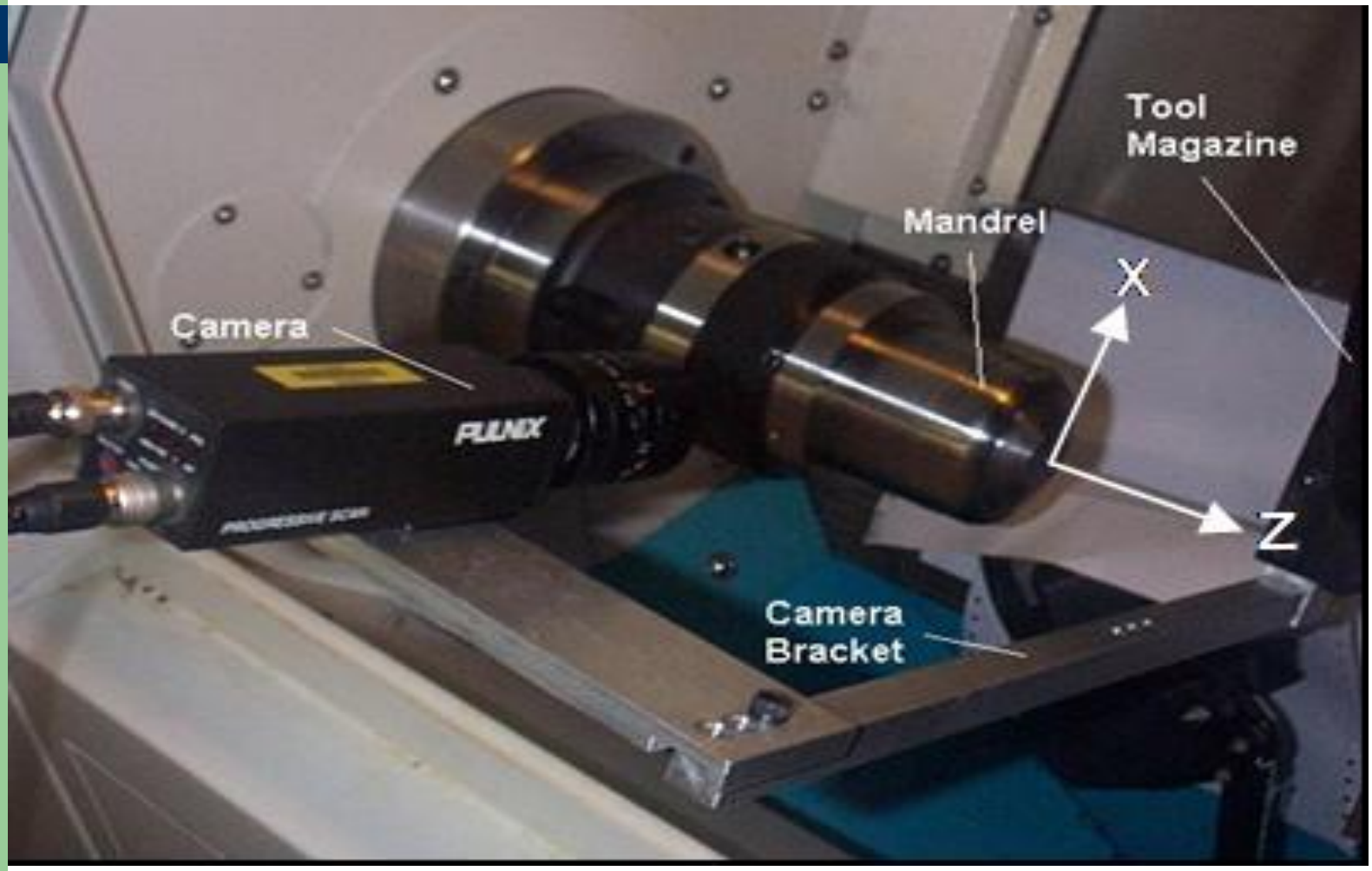


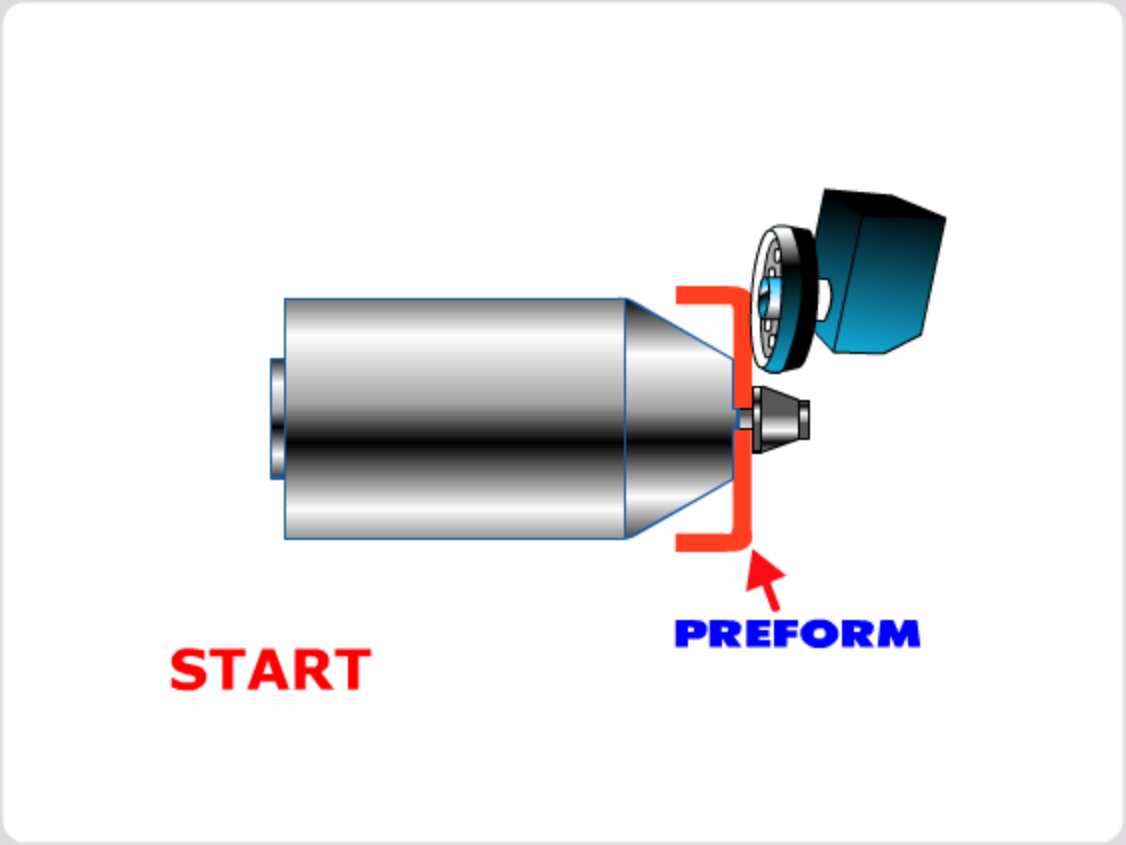
(a)

Sheer Spinning



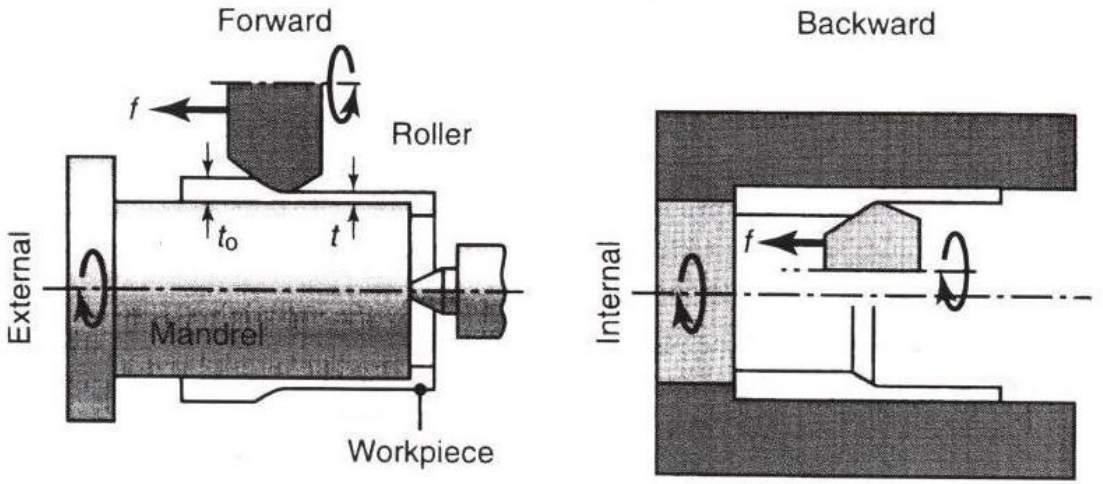
Sheer Spinning




PREFORM
START

Tube

- Great for tubes
- Similar to Sheer- reduces thickness from the inside or outside



Forming

- Superplastic/Diffusion Bonding
- Explosive
- Magnetic-pulse
- Peen
- Laser
- Micro
- Electrohydraulic

Superplastic

- Superplastic is a state when material has high ductile elongation within certain temperature ranges
- Common superplastic alloys: zinc-aluminum and titanium alloy

Advantages

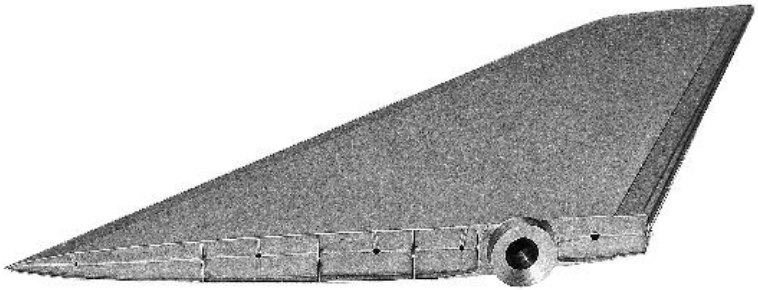
- Complex shapes
- Little or no residual stress
- Able to use tool with lower strength- low tooling cost

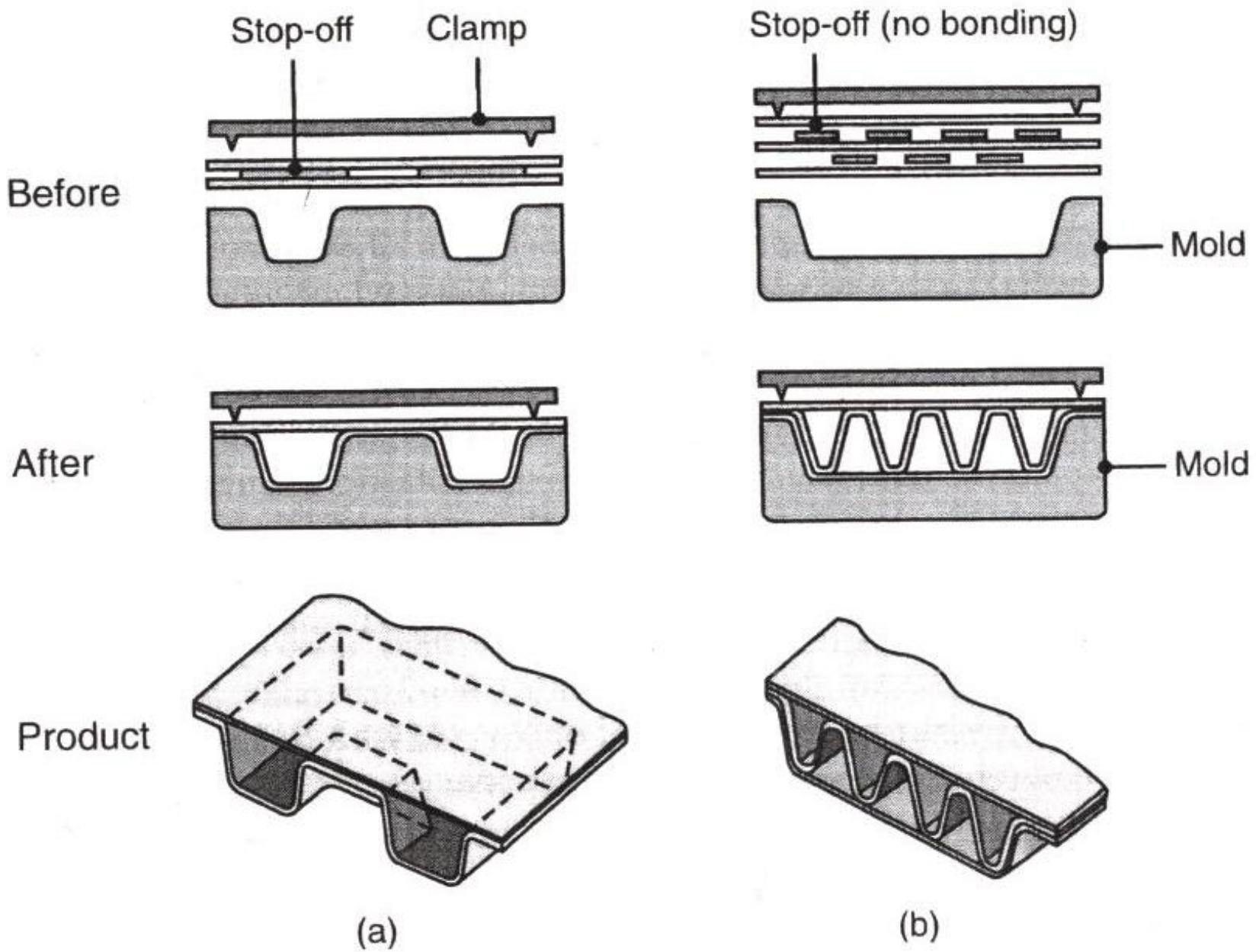
Disadvantages

- Material must not become superplastic at service temperature
- Low strain rates

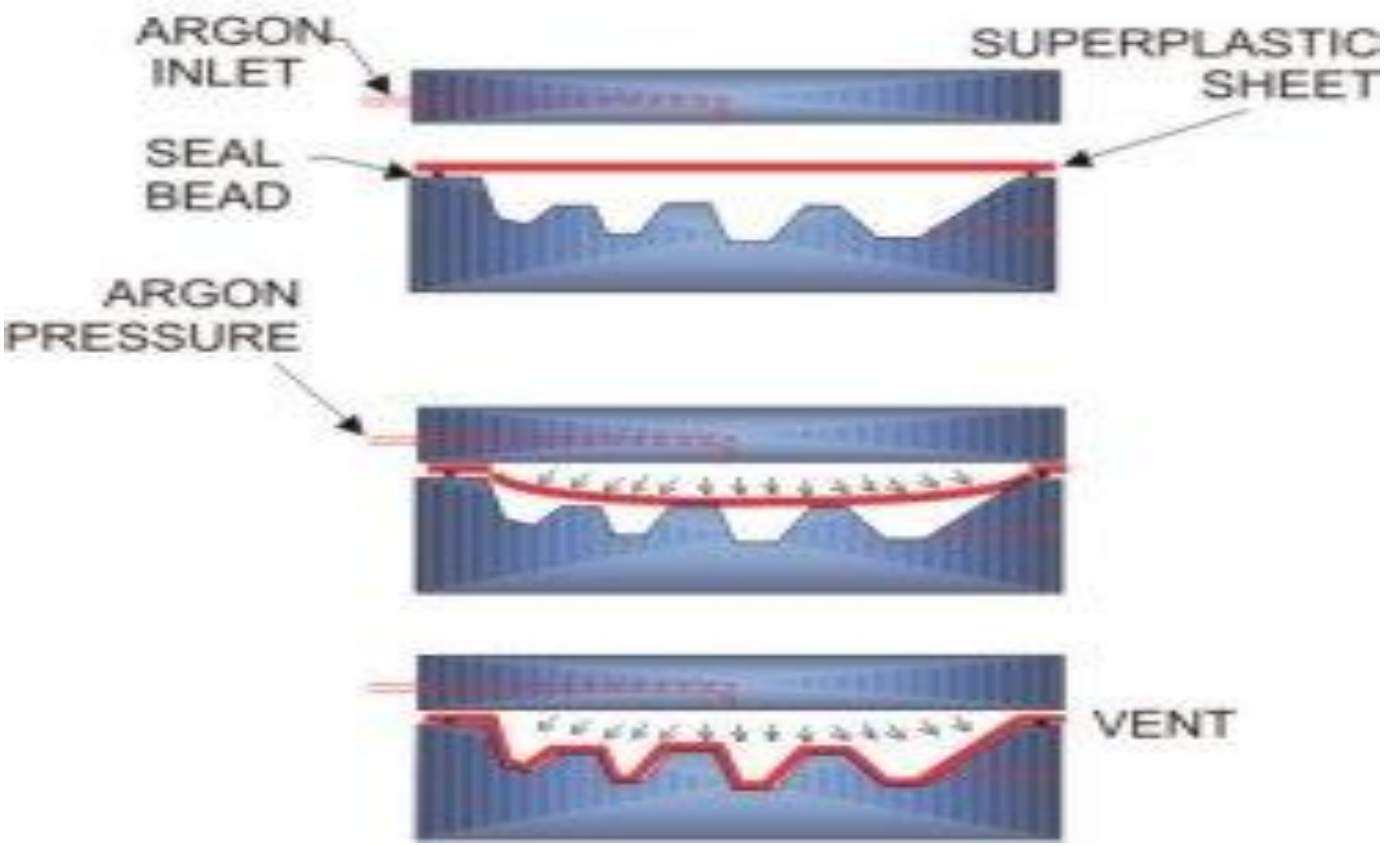
Diffusion Bonding/Superplastic

- Used for parts of aircrafts
- High stiffness-to-weight ratio




Stop-off
Clamp
Stop-off (no bonding)
Before
Mold
After
Mold
Product
(a)
(b)

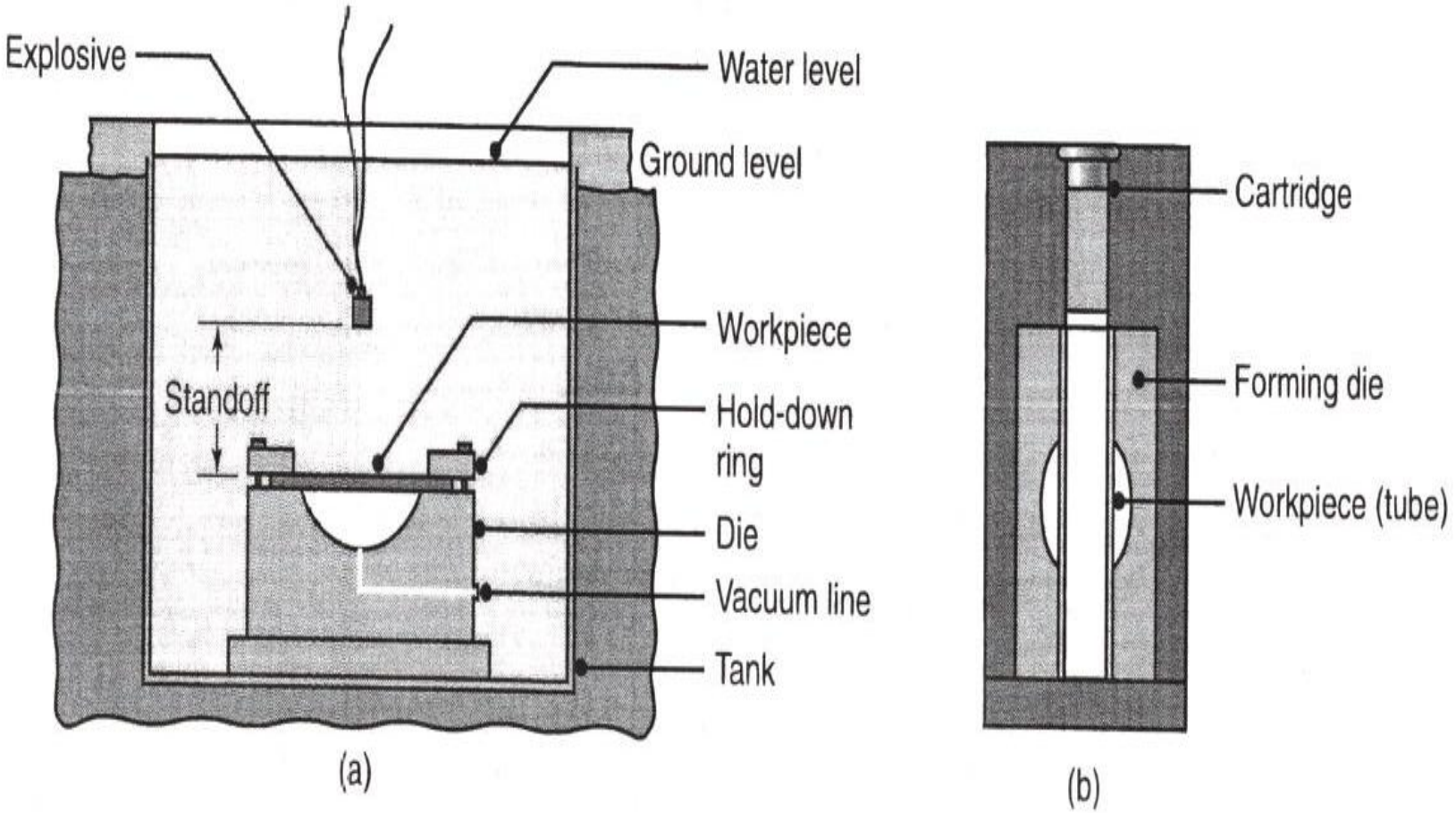
Diffusion Bonding



Explosive

- Uses shockwave (pressure) to force formation
- Material must be ductile at high rate of deformation

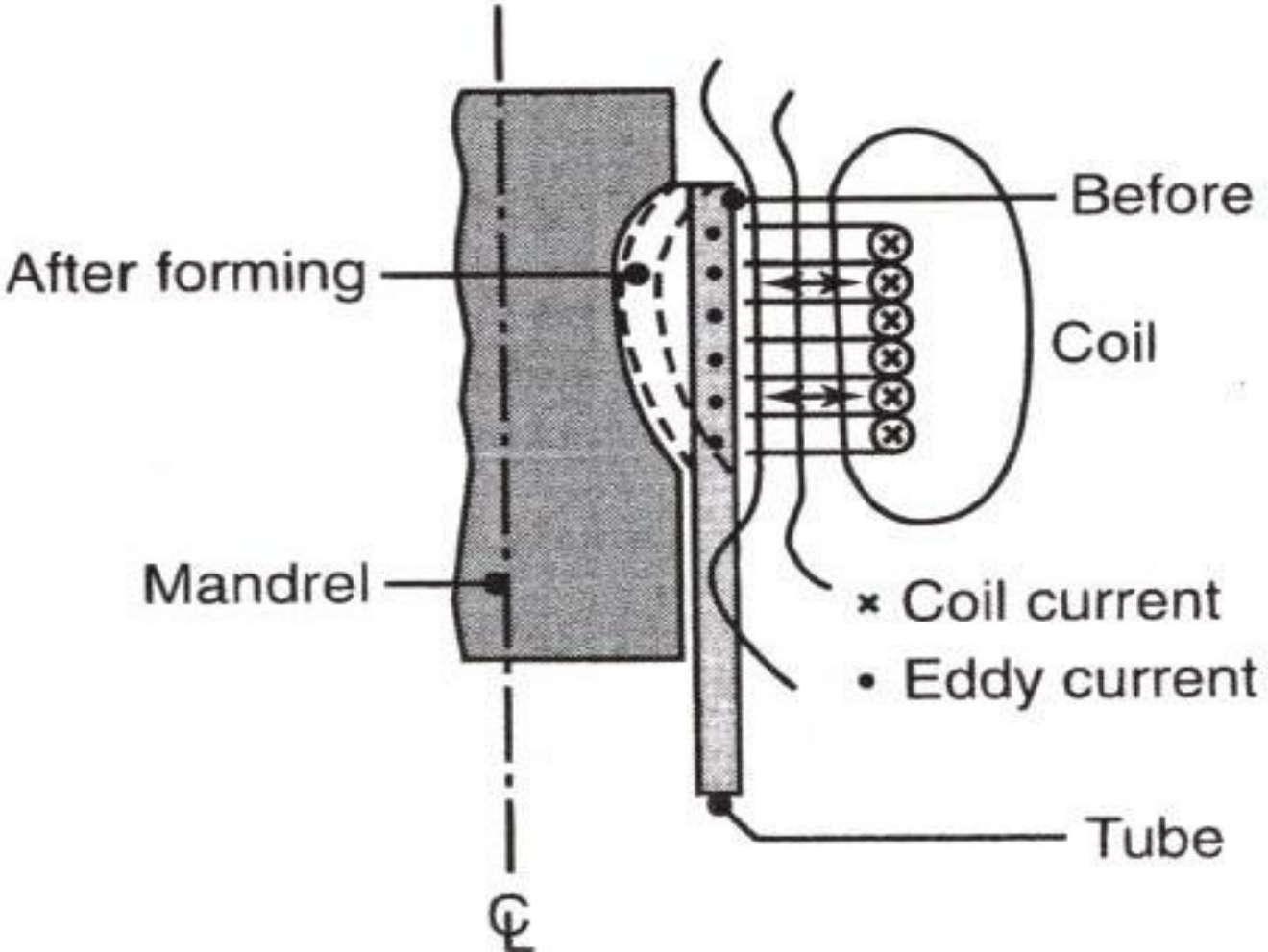
Explosive


Explosive
Water level
Ground level
Workpiece
Standoff
Hold-down ring
Die
Vacuum line
Tank
(a)
Cartridge
Forming die
Workpiece (tube)
(b)

Magnetic-Pulse

- Uses magnetic force discharged from a magnetic coil
- Material must have electrical conductivity

Magnetic-Pulse



Peen Forming

Peen Forming

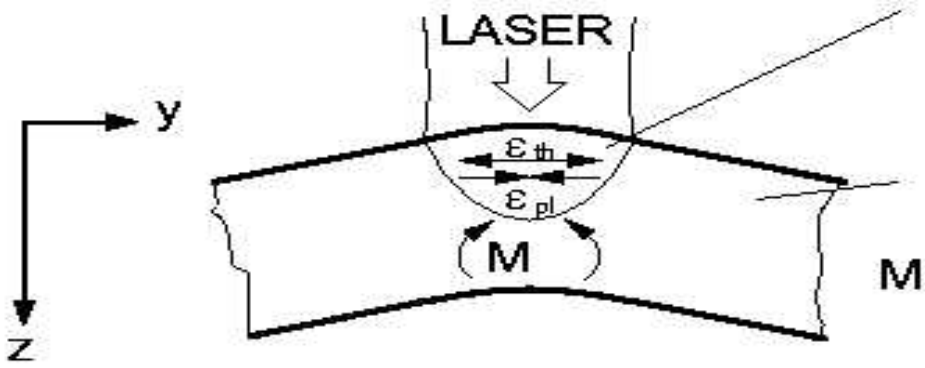
- Used to produce curvature by discharging steel balls (little hammers)
- Material shaped by shot peen has higher resistance to flexural bending fatigue

Peen Forming

Laser Forming

- Uses laser to heat material locally for forming
- Laser causes thermal stress and deformation
- For bending or straightening

heating - counterbending

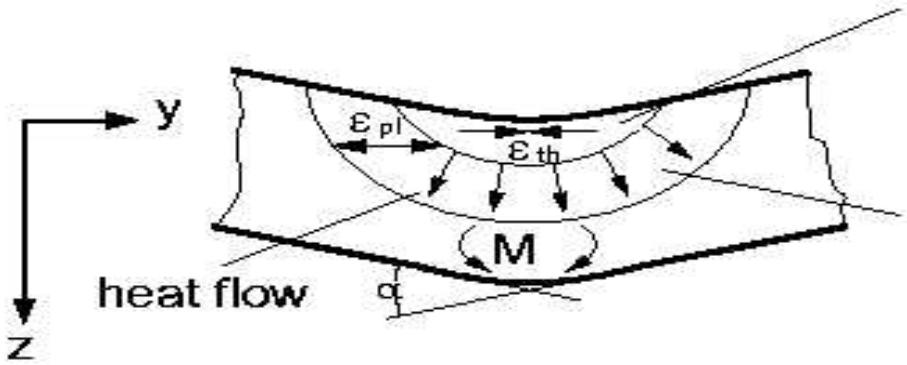


heated zone
compressive stress
1

sheet metal

M: Moment due to section modulus and bend angle α

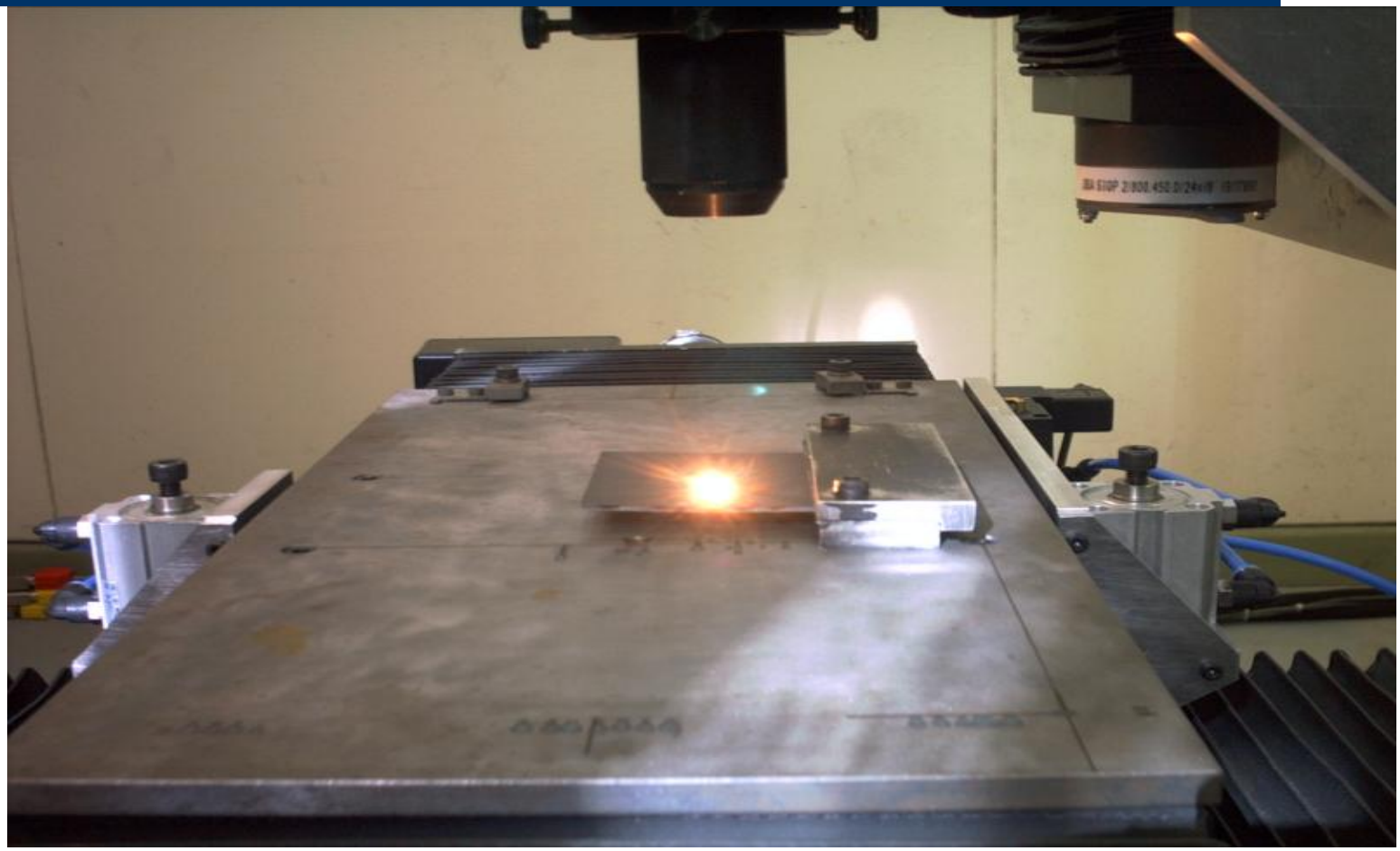
cooling - positive bending



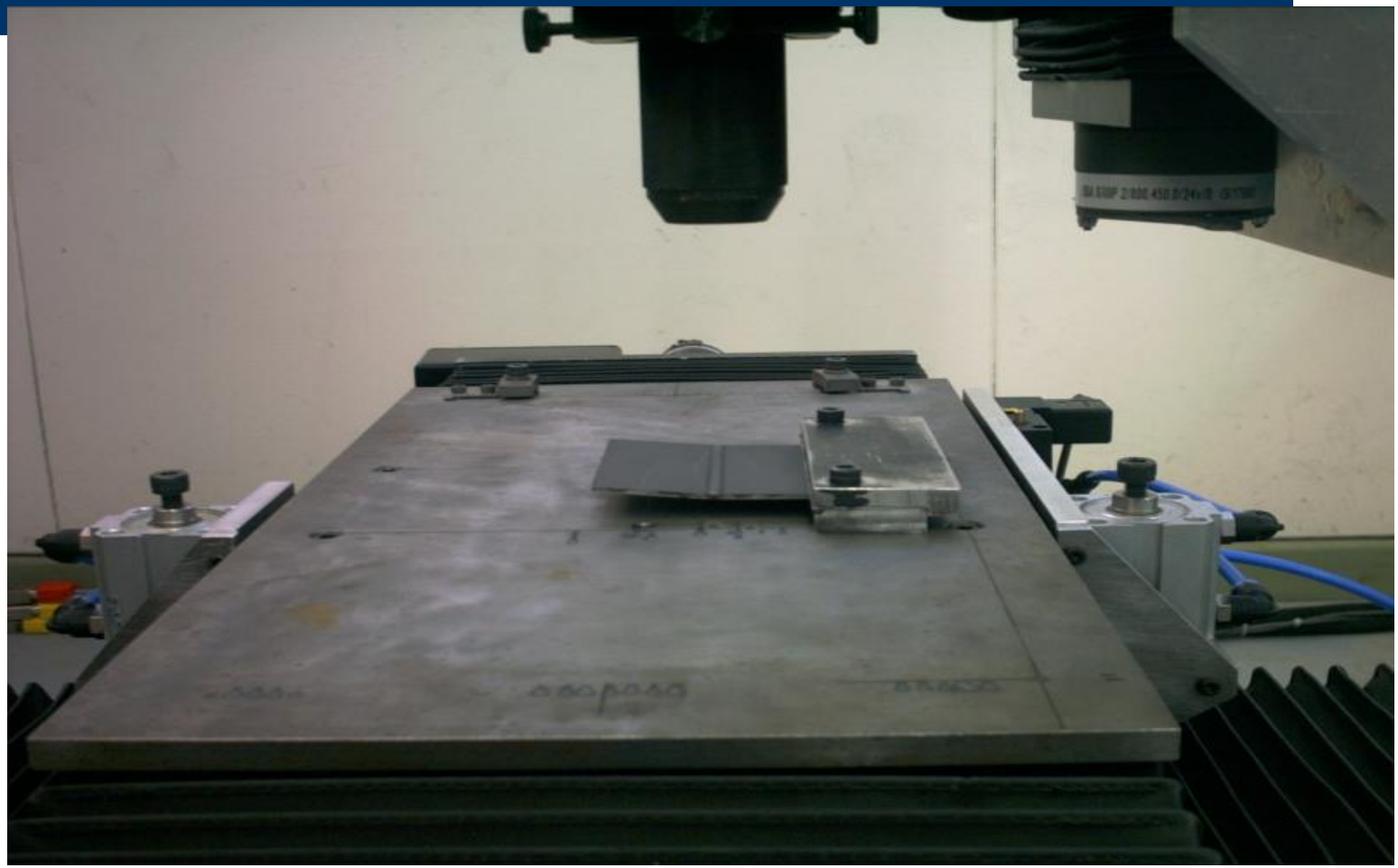
compressed zone
tensile stress
2

expansion
compressive stress
3

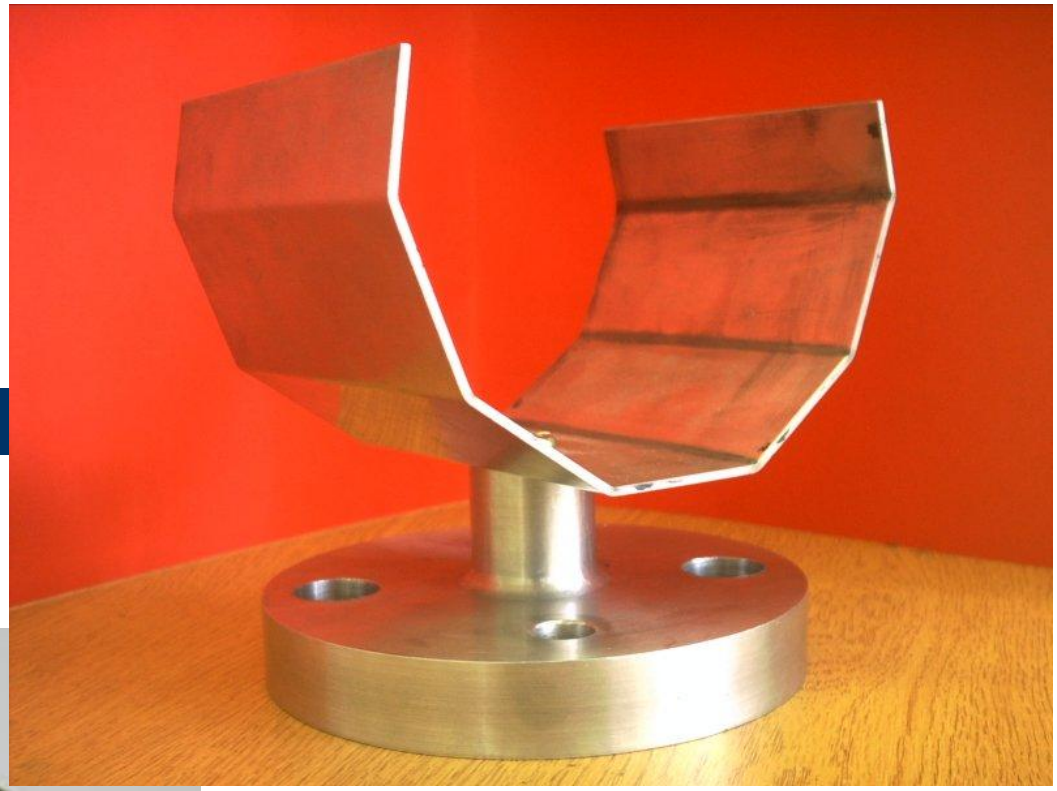
During Pass

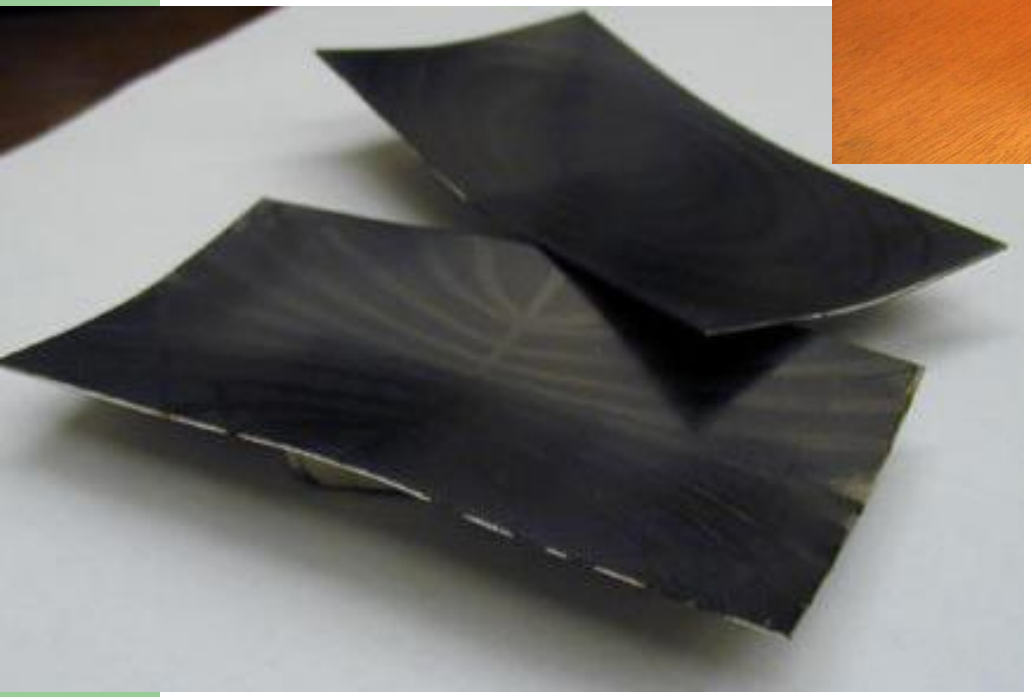


After Pass



Result





Microforming

- A family of process that produce small metallic parts

Fig. 1: Forming Assembly

Fig. 2: Segmented Dies

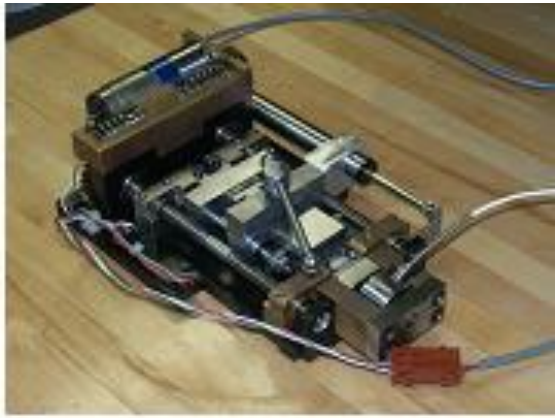
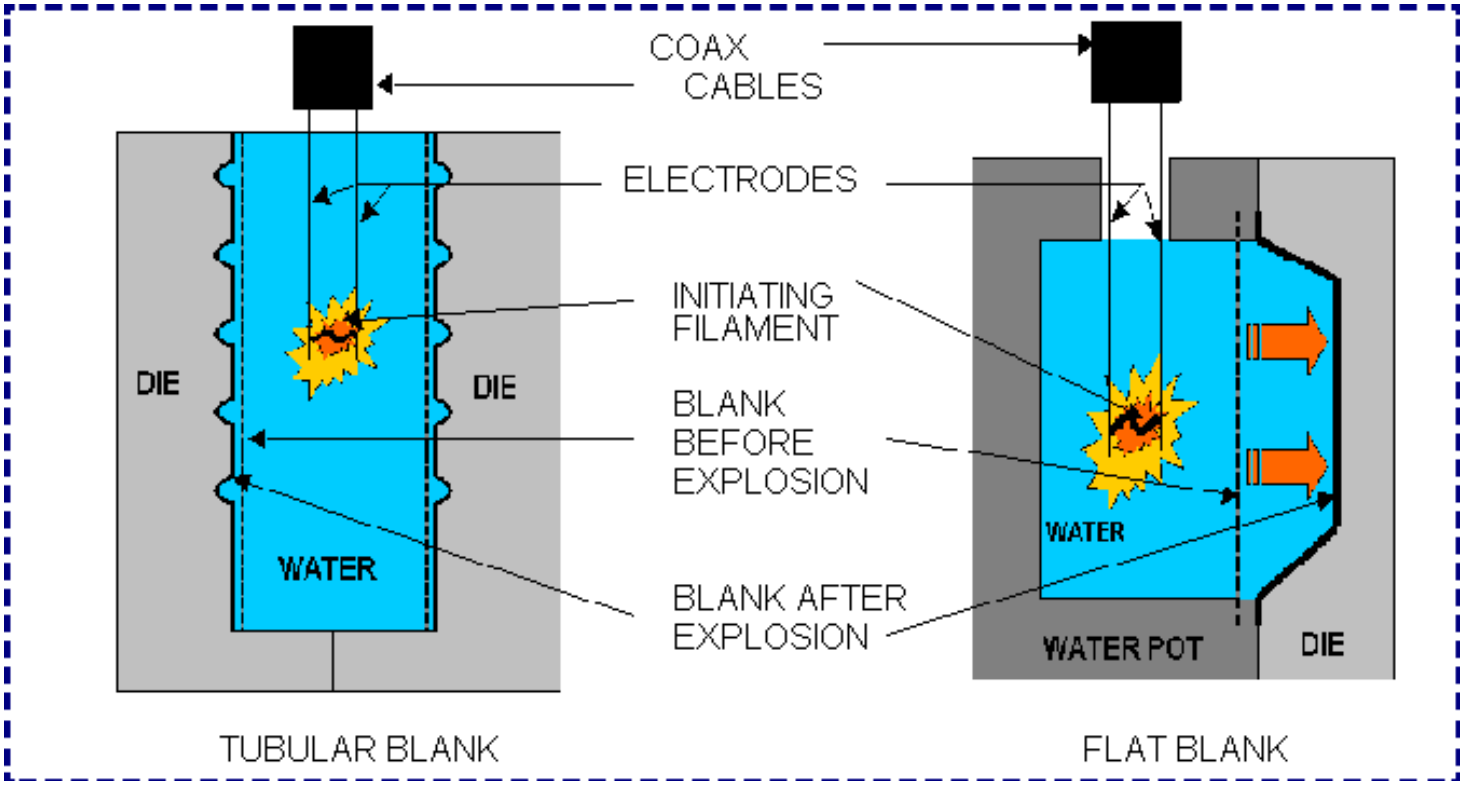


Fig. 3: Loading Stage

Electrohydraulic

- Similar to Explosive forming
- Discharges energy between electrodes to create shockwaves
- Used under water medium to develop pressure
- Less energy than Explosive

Electrohydraulic

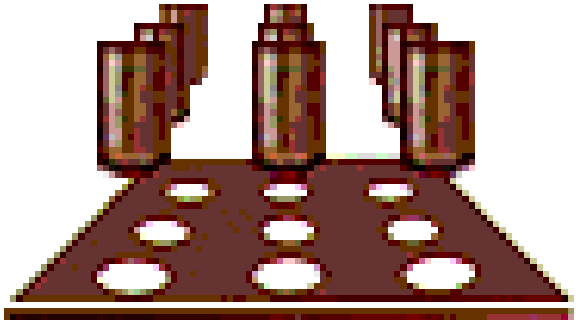


Sheet Metal Forming Techniques

- Blanking
- Stamping
- Pressing
- Drawing
- Deep Drawing

Cost Optimization With Blanking

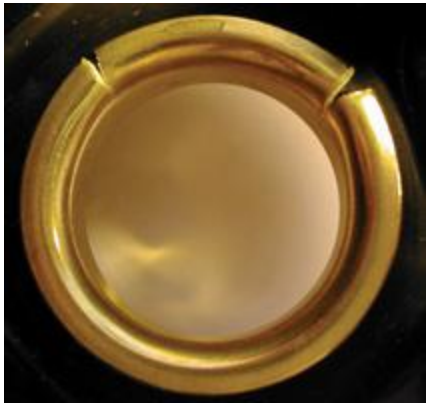
- Parts should be nested into patterns to reduce scrap metal
- Patterns should fit the sheet of metal they will be punched from to minimize waste



Producing Better Blanks

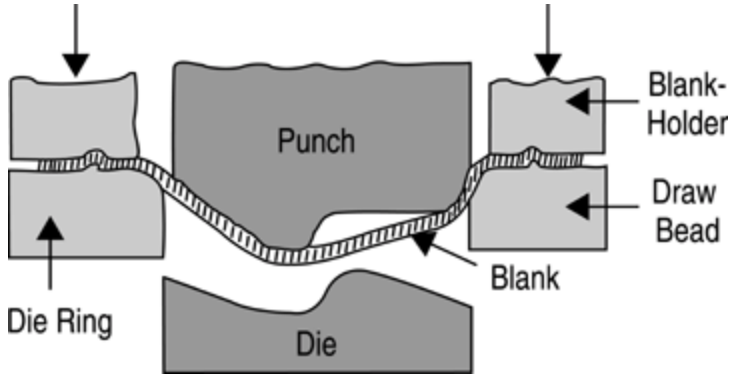
- If blanks are not cut properly, the metal can be stretched be cutting instruments as it is sheared
- This can lead to microcracks and distortion in the blank

Microcracks can lead to cracks and distortion as a blank is shaped



Stamping, Drawing, Pressing

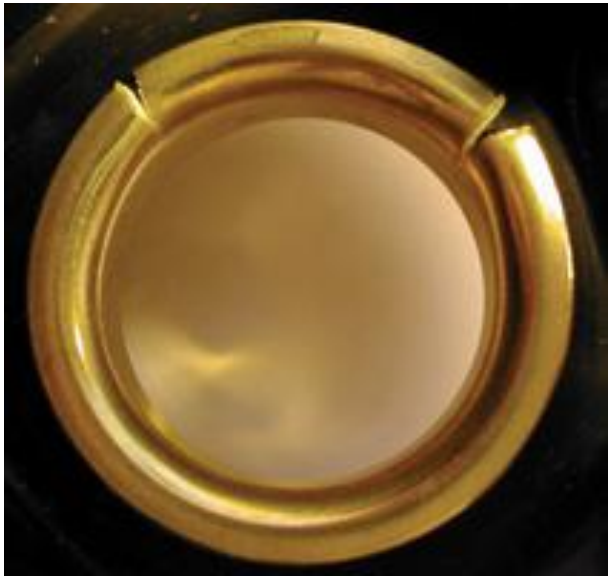
- Metal clamped around edges and forced into cavity by punch
- Metal can wrinkle, fracture, buckle, or not bend properly



Design to Increase Bend Precision

- Notching flanges to be bent can prevent buckling
- Holes placed close to bends can lead to warping in the bends.
- Flanges should be notched to prevent tearing of the metal when they are bent
- Reduce localized necks, as these can lead to tearing.

Examples of Metal Failures in Forming



Equipment for Sheet Metal Forming

- Most machinery used to press metal use hydraulic or pneumatic pressing, or a combination of the two
- Blanks are pressed into a die specific to the design

Machine for making blanks

Factors for Press Selection

- Type of forming
- Size and Shape of Dies
- Size and Shape of Work pieces
- Length of stroke of the slides, operating speed
- Number of slides: Single, Double, or Triple action press

More Factors for Press Selection

- Maximum force required vs. press capacity
- Type of press
- Press control systems (computer, mechanical, etc…)
- Features for changing dies
- Safety of machine operators

Example of Blanking Machine

- State of the art blanking machine by Minister Machine Company
- High speed machine for forming high strength metals, uses 1,000-ton press

- This is necessary as metals such as steel continue to be made stronger

Other Examples of Metal forming machinery

- Steel slitting machine, used to create strips that can be quickly stamped into blanks

- Metal bending machine for tight angles

Economics of Sheet-Forming Operations

- Small, simple parts are very cheap to make
- This is because large numbers of pieces can be made quickly, and the cost per part is minimized
- Large parts, such as aircraft body paneling, can be very costly to make
- Cost varies substantially based on thickness of sheet formed

Equipment Costs

- Machines used in manufacture can be expensive to purchase and maintain
- However, these are largely automated, and the cost of labor is reduced

- Many sheet-formed parts need to be hand finished to remove things like burrs on the sheared edges

Burred edge

Conclusion

- Sheet forming is good for applications where large numbers of parts can be made from sheet metal.
- Sheet metal pressing becomes cheaper than other manufacturing processes ~700 units
- Parts and manufacturing processes must be designed so parts are formed correctly and quickly

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