METAL FORMING

Hot & Cold Forming:

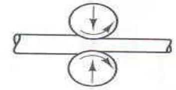
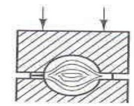
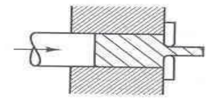
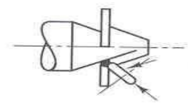
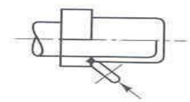
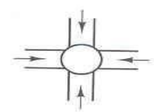
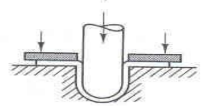
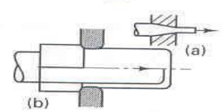
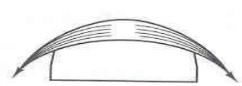
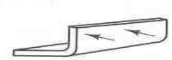
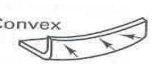
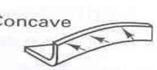
Process based on the metal ability (Plasticity) to flow plastically while remaining in solid state, without deterioration of its properties

Advantages:

- **N**o material waste in bringing the material to the desired shape.
- Economical process (vs. cutting)
- Traditionally ***a hot process*** → Lower forming forces are required due to it increased plasticity.
- The total loss of energy involved would be smaller in forming
- Forming will affect its structure → **reorientation** of the grains →the properties of will become more directional dependant.

Rolling	Spinning
Stretching	Forging
Drawing	Bending
Extruding	

TABLE 17-2. Classification of Some Forming Operations

Number	Process	Schematic Diagram	State of Stress in Main Part During Forming[a]
1	Rolling		7
2	Forging		9
3	Extrusion		9
4	Shear spinning		12
5	Tube spinning		9
6	Swaging or kneading		7
7	Deep drawing		In flange of blank, 5 In wall of cup, 1
8	Wire and tube drawing		8
9	Stretching		2
10	Straight bending		At bend, 2 and 7
11	Contoured flanging	(a) Convex 	At outer flange, 6 At bend, 2 and 7
		(a) Concave 	At outer flange, 1 At bend, 2 and 7

The Forming Process is Dependent on

1. Independent variables (the engineer has direct control over)
2. Dependent variables (consequence of the independent variables)
3. Their inter-relations

Independent variables	Dependent Variables
Starting material	Force or power requirement
Starting geometry	Material properties of product
Tool or die geometry	Final temperature
Lubrication	Surface finish or precision
Starting temperature	Nature of material flow
Speed of operation	
Amount of deformation	

Relationship between the two types of variables is established through:

- **Experience**
- **Experiments**
- **Modeling**

FORMING

1. **Hot Working : Temp. > Recrys. Temp., (> $0.6*T_{melt}$)**

   Simultaneous Recrystallization with deformation

2. **Cold Working : Temp. < Recrys. Temp., (<$0.3*T_{melt}$)**

   NO ***Simultaneous Recrystallization with deformation***

2. **Warm Working : Temp. < Recrys. Temp., ($0.3*T_{melt} < T < 0.6*T_{melt}$)**

Hot working

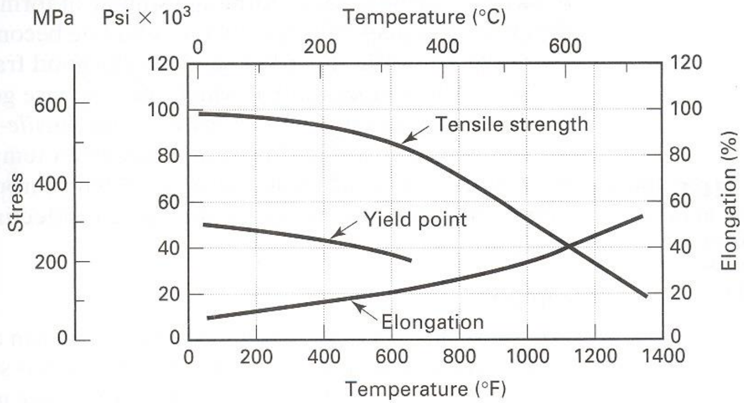


FIGURE 2-29 Some effects of temperature on the tensile properties of a medium-carbon steel.

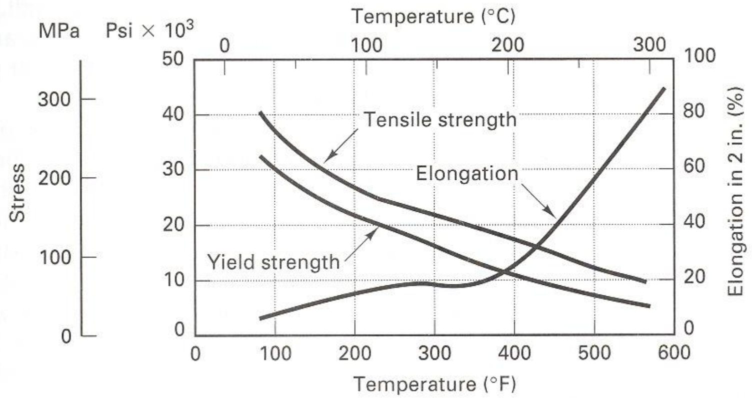


FIGURE 2-30 Effects of temperature on the tensile properties of magnesium.

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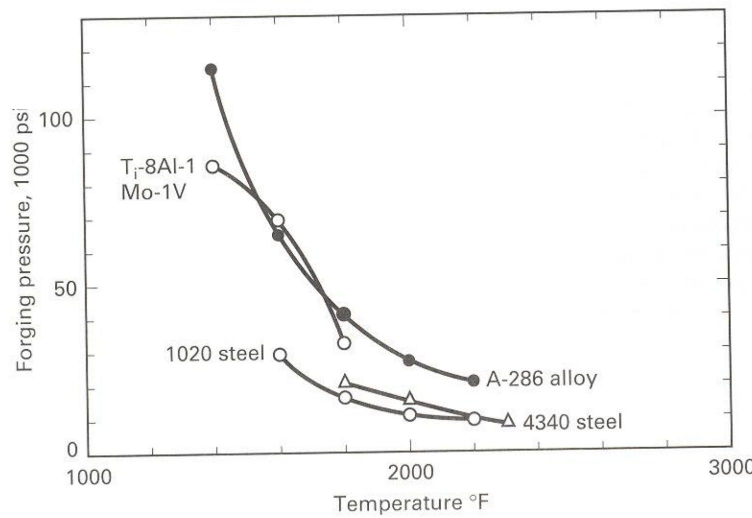


Cold Working

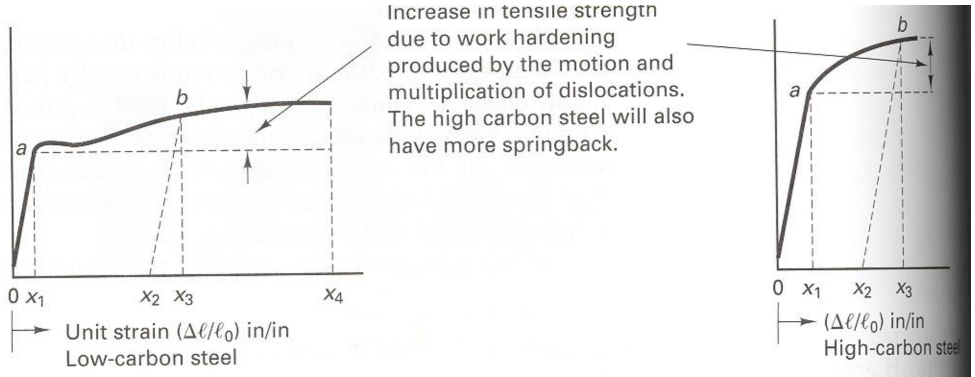


FIGURE 17-6 Use of true stress–true strain diagrams to assess the suitability of two metals for cold working.

FIGURE 17-8 Mechanical properties of pure copper as a function of the amount of cold work (expressed in percent).

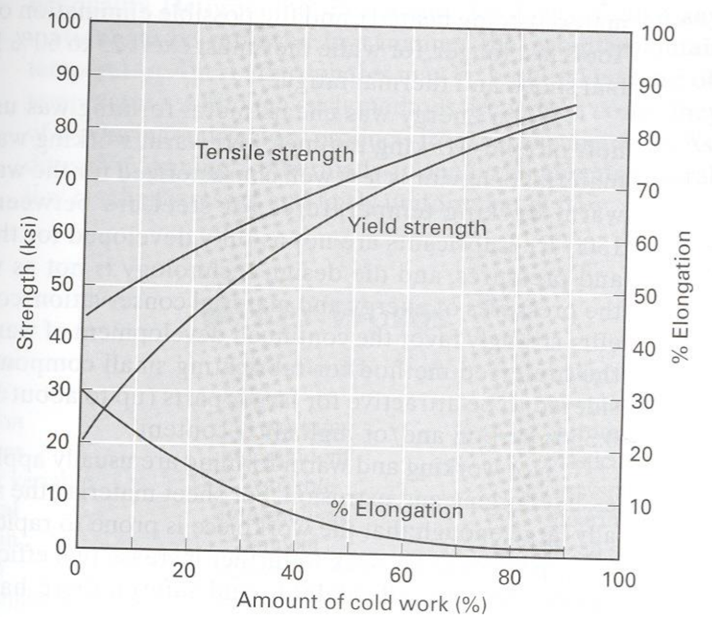
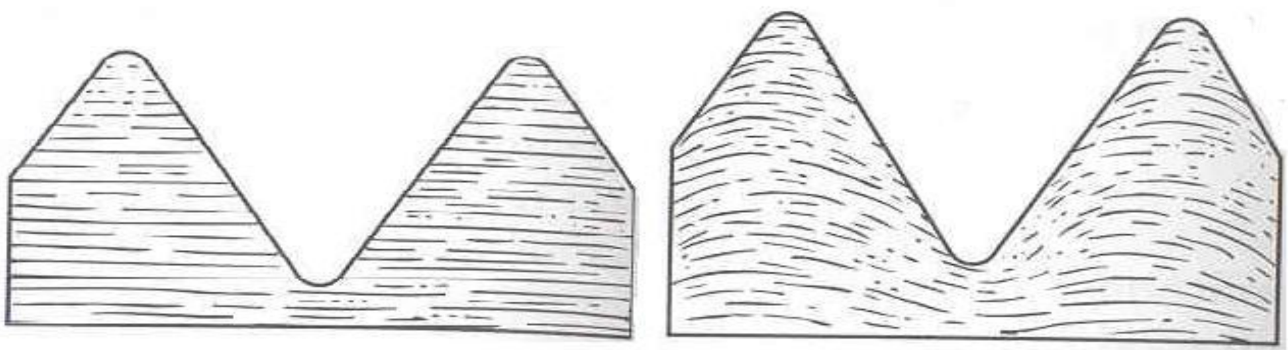


FIGURE 17-4 "Fiber" structure of a hot-formed (forged) transmission gear blank. *(Courtesy of Bethlehem Steel Corporation.)*



(a)

(b)

FIGURE 17-5 Schematic comparison of the grain flow characteristics in a machined thread (a) and a rolled thread (b). The rolling operation further deforms the axial structure produced by the previous wire- or rod-forming operations, while machining simply cuts through it.

HOT WORKING PROCESS

Definition:

It is the plastic deformation of metal above its re-crystallisation temperature **(that depends on the metal), steel ~1200^0 C**

Advantages:

-Plastic deformation above this temperature ***does not produce STRAIN HARDENING***

-Does not cause any increase in strength or in hardness of metal

→ Any shape can be formed by hot working process, taking advantage of its lower strength.

-Reduce chemical and structural in-homogeneities

Hot Working Processes:

Rolling
Forging
Extrusion — **squeezing**
Hot Drawing
Pipe Welding
Piercing

HOT ROLLING: From Iron ore → refining process → **Ingots**

Two Steps:

1. Rolling steel → intermediate shapes: Slabs, Blooms or Billets
2. Processing the above into plates, sheets, bar, stock, structural shapes or foils.

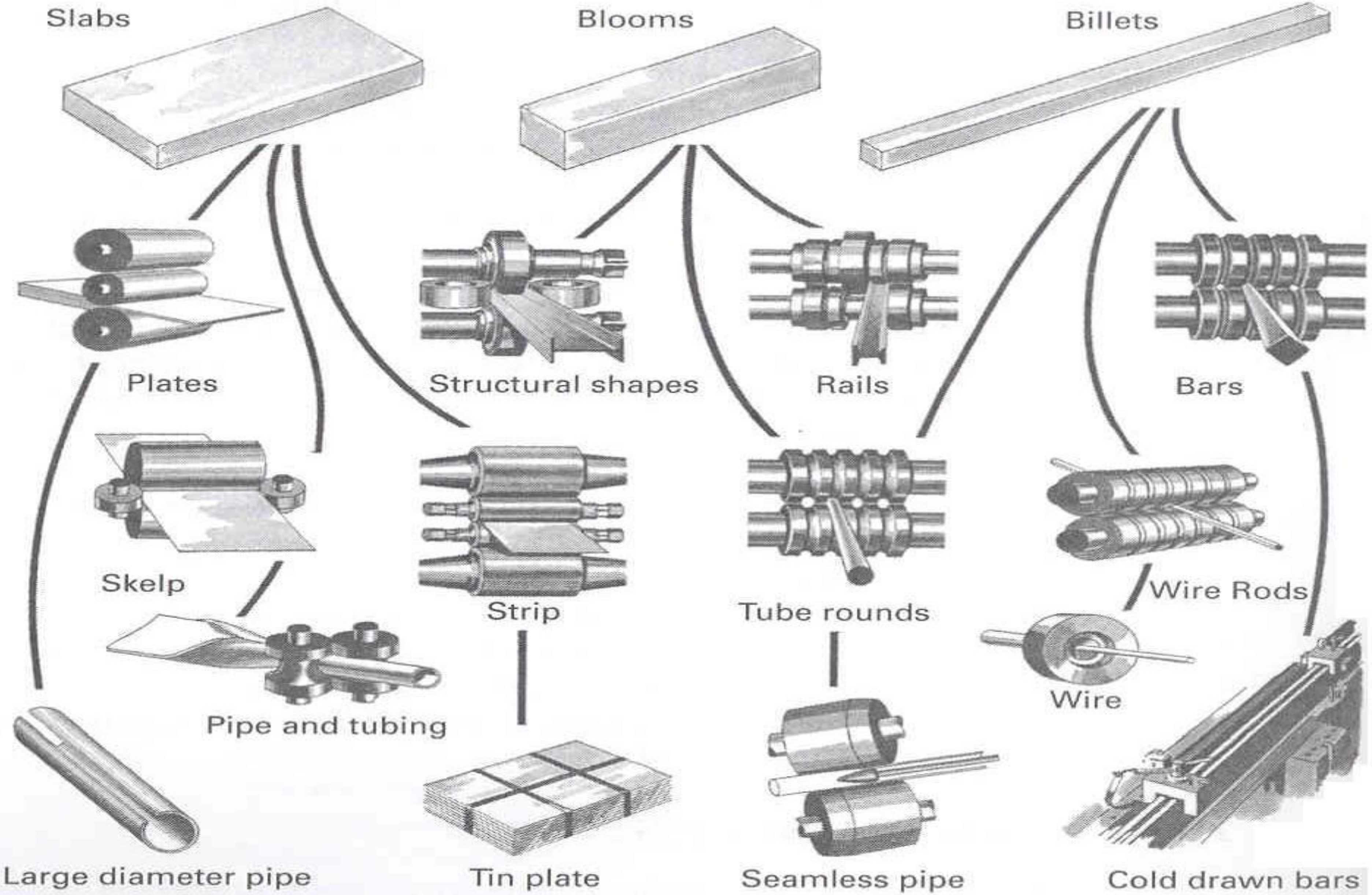


FIGURE 18-1 Schematic flowchart for the production of various finished and semifinished steel shapes. Note the abundance of rolling operations. *(Courtesy of American Iron and Steel Institute, Washington, D.C.)*

HOT ROLLING→ passing heated metal between two rolls → **Deformation**

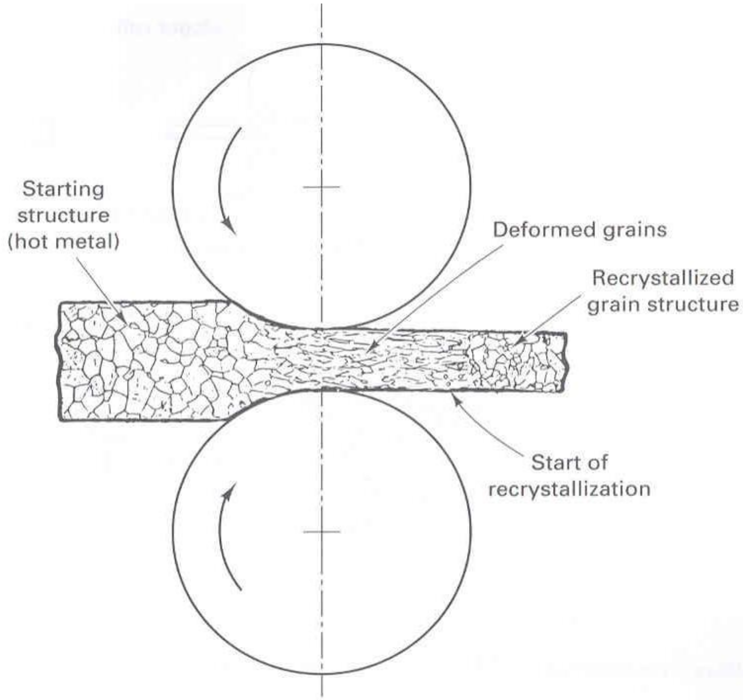


FIGURE 18-2 Schematic representation of the hot-rolling process, showing the deformation and recrystallization of the metal being rolled.

The required temperature should be higher than the recrystallisation temperature of metal, by 50-100 C, in order to terminate rolling and have complete recrystalization.

Depends on friction between the rolls and the incoming metal,
because of accelerating the metal forward and side-ward

- The amount of deformation obtained in a single pass must be evaluated
- If the required deformation ratio is to high, the rolls will skid over stationary metal.
- Metal has to be preheated uniformly to the proper temperature → soaking

(steel >1200^{0}C)

INTEGRATED ROLLING MILLS:

Allow the cast material to be processed by
rolling without loosing its heat from the casting process, that is,
without loosing its heat from the casting process, that is,

Without re-heating → the hot ingot send directly to the rolls
→ ***less energy lost*** (ex. Steel requires about 1200^0 C)

The cross section can be reduced by x17 after the hot rolling

Smaller DIA for the roll, lower deformation force required.

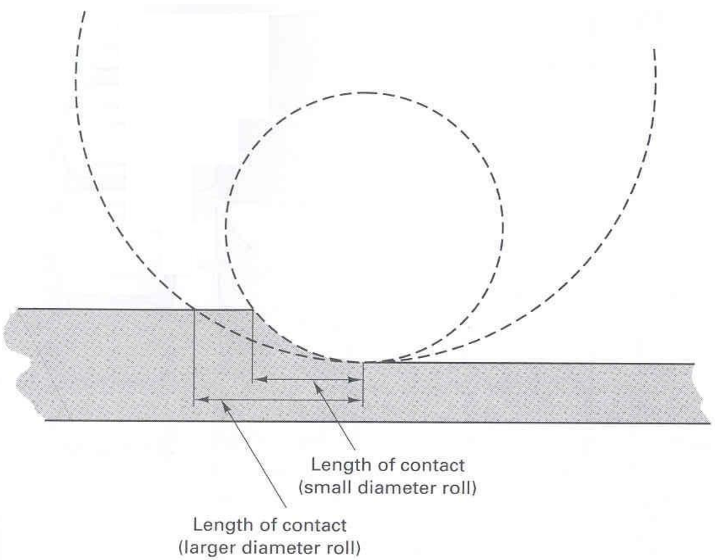


FIGURE 18-4 Schematic showing the effect of roll diameter on length of contact for a given reduction.

A. Two high *reversing or non-reversing* configurations for primary roughing rolls of **0.6 → 1.2m DIA**

B. Three high mill stands → elevators are used to bring the blooms between the consecutive rolls

C. Four – high and cluster → use smaller roller DIA → less stiffness but require lower load → back-up rollers are used to support smaller DIA rollers

D. Planetary configuration reduces thickness more than regular by extra feed which is necessary to push the material between the rolls

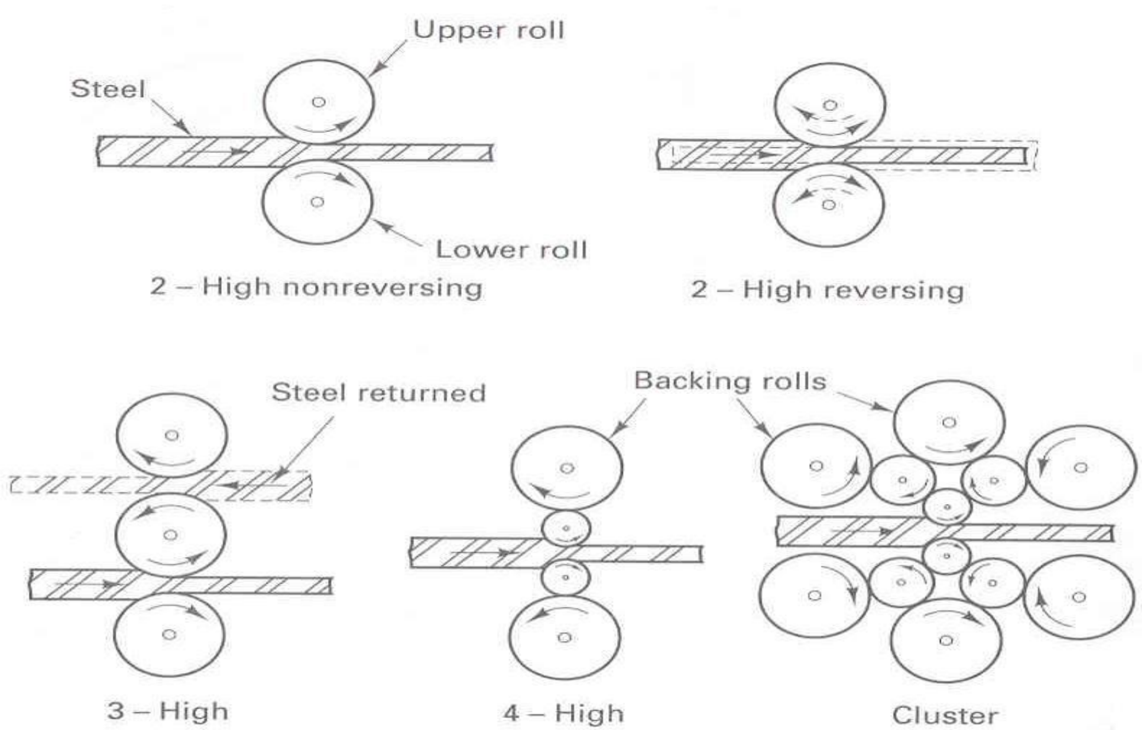


FIGURE 18-3 Various roll configurations used in rolling operations.

CONTINUOUS ROLLING MILLS provide one direction of metal flow with subsequent Rolls running faster (100Km/h)- cooling water is used

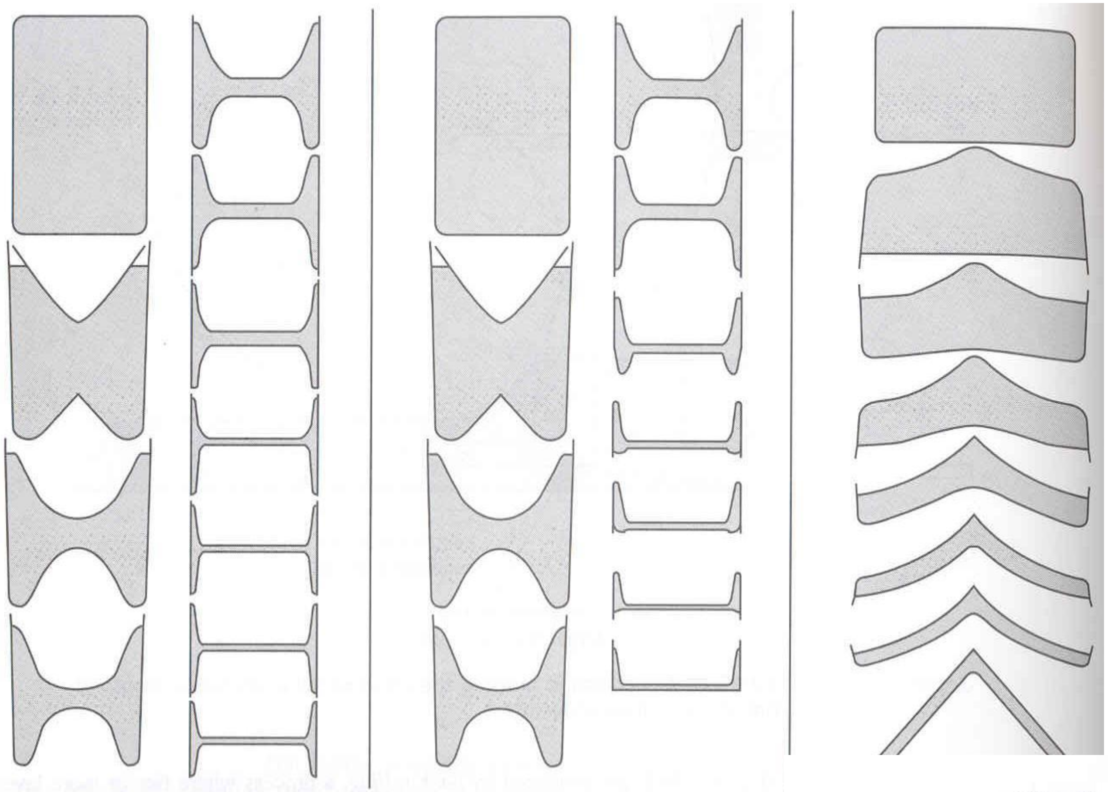


FIGURE 18-5 Typical roll-pass sequences used in producing various structural sha

Same amount of materials is passed through all the rolls.

Following roll runs faster.

Lower the cross section→higher the speed.

Ring Rolling

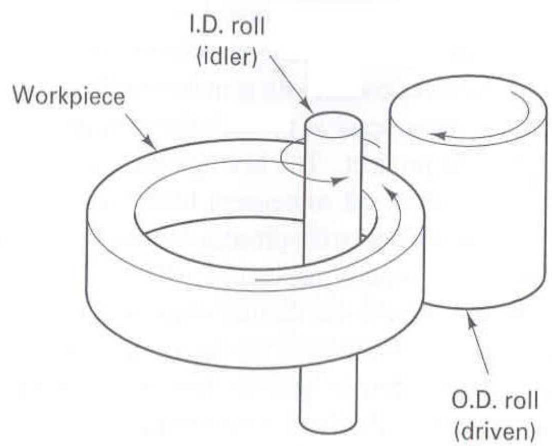


FIGURE 18-6 Schematic of a horizontal ring rolling operation. As the thickness of the ring is reduced, its diameter will increase.

Any Cross Section.

Products in rockets, engines, airplanes, etc.

PROPERTIES OF HOT ROLLED PRODUCTS

- ***Do not build residual stresses***

- Exhibit only ***low tendency to directional properties*** particularity in thicker plates.

- Surface of these products is affected by hot rolling

  - Rough
  - covered by oxides – scale
  - high tolerances 2-5% of the size

Rolling: Means of continually changing the shape of the material

HOT FORGING

- Can be obtained by means of localized compressive forces
- Machines: Hammers, Presses (drop hammer - blacksmiths)
- Metal: *drawn –out , up-set* and *squeezed*

Forging Types:

1. **Open-die drop-hammer forging**
2. **Impression-die drop forging**
3. **Press forging**
4. **Upset forging**
5. **Automatic hot forging**
6. **Roll forging**
7. **Swaging**

A. OPEN-DIE HAMMER FORGING (FREE FORGING)

- Metal heated and placed on the anvil
- Impacted by a falling hammer →raised by board & rollers
- Weight of the hammer – up to 12000 Kg
- Flat hammer and anvils can be used
- The operator needed (handling during the blows)
- Mechanical manipulators can be used too
- Process is slow and depends on the skill of the operator
- Equipment – simple and cheap

- Dis Adv.
- Needs skilled operator
- Not suitable for production

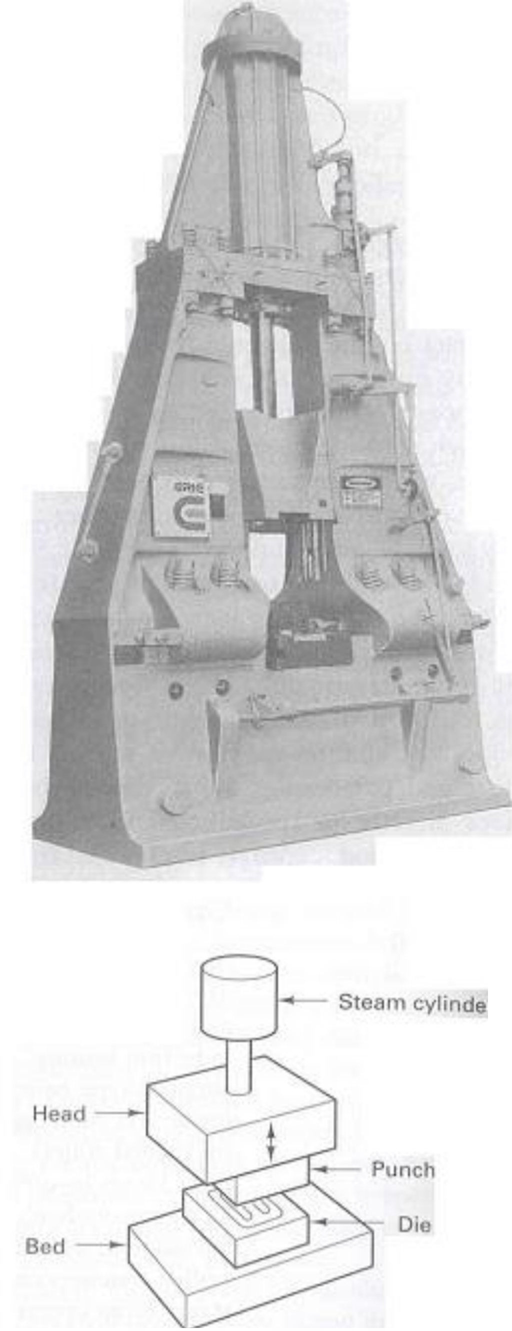
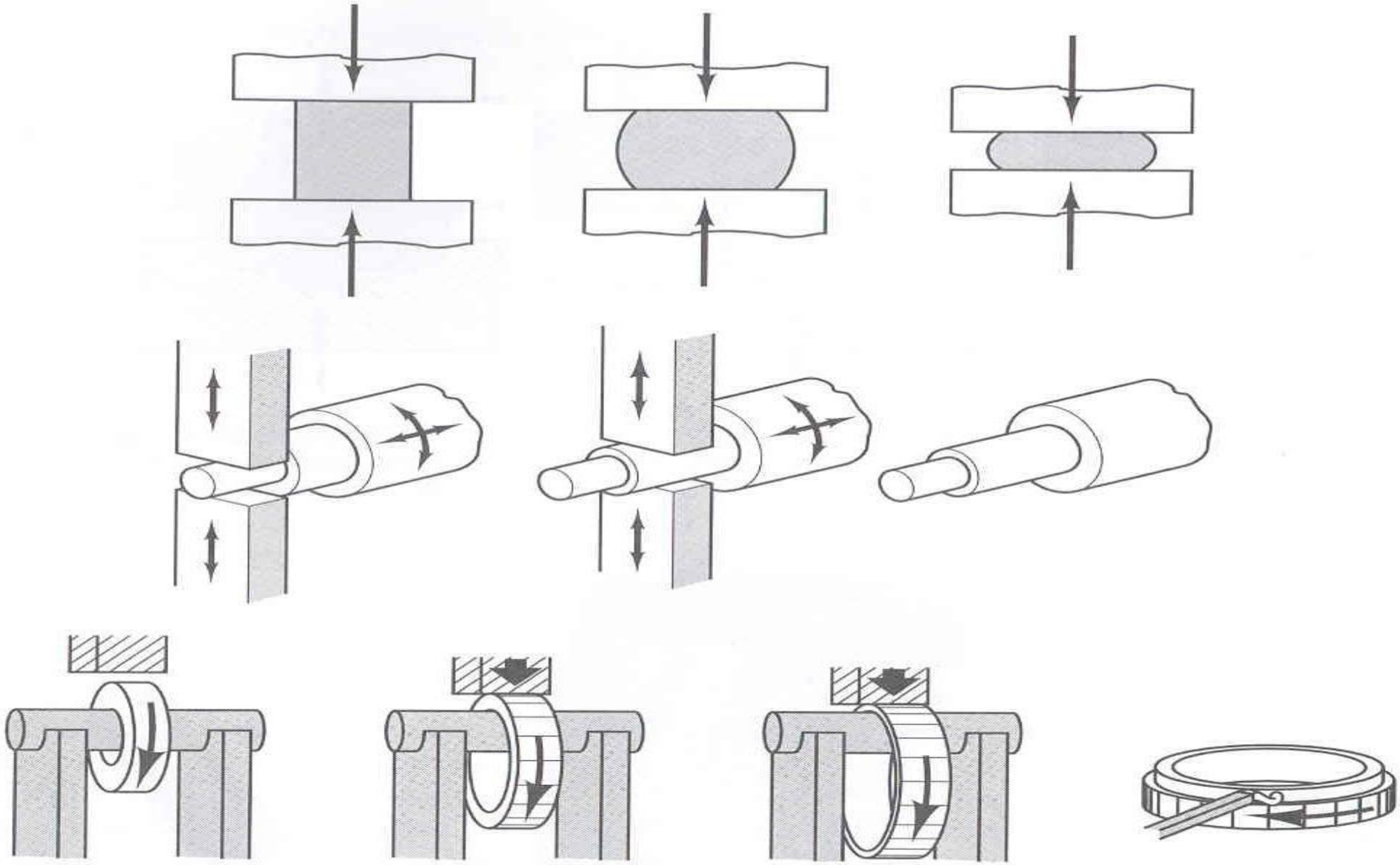


FIGURE 18-7 Double-frame drop hammer and a schematic of the basic tooling. *(Courtesy of Erie Press Systems, Erie, Pa.)*



1 Preform mounted on saddle/mandrel.

2 Metal displacement–reduce preform wall thickness to increase diameter.

3 Progressive reduction of wall thickness to produce ring dimensions.

4 Machining to near net shape.

FIGURE 18-8 (*Top*) Schematic of the unrestrained flow of material in open-die forging. Note the barrel shape that forms due to friction between the die and material. (*Middle*) Open-die forging of a multidiameter shaft. (*Bottom*) Forging of a seamless ring by the open-die method. *(Courtesy of Forging Industry Association, Cleveland, Ohio.)*

B. Impression – Die Drop Forging

Shaped die is used to control the flow of metal and the shape of forging

→ **Two parts Make die**

1st part –attached to the hammer – Die must have a guide

2st part – attached to the anvil – draft

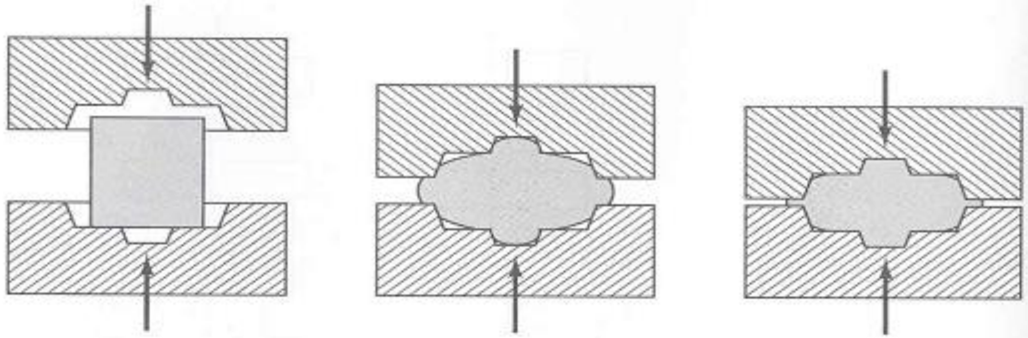


FIGURE 18-9 Schematic of the impression-die forging process showing partial die filling and the beginning of flash formation in the center sketch, and the final shape with flash in the right-hand sketch.

- Heated metal is placed in the 2nd part (fixed)
- As a result of hammering, the metal fills – up the die cavity
- Excess metal is forming a flash
- Flash is trimmed by trimming die or cut in a further process

- Particular directional grain structure is obtained together with **fine – grain structure** Without voids_
- As the result, higher **strength /weight ratio (20%)** of the work piece is obtained than using casting or metal cutting techniques
- The same **open-die forging hammers** are used.
- Trend to mechanise the casting and forging process in a single continuous process → **like in rolling**

1. Casting – produce a pre-formed part
2. Cast part is transferred from a mould into a forging die (still hot)
3. Part is forged in a die
4. Part is trimmed in a trimming die

→ save energy

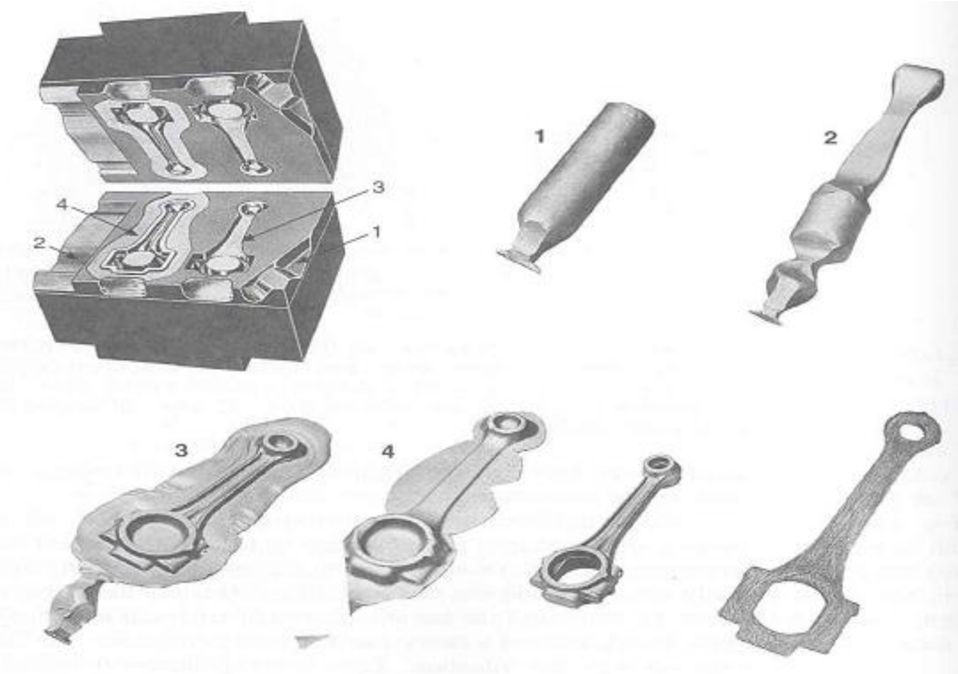


FIGURE 18-10 Impression drop-forging dies and the product resulting from each impression. The flash is trimmed from the finished connecting rod in a separate trimming die. The sectional view shows the grain fiber resulting from the forging process. *(Courtesy of Forging Industry Association, Cleveland, Ohio.)*

Impact machine can be also used – horizontal – no anvil → foundations are much lighter

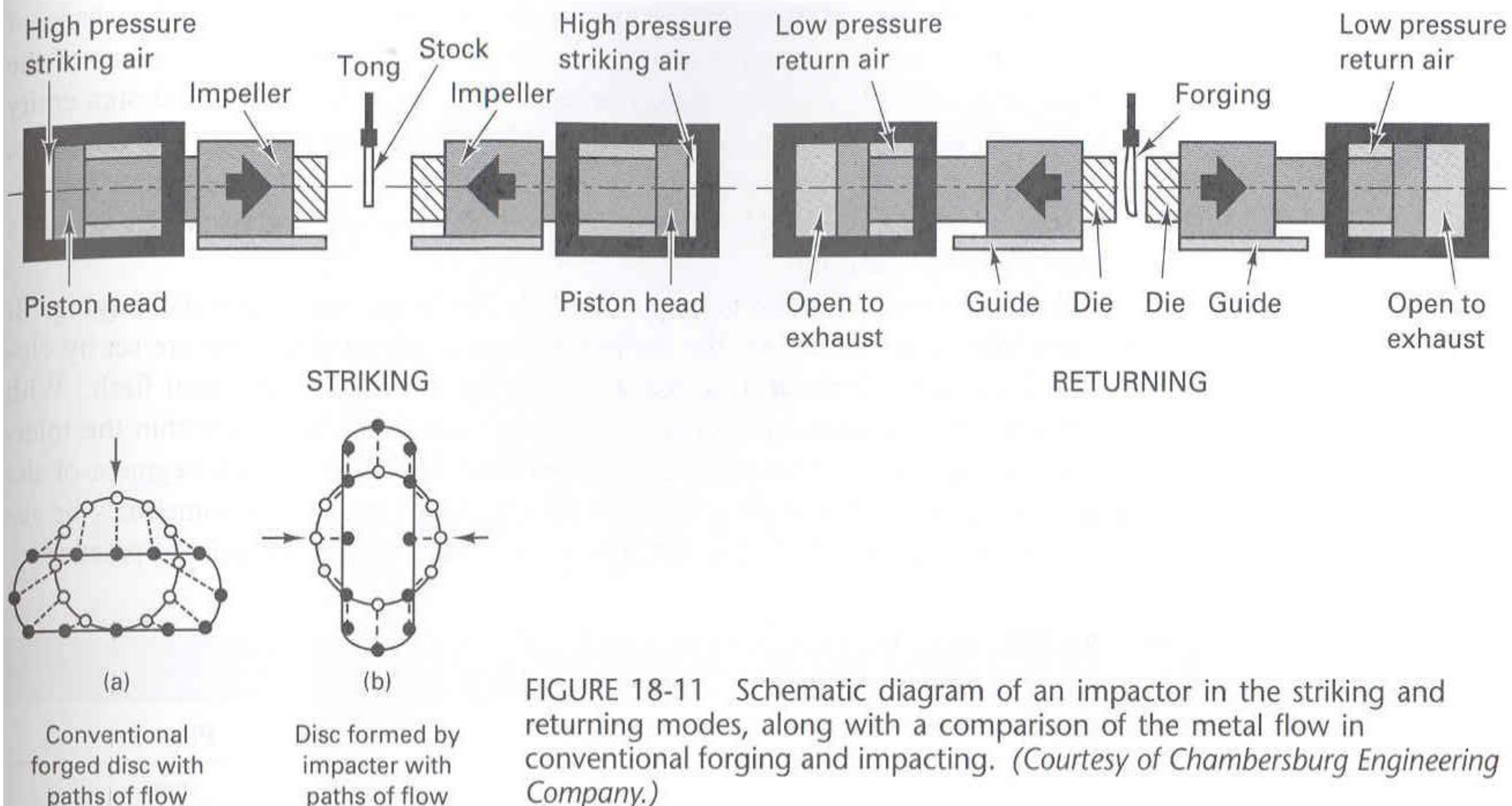
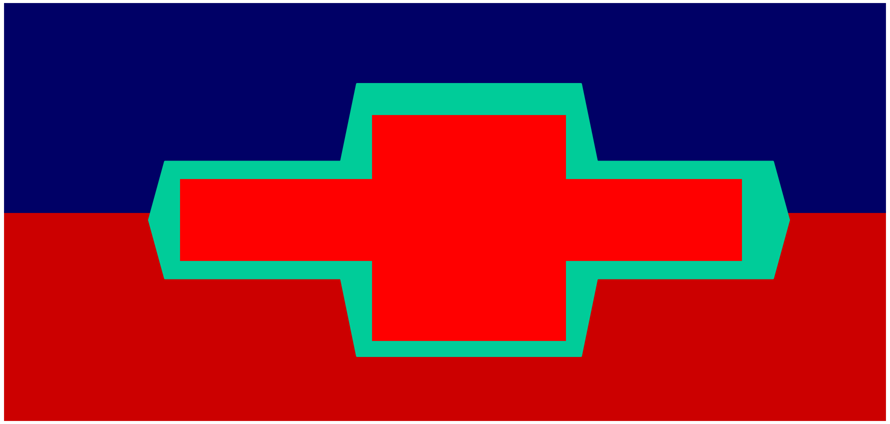


FIGURE 18-11 Schematic diagram of an impactor in the striking and returning modes, along with a comparison of the metal flow in conventional forging and impacting. *(Courtesy of Chambersburg Engineering Company.)*

DESIGING OF A DIE

– complex process

- **Tool steel**
  (high alloy steel, tough, not to crack)
- The die must resist to – impact, wear, high temp.
- If cooled → expensive
- Draft angles 5^0-7^0 –steel and 3^0 for Al
- Large radii and fillet assured (no cutting edges)
- Both sections should be well balanced
- Parting lines → one plane if possible
- Made on CNC machines
- Tolerances → taken into consideration – for forging ~ 3%



C. PRESS FORGING uses press with **continuous force action**

- For large pieces – press forging is rather required
- Allows to deform the interior regions of the workpiece (not just superficial)
- Difficult to be done by hammering because of the dissipation of the hammer energy in foundation
- The **slow squeezing action** → more uniform metal flow within the die
- Long contact of the work piece with the die → it cools fast →heated dies are used.

Advantages:

- Less draft → more accurate → no flash
- One closing of the die may be enough to form the piece → faster process
- More uniform structure obtained
- Better surface finish → less scale
- Press equipment – more expensive than hammer presses

Mechanical presses:

Actuated by crankshaft mechanism

Hydraulic

Screw actuated

Anvil fixed on a special foundation

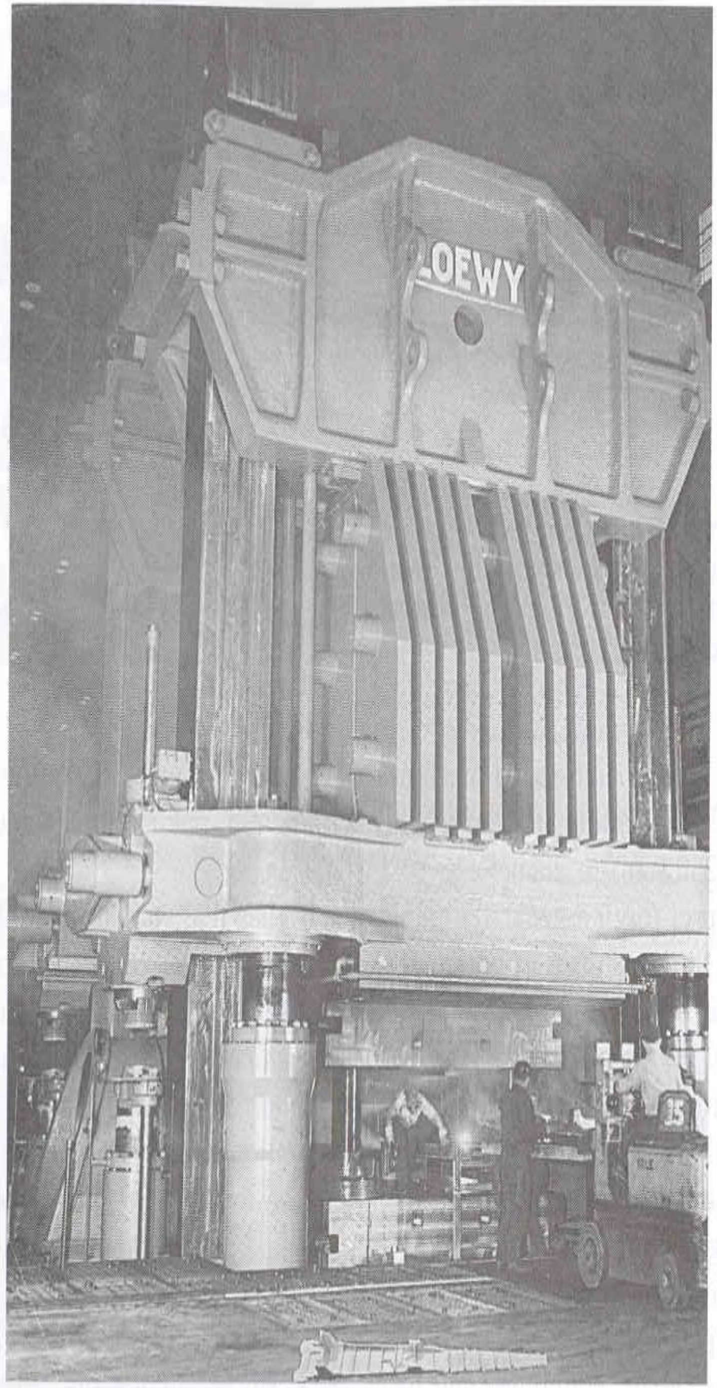


FIGURE 18-12 A 35,000-ton (310-MN) forging press. In the foreground is a 262-lb, 121-in. aluminum part that was forged on this press. *(Courtesy of Wyman-Gordon Company.)*

D. UPSET FORGING : Partial forging → in a bar, the end can be upset forged → heads of screws, engine valves and pushing rolls

$L_{overhang} < 3D$ $D1 <= 1.5D$ $L_{free} < 1D$

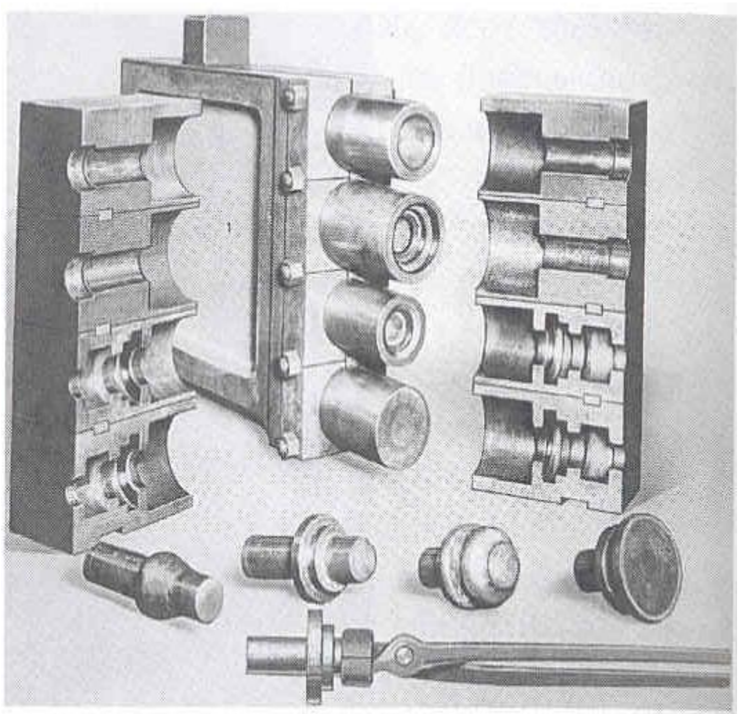


FIGURE 18-13 Set of upset forging dies and punches. The product resulting from each of the four positions is shown along the bottom. *(Courtesy of Ajax Manufacturing Company.)*

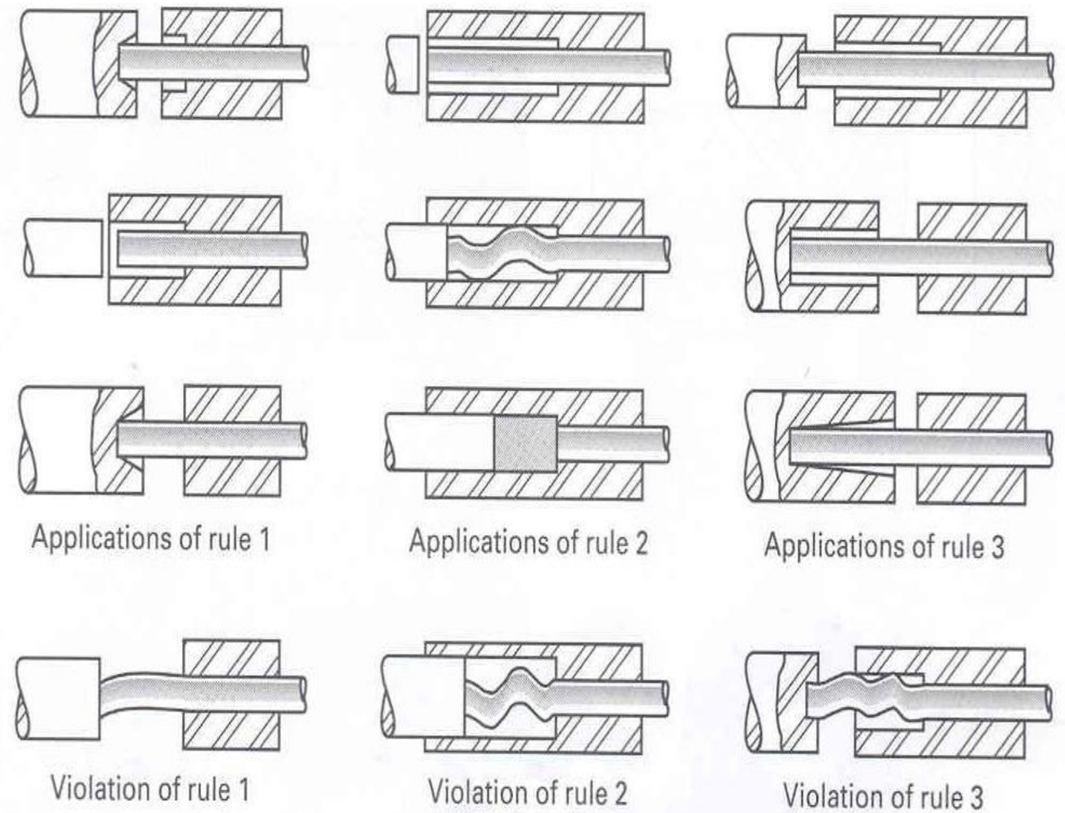


FIGURE 18-14 Schematics illustrating the rules governing upset forging. *(Courtesy of National Machinery Company.)*

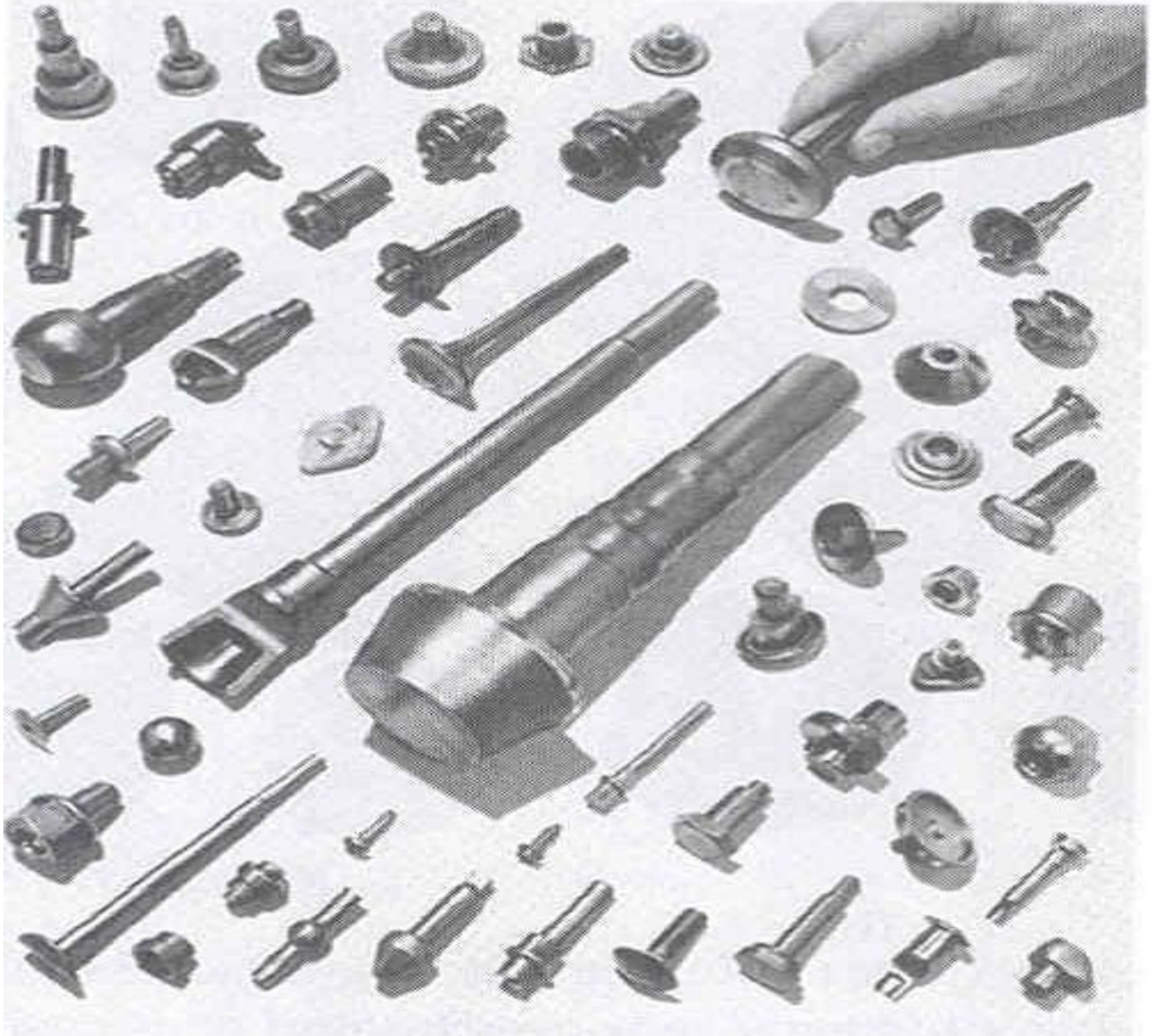


FIGURE 18-15 Typical parts made by upsetting and related operations. *(Courtesy of National Machinery Company.)*

E. Automatic Hot Forging : Automatic Upset Forging

Steel bars at room temp → [ ] →Fully forged , 180pc/min, Max 7" dia,

Induction Heating →Descaling→Ind. Blanks→Forging steps→Piercing

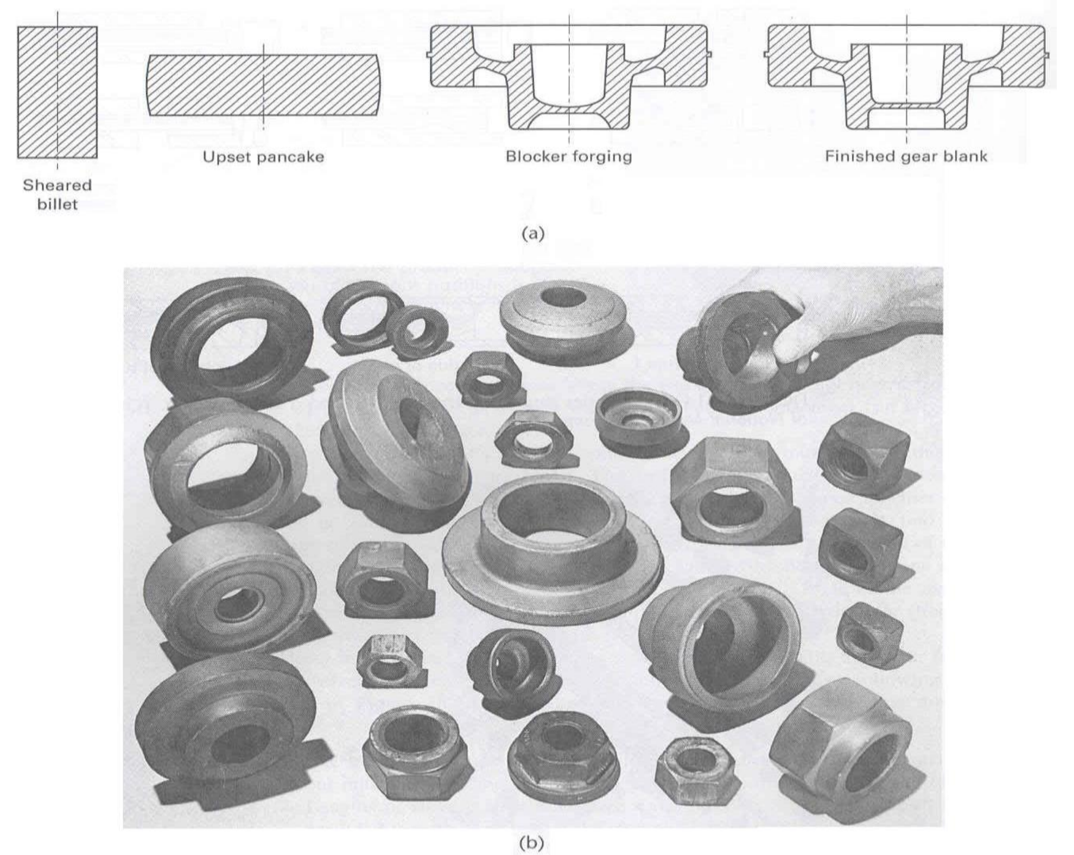


FIGURE 18-16 (*Top*) Typical four-step sequence to produce a spur-gear forging. The sheared billet is progressively shaped into an upset pancake, blocker forging, and finished gear blank. (*Bottom*) Samples of ferrous parts produced by automatic hot forging at rates between 90 and 180 parts per minute. *(Courtesy of National Machinery Company.)*

F. ROLL FORGING

- **To reduce the section in the middle of a shaft-like part:**

Machine → two semi-cylindrical rolls with different size grooves → eccentric → the bar is placed consecutively between rolls, first in larger, than in smaller grooves → skilled operator.

Wagon wheels – manufactured bv hot – roll forging

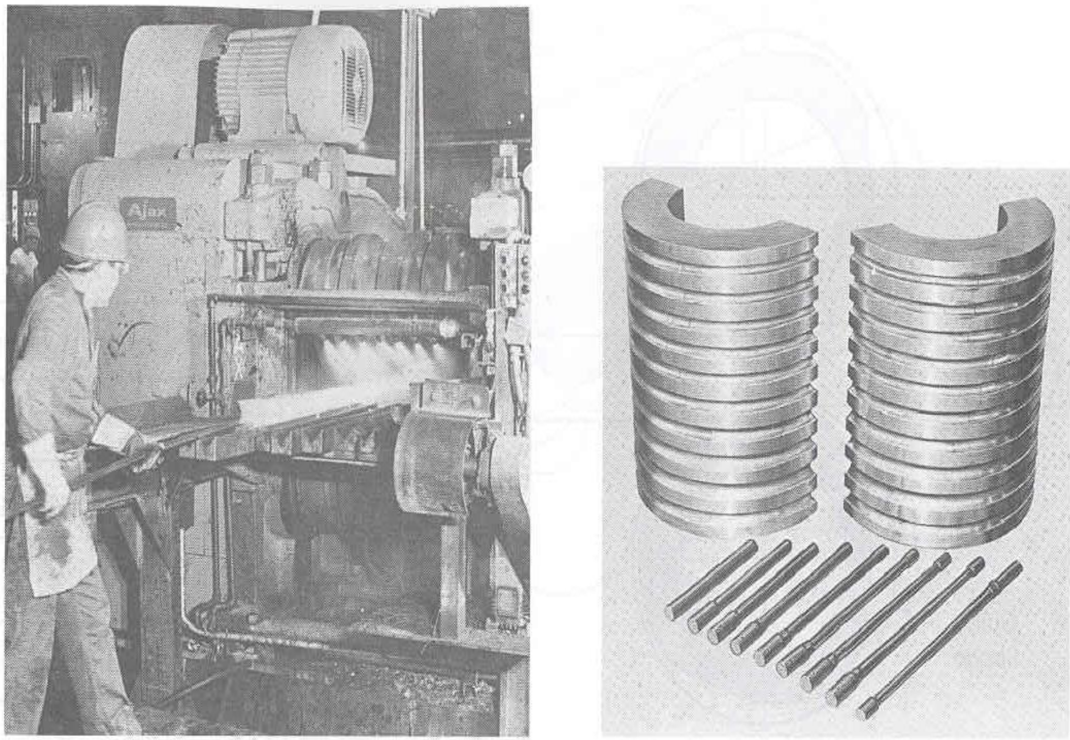


FIGURE 18-17 (*Left*) Roll forging machine in operation. (*Right*) Rolls from a roll forging machine and the various stages in roll forging a part. *(Courtesy of Ajax Manufacturing Company.)*

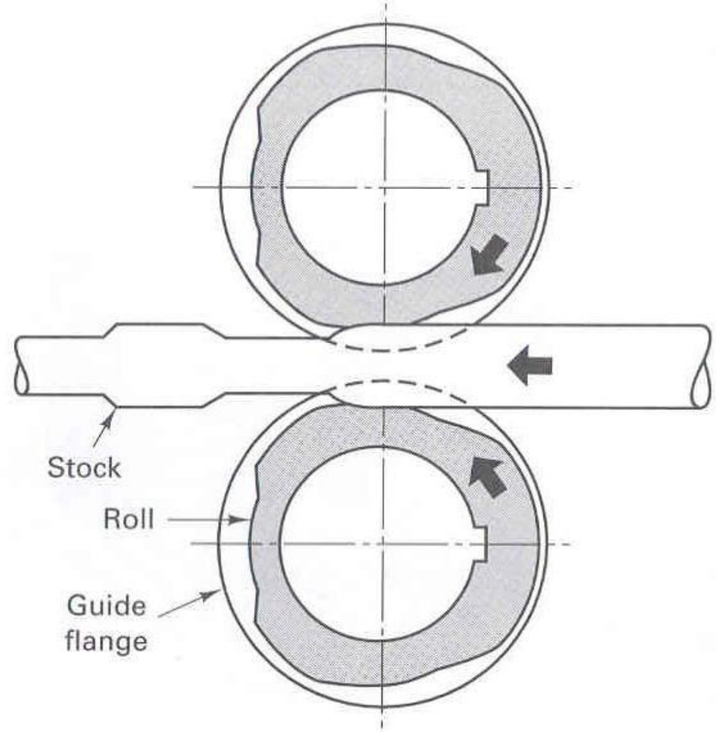


FIGURE 18-18 Schematic of the roll forging process showing the two shaped rolls and the stock being formed. *(Courtesy of Forging Industry Association, Cleveland, Ohio.)*

G. HOT SWAGING OF TUBES

• Tube/rod is forced (pushed) in to a die, to form the end → for production of gas cylinders (examples)

•***Hammering of the rod or tube by Die itself*** to reduce the diameter

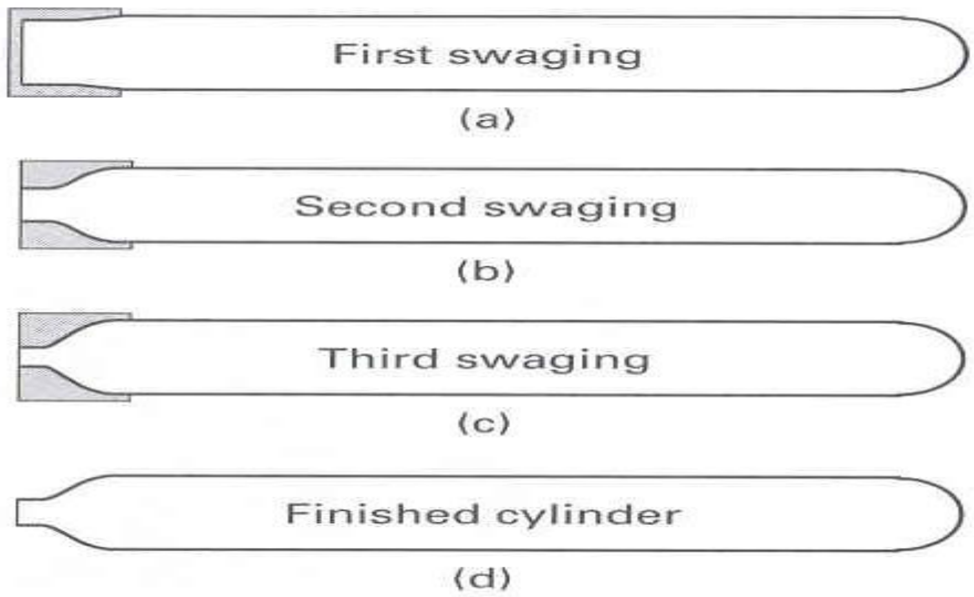
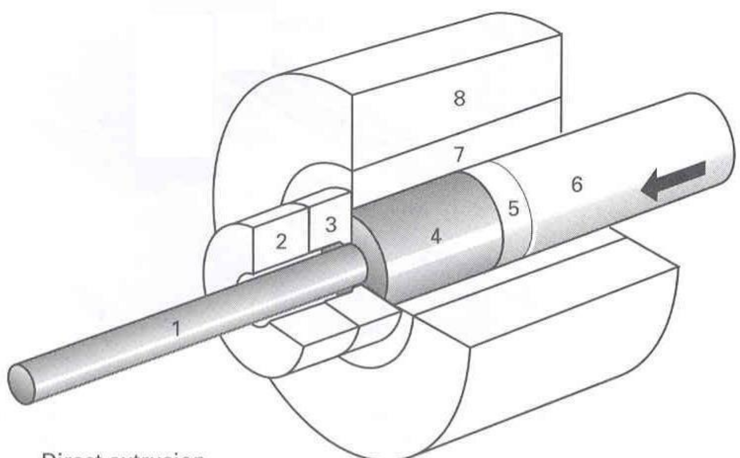


FIGURE 18-19 Steps in swaging a tube to form the neck of a gas cylinder. *(Courtesy of USX Corporation.)*

EXTRUSION

- **Metal placed in a confined chamber**
- A piston pushes ***(compresses)*** the metal out the chamber through a die
  → Limitation: affects structure –good for metals with relatively low yield strength & low thermal expansion coefficients – lead, copper, aluminium, steel with special lubricants – glass based – to prevent the welding of steel to the die.
- Products: structural shape non- ferrous metal simple wires can be extended, hollow shapes (pipes with seam or seamless)
- Single extrusion area ratios: up to 100
- Tolerances 0.3% (10 times better than rolling)
- very cost effective



Direct extrusion

1 Extrusion
2 Die backer
3 Die
4 Billet
5 Dummy block
6 Pressing stem
7 Container liner
8 Container body

FIGURE 18-20 Direct extrusion schematic showing the various equipment components. *(Courtesy of Wean United, Inc., Hydraulic Machinery Division.)*

METHODS

- •Direct extrusion (less complex)
- •Indirect extrusion (less friction)
- •High speeds for low strength metals

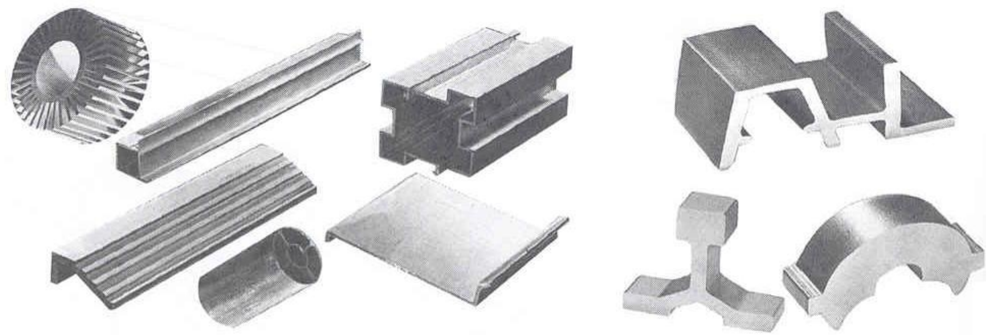


FIGURE 18-21 Typical shapes produced by extrusion. (*Left*) Aluminum products. (*Courtesy of Aluminum Company of America.*) (*Right*) Steel products. (*Courtesy of Allegheny Ludlum Steel Corporation.*)

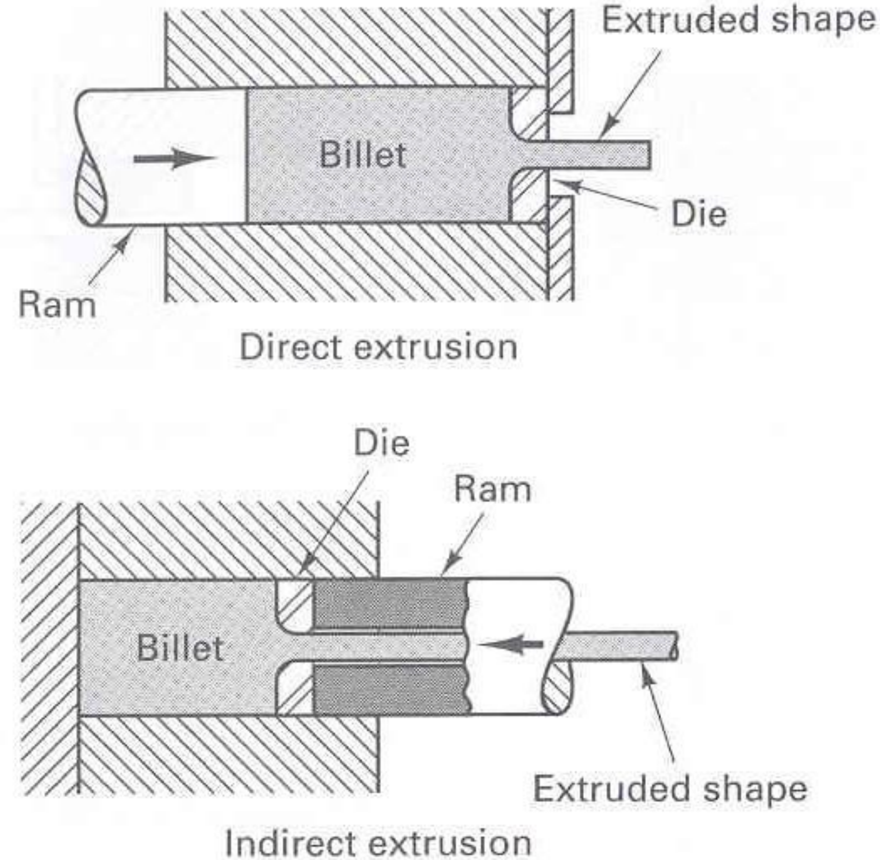


FIGURE 18-22 Direct and indirect extrusion. In direct extrusion, friction with the chamber opposes forward motion of the billet. For indirect extrusion, there is no friction, since there is no relative motion.

Extrusion of hollow shapes

- Stationary mandrel process
- Spider mandrel – the metal divides and come back by welding metal flow; can cause cracks & defects → shearing forces at the surface
- ***Lubricants can not be used***

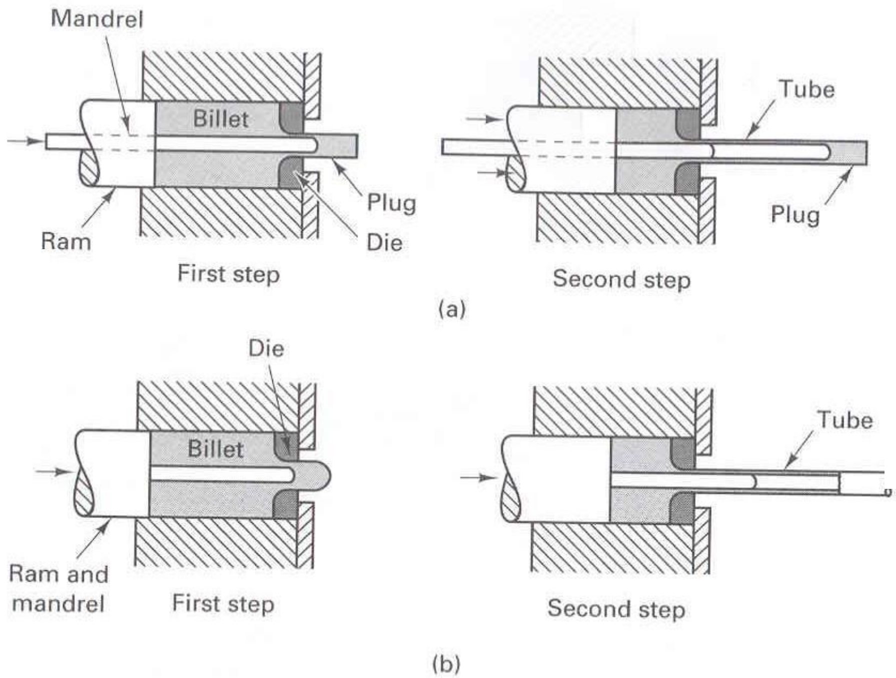


FIGURE 18-24 Two methods of extruding hollow shapes using internal mandrels. In the upper schematic the mandrel and ram have independent motions; in the lower sequence they move as a single unit.

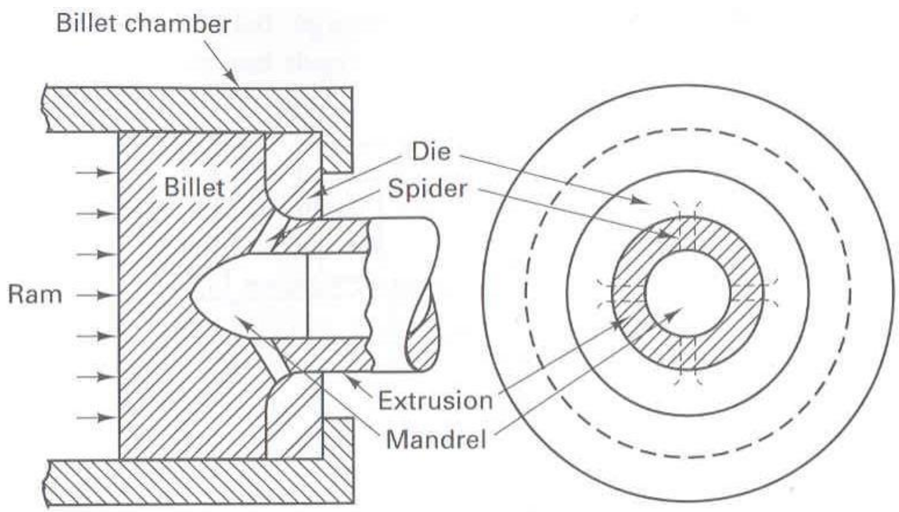
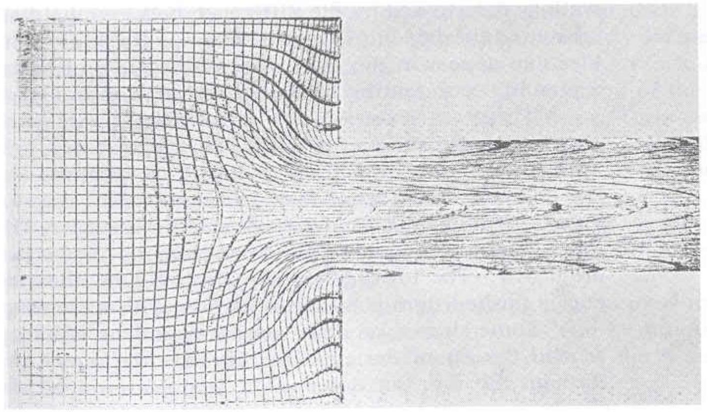


FIGURE 18-25 Hot extrusion of a hollow shape using a spider-mandrel die. Note the four arms connecting the die and the mandrel.

FIGURE 18-26 Grid pattern showing the metal flow in a direct extrusion. The billet was sectioned and the grid pattern was engraved prior to extrusion.



HOT DRAWING

- Sheets or plates of metal are formed into deep cups by drawing

  → a set of single consecutive dies or multiple dies.

  A problem – thinning can occur (ironing) during drawing

  (when gap is smaller than the thickness)

- Different wall thickness in cylindrical components – by H.D.

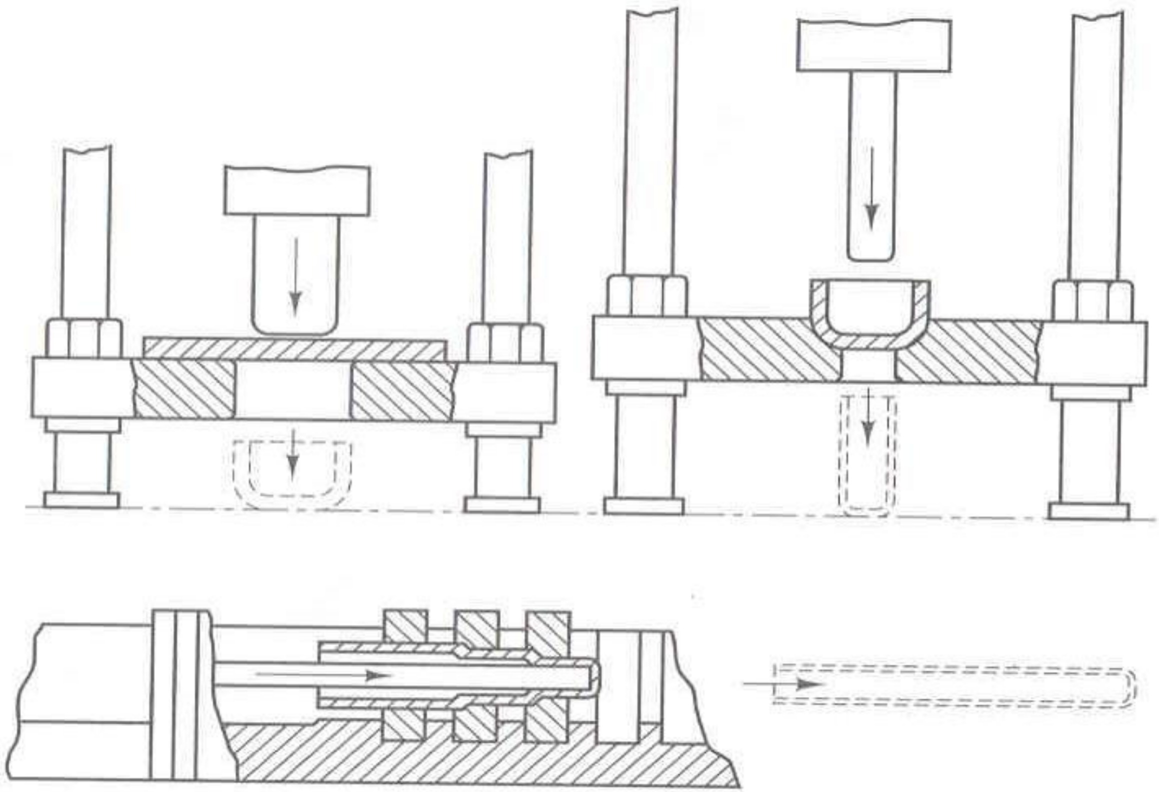


FIGURE 18-27 Methods of cup forming or hot drawing. (*Upper left*) First draw. (*Upper right*) Redraw operation. (*Lower*) Multiple-die drawing. (*Courtesy of USX Corporation.*)

PIPE PRODUCTION

- Seam type: welded → narrow strips of metal (skelp) are formed into pipes, and welded on the edges using the heat contained in the metal
- Two basic methods: butt-welding and lap-welding

- **BUTT WELDED PIPES** – small sizes – heated skelp is pulled through forming rolls that shape it into cylinder – no mandrel is necessary → very long pipes
- Pressure extended between the edges of the skelp welds the edges together – Rollers next shape the pipe

- **LAP – WELDED PIPES**

  – Large sizes – skelp has beveled edges;
  weld – made with a mandrel

  - Large sizes → up to 15” – length limited by mandrel

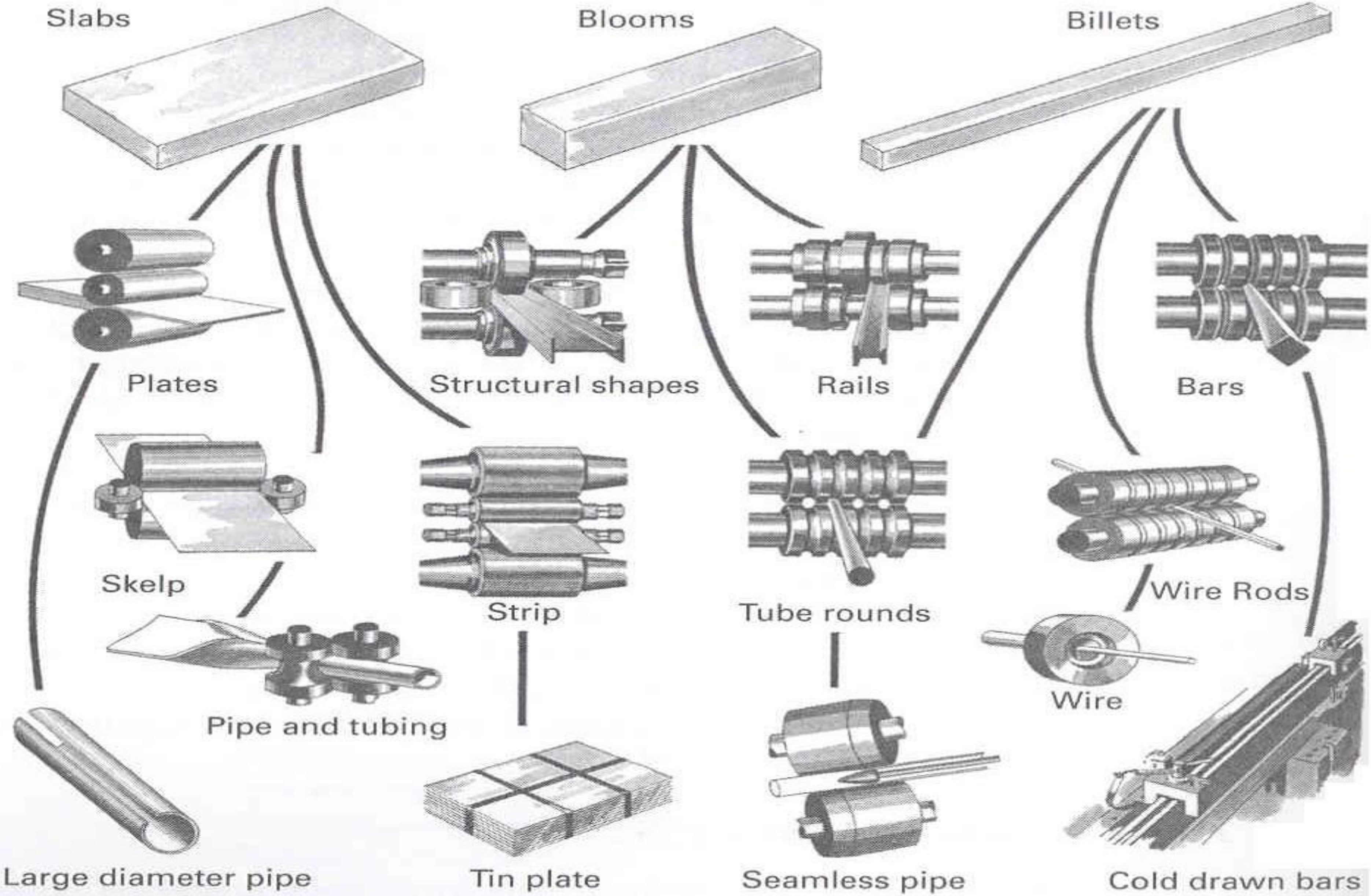


FIGURE 18-1 Schematic flowchart for the production of various finished and semifinished steel shapes. Note the abundance of rolling operations. *(Courtesy of American Iron and Steel Institute, Washington, D.C.)*

SEAMLESS PIPES

• MANNESMANN process (Piercing process)

• Round billet is center– punched at the end, heated and pushed between two large double tapered rolls. Rolls revolve in the same direction;

•their axes are inclined from the axis of billet in opposite directions.

•Gap between the rolls is less than the dia of the billet

• Deformation in elliptical shape → rotation + elliptical cross section → shear and cracks in the center of the billet → this billet is forced over a mandrel that enlarge the opening → seamless tubes

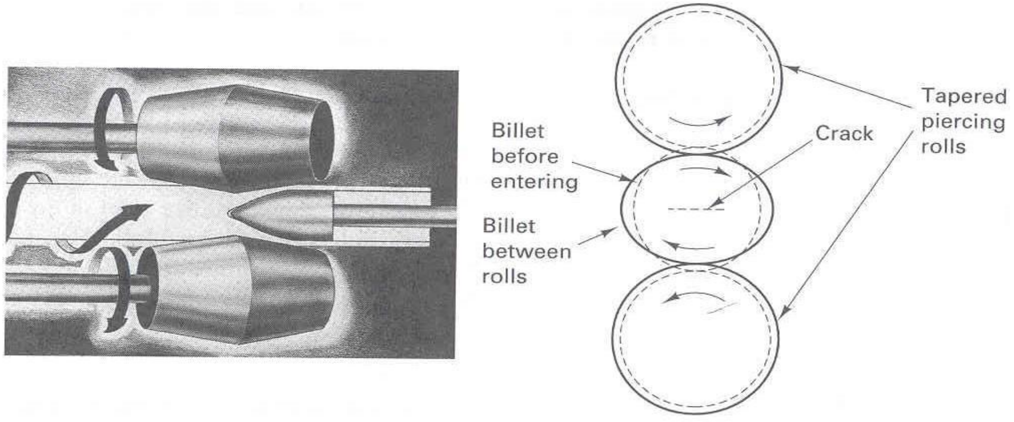


FIGURE 18-28 (*Left*) Principle of the Mannesmann process of producing seamless tubing. (*Courtesy of American Brass Company.*) (*Right*) Mechanism of crack formation in the Mannesmann process.

COLD FORMING

- Plastic deformation of metal below its recrystallisation temp.

ADVANTAGES:

1. No heating is required (energy)
2. Better surface finish
3. Improves strength properties

DISADVANTAGES:

1. High forces required
2. Strain hardening (require annealing before next process)
3. Directional properties (may be detrimental)
4. Mainly – for large volume production (high investment costs)
5. In the recent years → more and more applications. Good tensile properties → deciding about the choice of material
6. Stress strain diagram → important
7. Spring back – due to elastic deformation – deciding the size of the die
8. Similar equipment to hot working – more sophisticated, more powerful
9. Stronger machines are required
10. Furnaces –still required for annealing

FOUR BASIC TYPES OF PROCESS

*** Squeezing** *** Shearing** *** Bending** *** Drawing**

FIGURE 18-29 Some typical defects that occur during flat rolling: wavy edges, edge cracking, and center cracking.

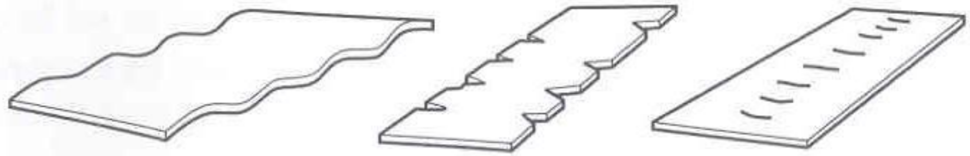


TABLE 19-1. Classification of the Major Cold-Working Operations

Squeezing		Bending	
1. Rolling	7. Staking	1. Angle	5. Seaming
2. Swaging	8. Coining	2. Roll	6. Flanging
3. Cold forging	9. Peening	3. Draw and compression	7. Straightening
4. Extrusion	10. Burnishing	4. Roll-forming	
5. Sizing	11. Hubbing		
6. Riveting	12. Thread rolling		
Shearing		**Drawing**	
1. Shearing; slitting	4. Notching; Nibbling	1. Bar and tube drawing	5. Stretch forming
2. Blanking	5. Shaving	2. Wire drawing	6. Sheet metal drawing
3. Piercing; lancing; perforating	6. Trimming	3. Spinning	7. Ironing
	7. Cutoff	4. Embossing	8. Superplastic forming
	8. Dinking		

COLD ROLLING : for finishing purposes only →

- Reduction ratios 10-50 % only
- Gives increased hardening effect
- Annealing – required between (not during) consecutive rolling > 900^0 C for steel, depending on C content

SWAGING – some kind of hammering – reducing the section

- End section of the bars and tubes by rotating the dies which open and close rapidly on the work → the end is becoming tapered or shaped
- Annealing > 900^0 C for steel → softening the material

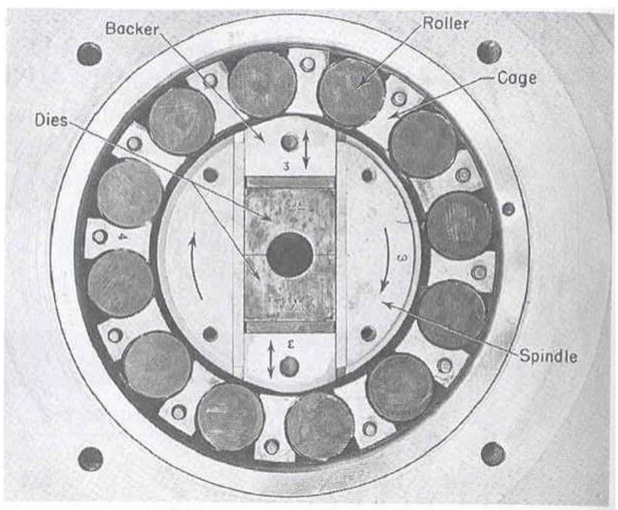


FIGURE 19-1 Basic components and motions of a rotary swaging machine. *Note:* The cover plate has been removed to reveal the interior workings. *(Courtesy of Torrington Company.)*

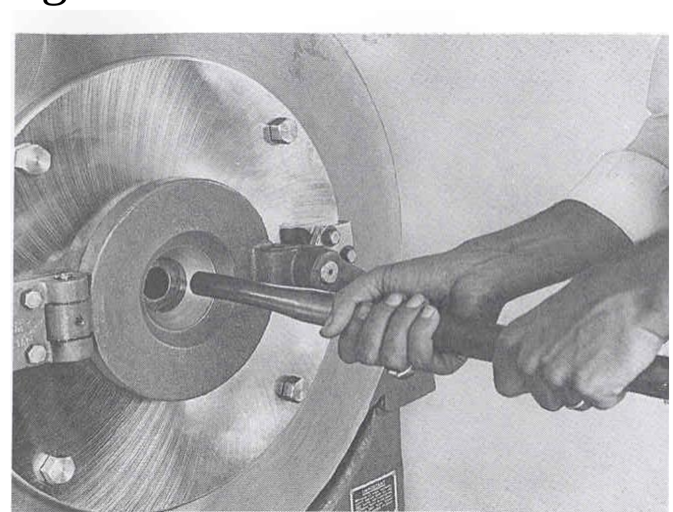


FIGURE 19-2 Tube being reduced in a rotary swaging machine. *Note:* The cover plate has been reinstalled. *(Courtesy of Torrington Company.)*

INTRAFORMING – Squeezes the tube in die → good internal shape duplicated from the mandrel

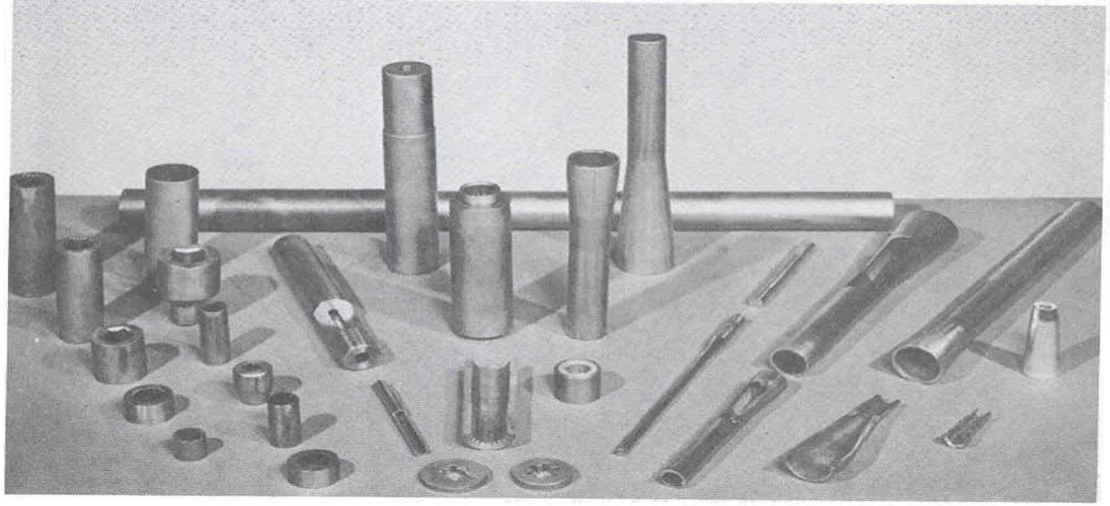


FIGURE 19-3 A variety of swaged parts containing internal details. *(Courtesy of Cincinnati Milacron, Inc.)*

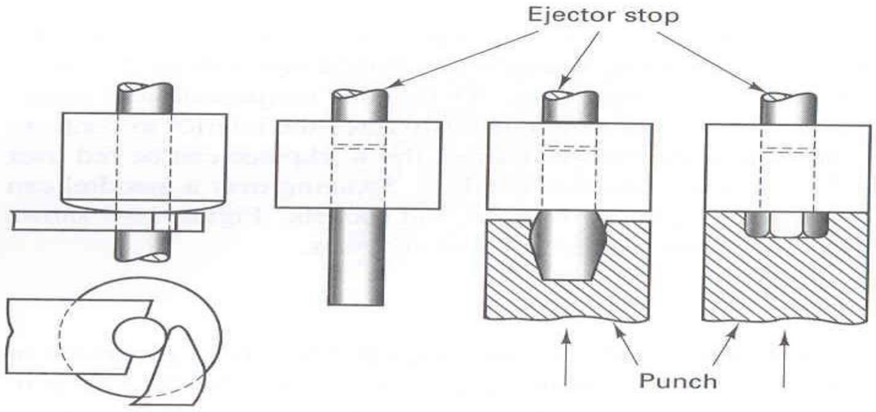


FIGURE 19-4 Typical steps in a shearing and cold-heading operation.

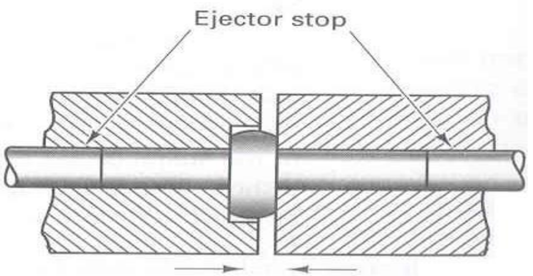


FIGURE 19-5 Method of upsetting the center portion of a rod. The stock is supported in both dies during upsetting.

COLD HEADING: cold upsetting (upset forging)

- Different types of dies can be used → billions of parts production
- Fast action presses are used > 3 Hz

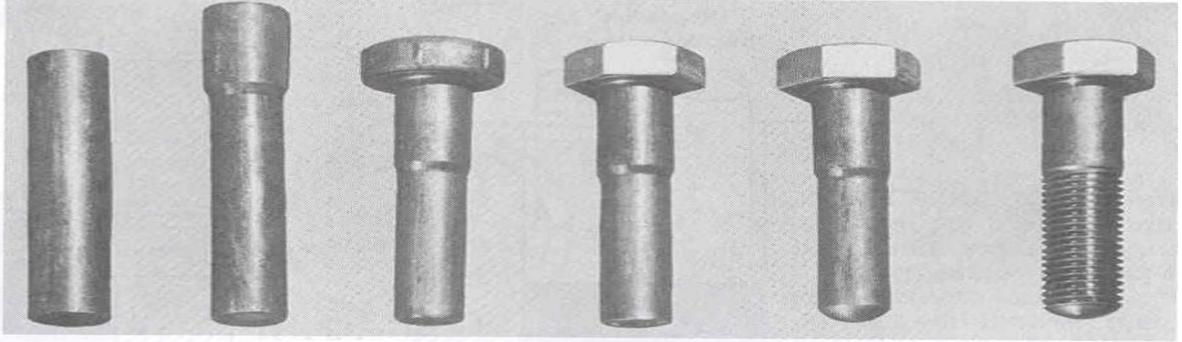


FIGURE 19-9 Steps in the forming of a bolt by cold extrusion, cold heading, and thread rolling. *(Courtesy of National Machinery Co.)*

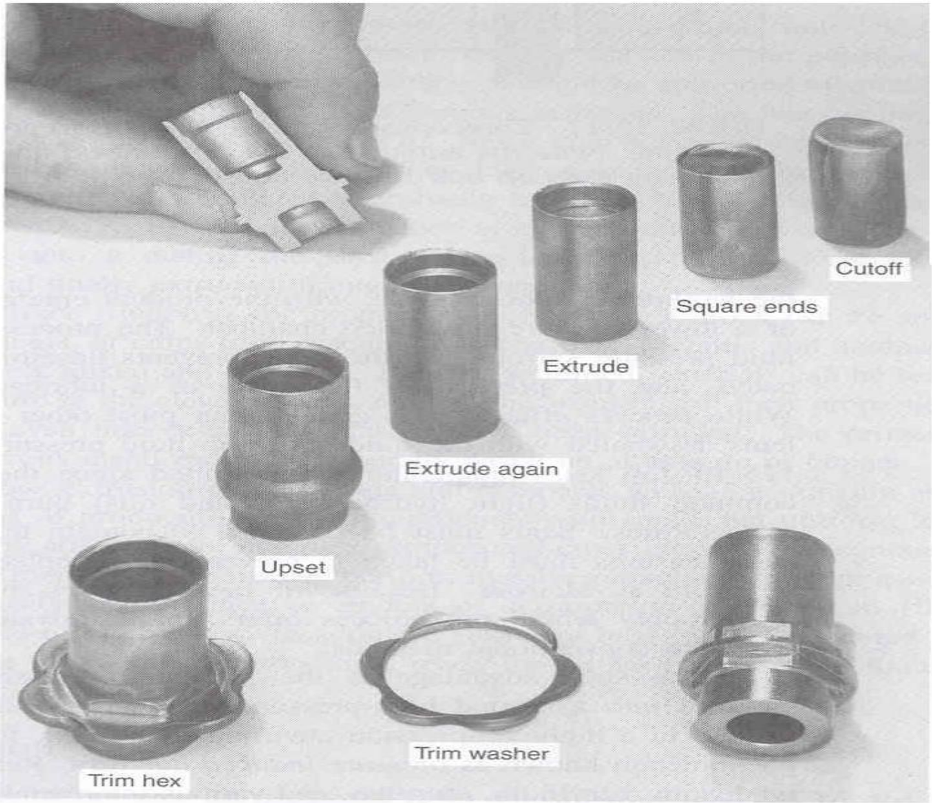
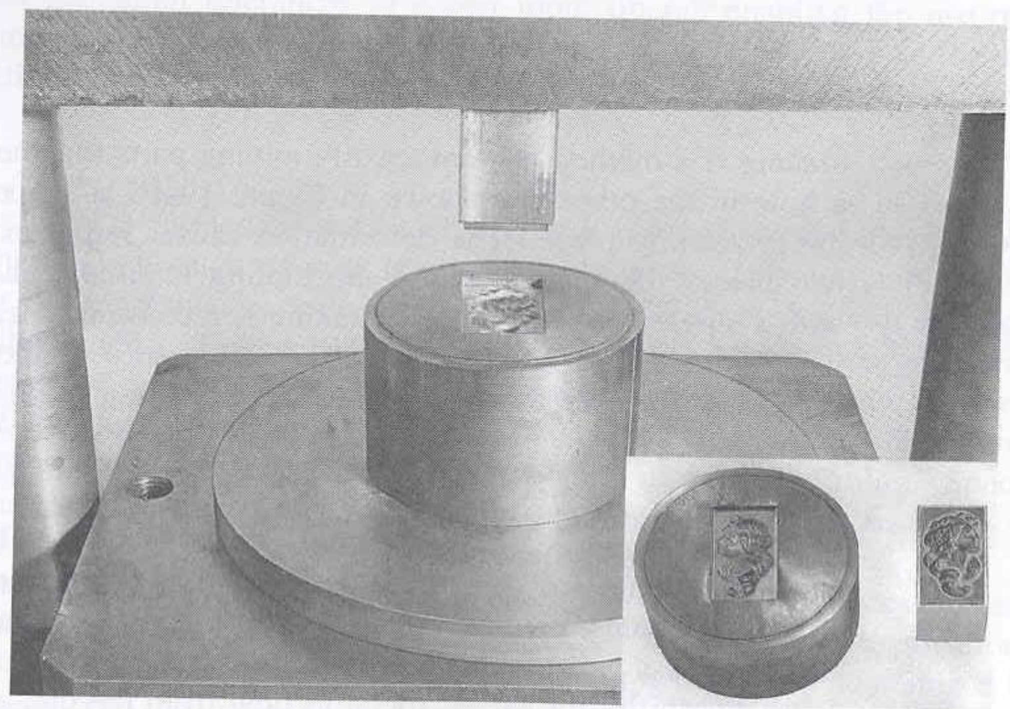


FIGURE 19-10 Cold-forming sequence involving cutoff, squaring, two extrusions, an upset, and a trimming operation. Also shown are the finished part and the trimmed scrap. *(Courtesy of National Machinery Co.)*

HUBBING : very popular operation →

- Produces recessed cavities by forcing a hardened steel hub into soft steel piece → operation performed in steps, with annealing as inter steps
- High capacity machines are used (8,000 tones)
- Multiple pieces of identical cavities can be produced economically
- Good surface finishing

FIGURE 19-18 Hubbing a die block in a hydraulic press. Inset shows close-up of the hardened hub and the impression in the die block. The die block is contained in a reinforcing ring. The upper surface of the die block is then machined flat to remove the bulged metal.



COINING & EMBOSSING

- Coining – shallow configurations on the surface of a piece (coins)
- High pressure are developed → metal is flowing & deforming
- No metal flow out of the die is allowed
- Embossing → shallow profiles on a thin metal (ex. Rotary embossing – to engrave)

RIVETTING & STAKING

- To fasten the parts together
- Not much pressure is required → small presses are being used with high operation frequency.

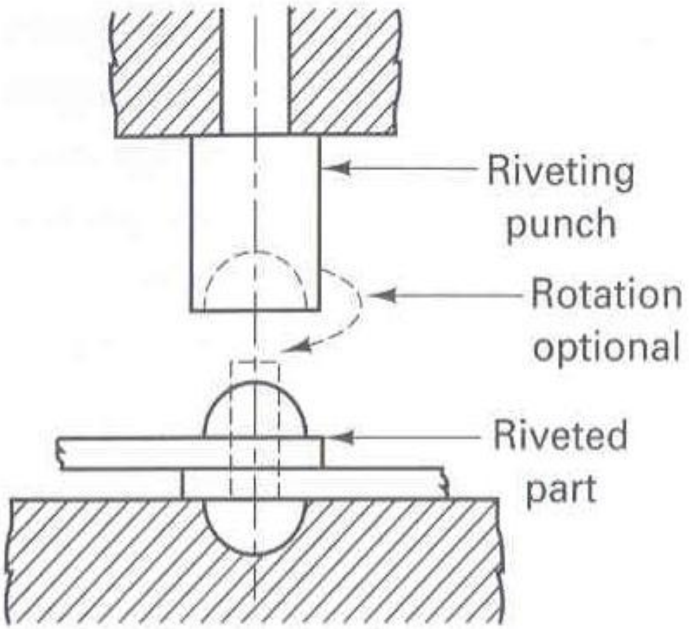


FIGURE 19-14 Joining components by riveting.

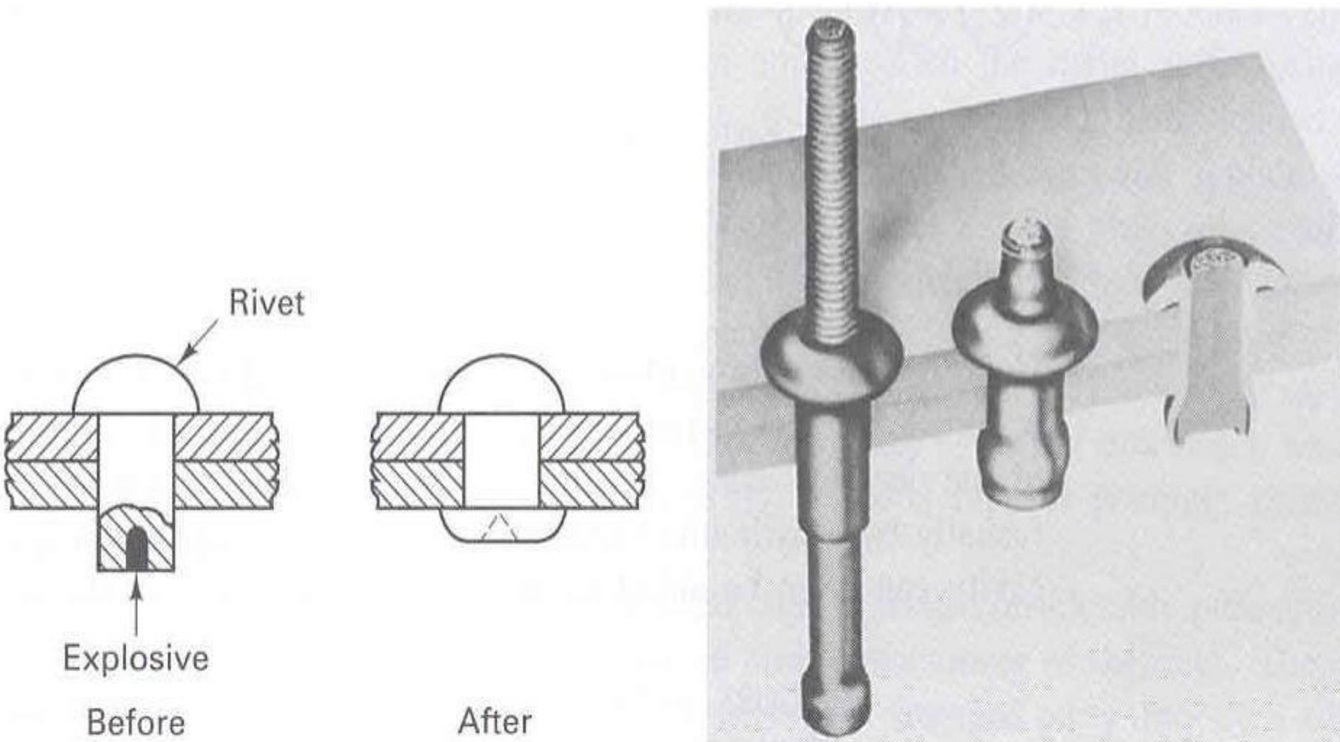


FIGURE 19-15 Rivets for use in "blind" riveting: (*left*) explosive type; (*right*) shank-type pull-up. *(Courtesy of Huck Manufacturing Company.)*

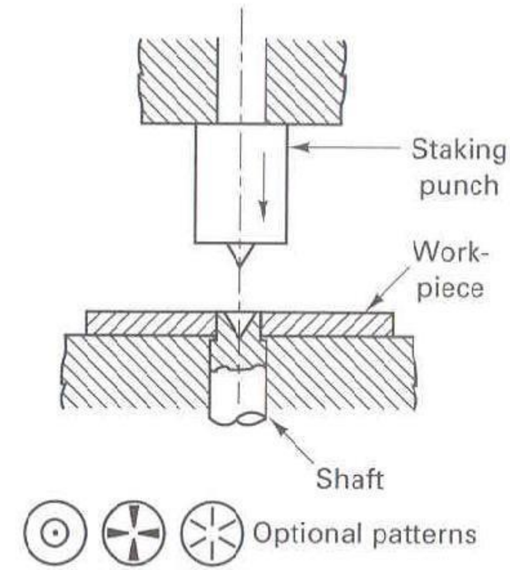


FIGURE 19-16 Fastening by staking.

ROLL FORMING (not roll - forging)

- The metal strips are ***progressively formed*** into desired shapes as they are passing through consecutive pairs of rolls, like for pipes in hot process
- The tubular sections can be welded by roll welding after being formed → ***closed profiles***
- Variety of profiles, including ***tubes*** are made
- Corners : have the bending radius not greater than sheet thickness
- ***High cost*** to the equipment → ***high productivity***

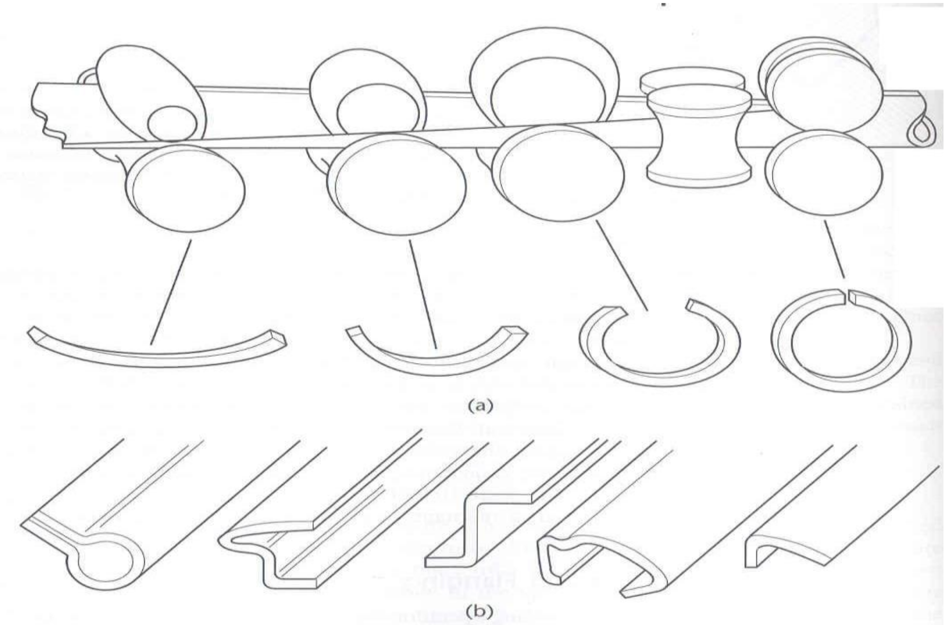


FIGURE 19-30 (a) Schematic representation of the cold roll-forming process being used to convert sheet or plate into tube. (b) Some typical shapes produced by roll forming.

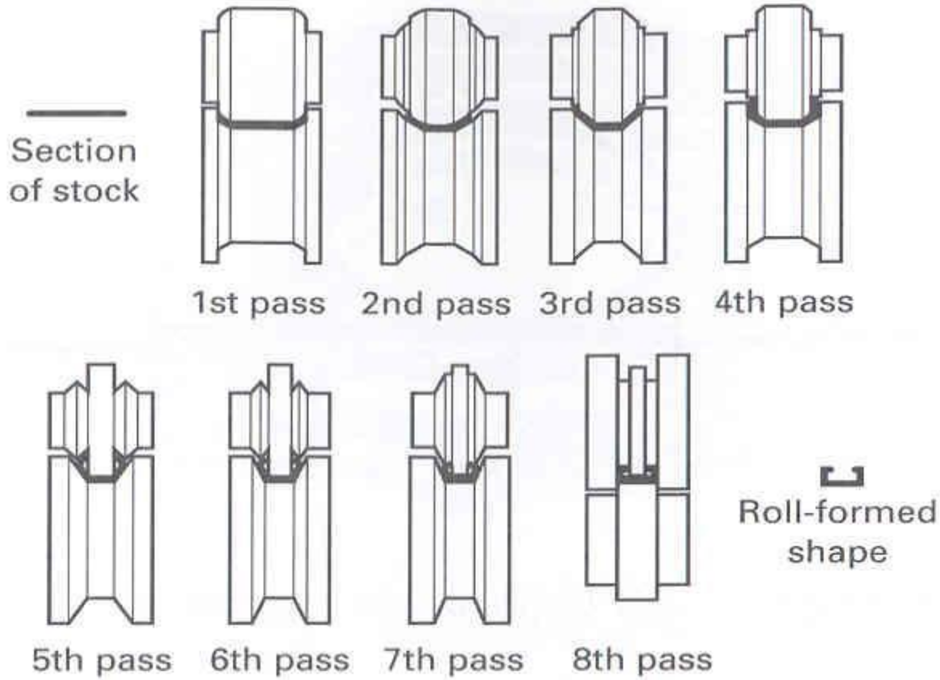


FIGURE 19-31 Eight-roll sequence for the roll forming of a box channel. *(Courtesy of the Aluminum Association, New York.)*

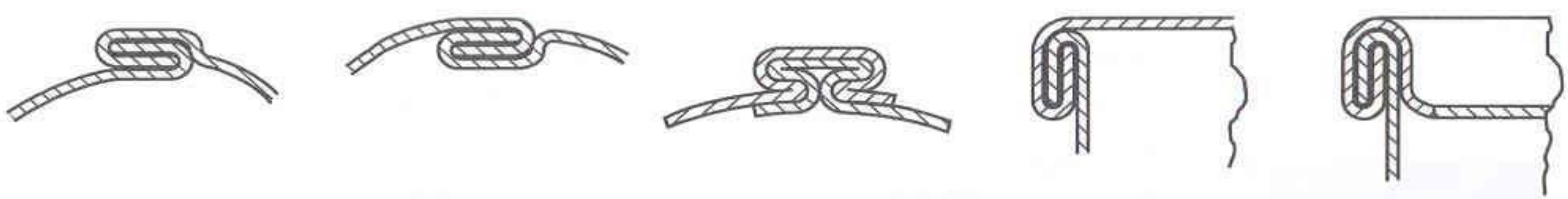


FIGURE 19-32 Various types of seams used on sheet metal.

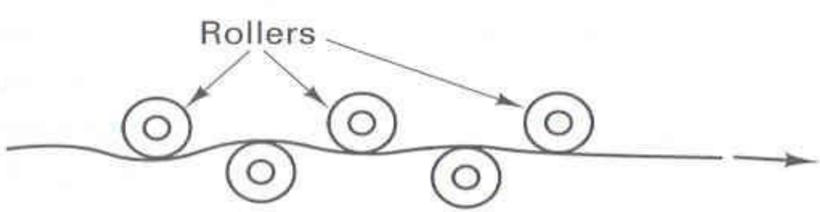


FIGURE 19-33 Method of straightening rod or sheet by passing it through a set of straightening rolls. For rods, another set of rolls is used to provide straightening in the transverse direction.

COLD EXTRUSION

- As cold working process, extrusion is mainly used for ***soft materials***. ***(mild steel*** can be extruded***)***
- Combined with ***cold heading***
- By hydrostatic extrusion :- Backward or Forward, die open or closed
- Used to produce thin wall cylinders from thicker wall materials

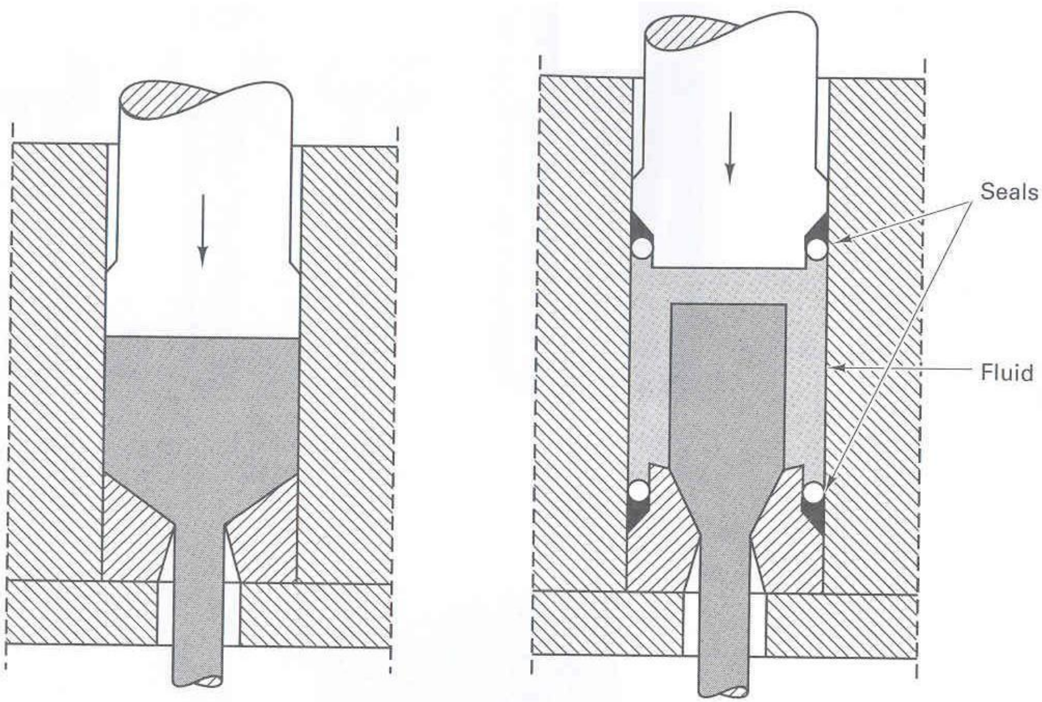


FIGURE 19-11 Comparison of conventional (*left*) and hydrostatic (*right*) extrusion. Note the addition of the pressurizing fluid and the O-ring and miter-ring seals on both the die and ram.

Avoid upsetting and reduce the friction

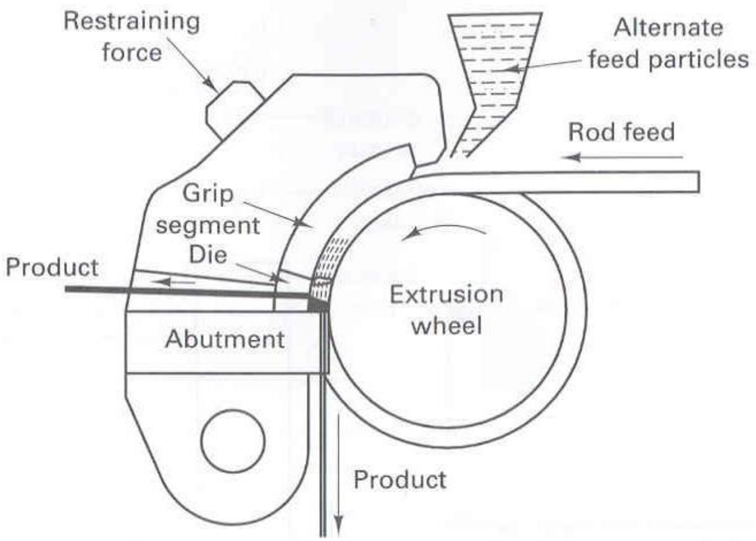


FIGURE 19-12 Cross-sectional schematic of the Conform continuous extrusion process showing various types of feeds and alternate locations of product withdrawal. *(Courtesy of United Kingdom Atomic Energy Authority, Springfields Nuclear Laboratories.)*

Replacement for wire drawing

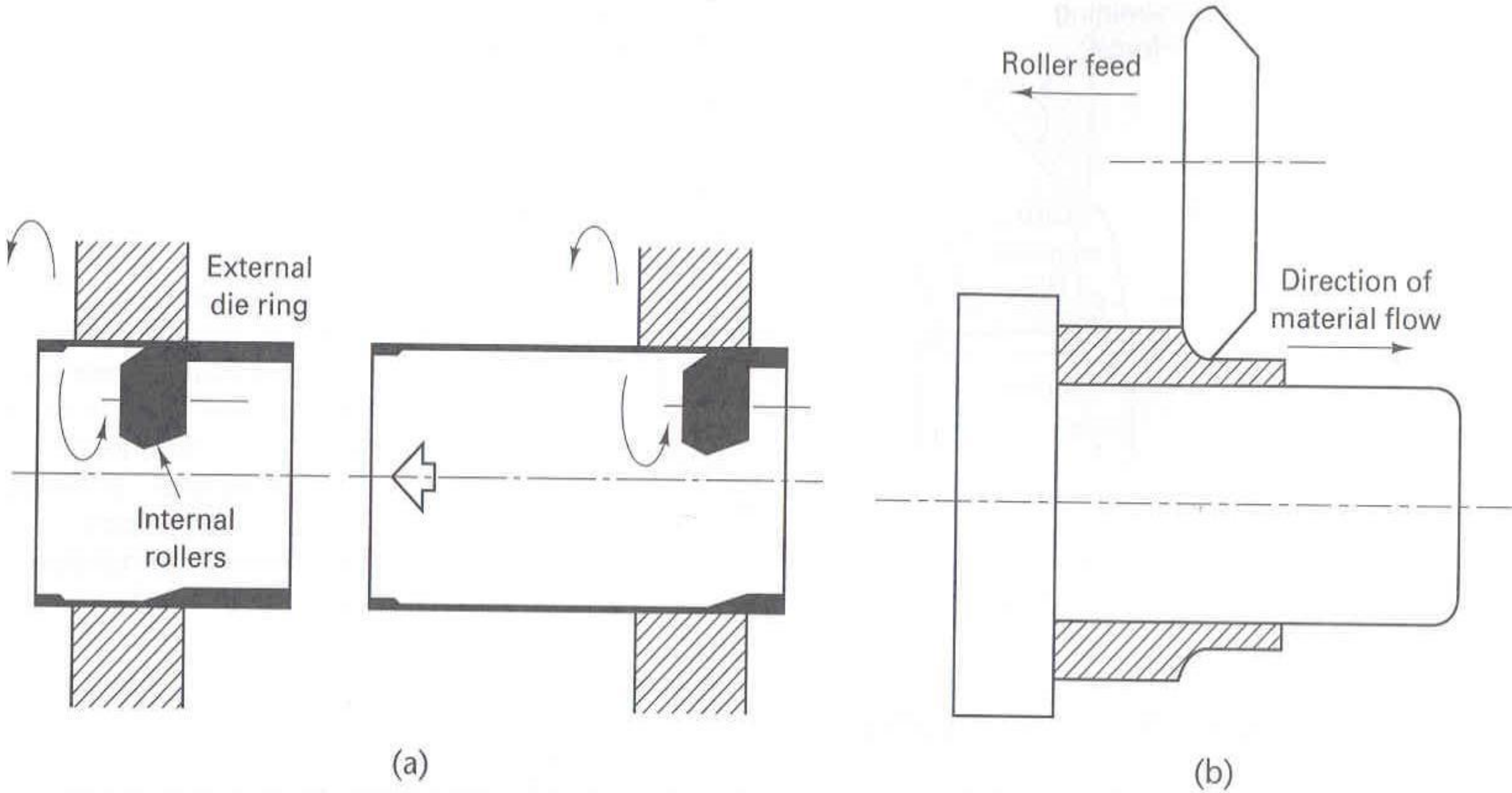


FIGURE 19-13 The roll extrusion process: (a) with internal rollers expanding the inner diameter; (b) with external rollers reducing the outer diameter.

BENDING

- Deformation of metal pieces with almost ***no change in the cross- section area***
- Bar folders can be used for bending of different work pieces
  → manually operated, usually.
  For heavier pieces, press brake → Different kinds of bends
- Minimum radius ~ thickness of metal sheet
- Tolerance ~ 1 mm

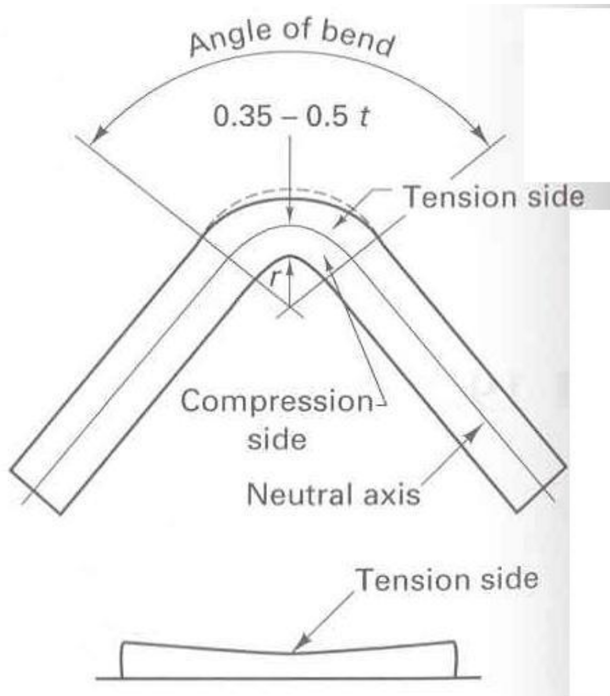


FIGURE 19-20 (*Top*) Nature of a bend in sheet metal showing tension on the outside and compression on the inside; (*bottom*) upper portion of the bend region, viewed from the side, showing how the center portion thins more than the edges.

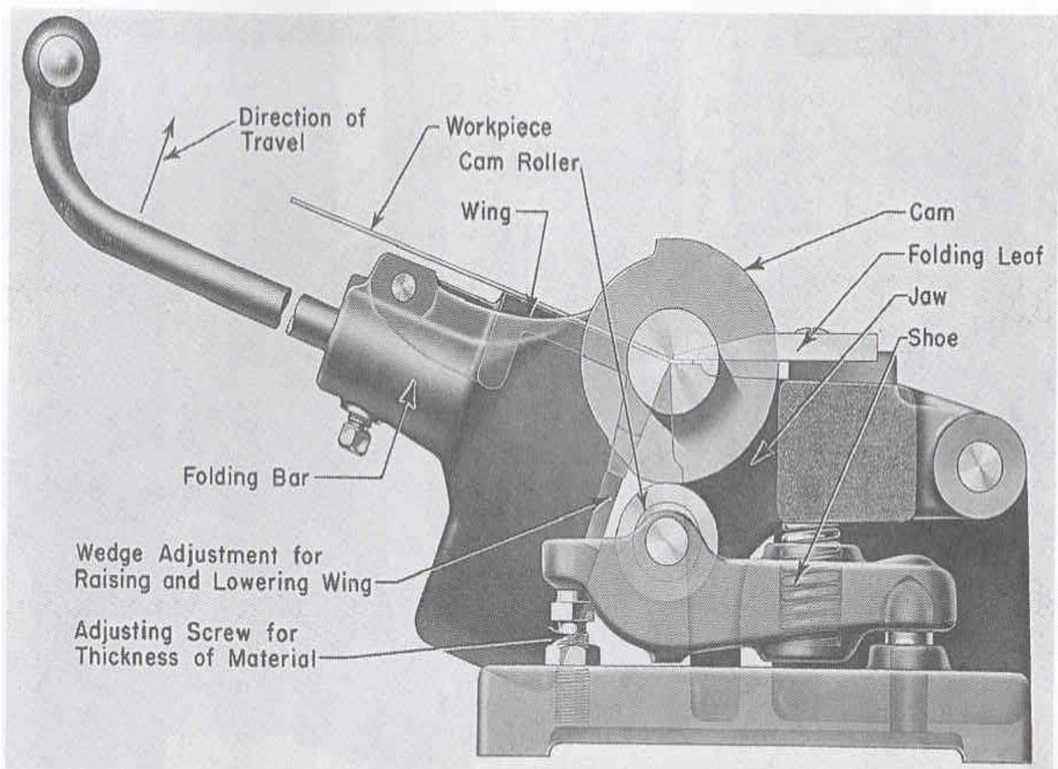
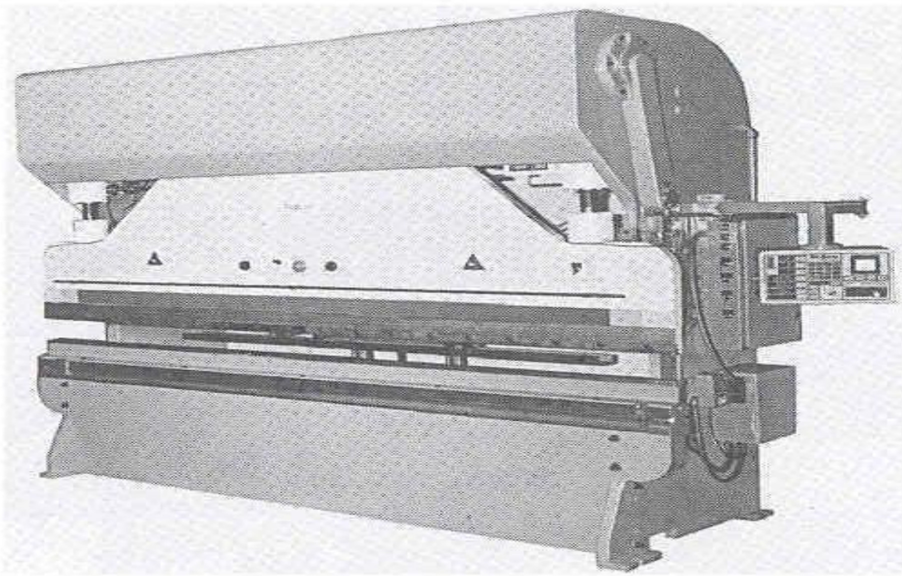


FIGURE 19-21 Phantom section of a bar folder, showing position and operation of internal components. *(Courtesy of Niagara Machine and Tool Works.)*



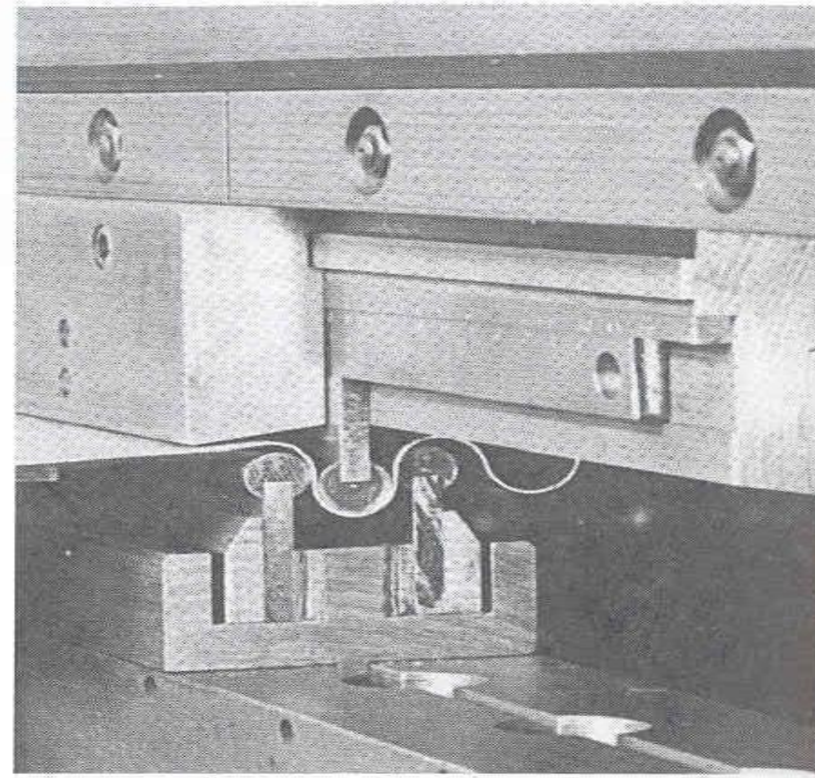


FIGURE 19-22 (*Left*) Press brake with CNC gauging system. *(Courtesy of DiAcro Division, Houdaille Industries, Inc.)* (*Right*) Close-up view of press brake dies. *(Courtesy of Cincinnati Incorporated.)*

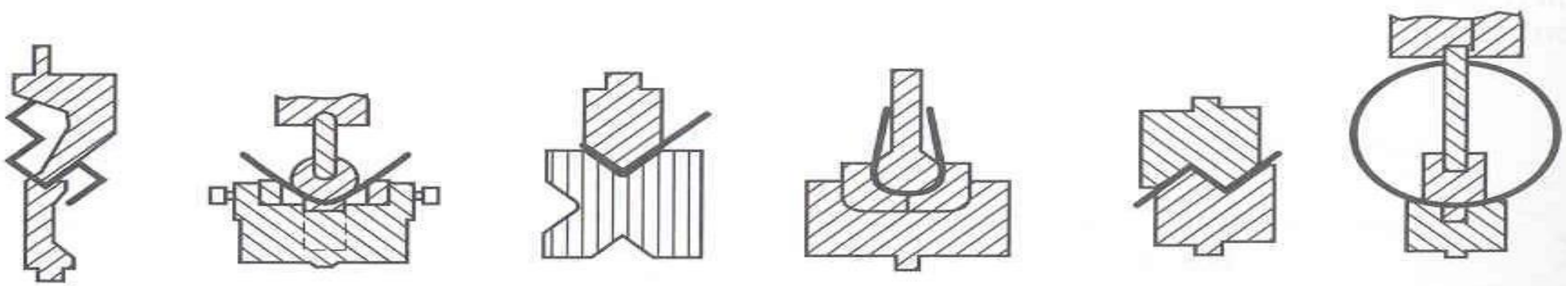


FIGURE 19-23 Press brake dies used to form various angles and rounds. *(Courtesy of Cincinnati Incorporated.)*

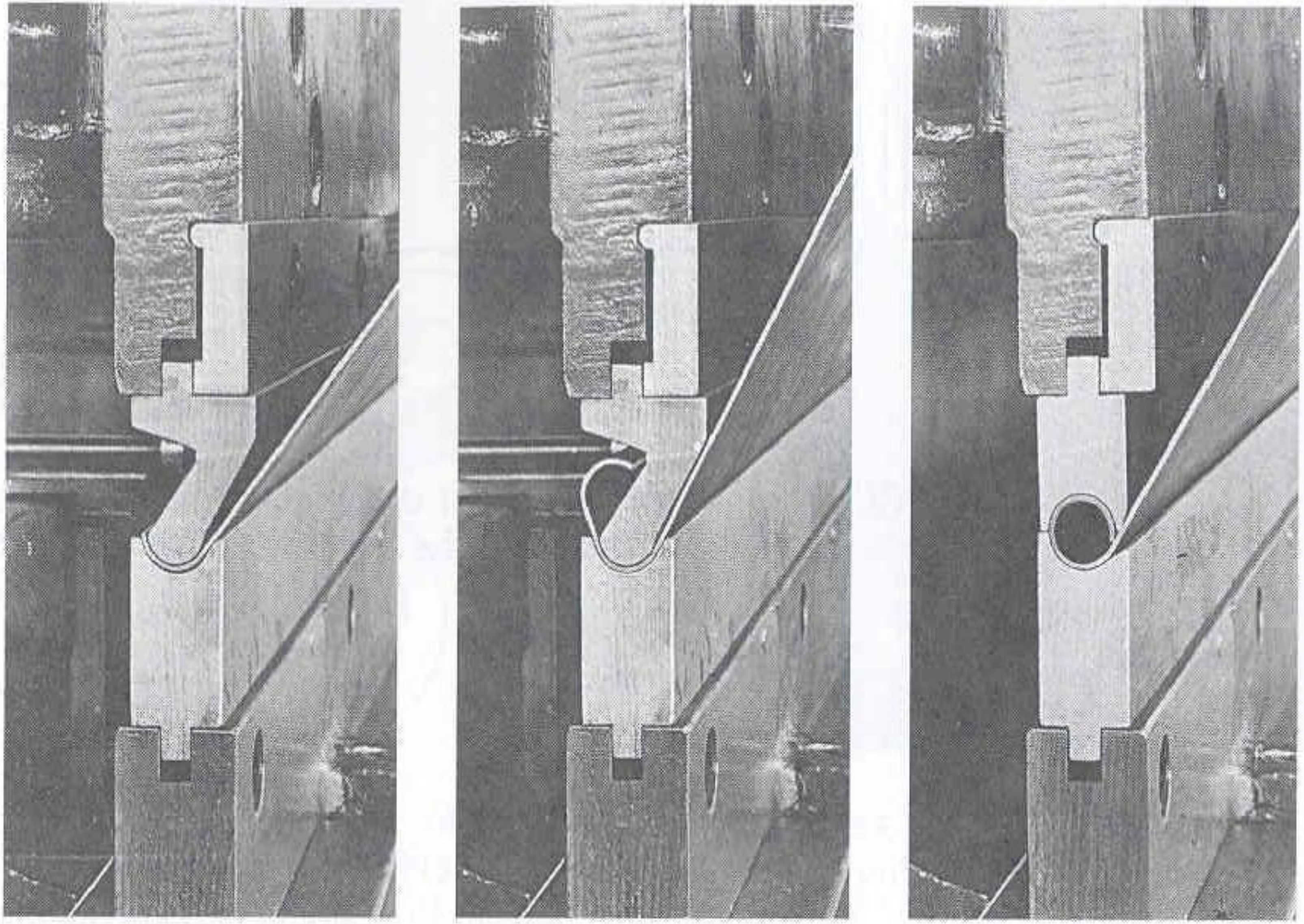
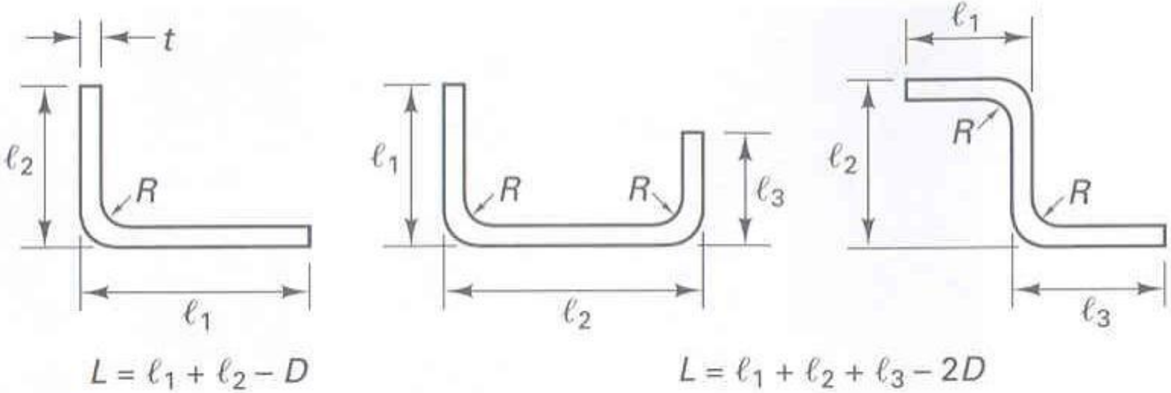


FIGURE 19-24 Dies and stages used in the press brake forming of a roll bead. *(Courtesy of Cincinnati Incorporated.)*



R	D
t	1.7 t
2 t	2.0 t
3 t	2.5 t

FIGURE 19-26 One method of determining the blank size for several bending operations. Due to thinning, the product will lengthen during forming.

Account for spring-back

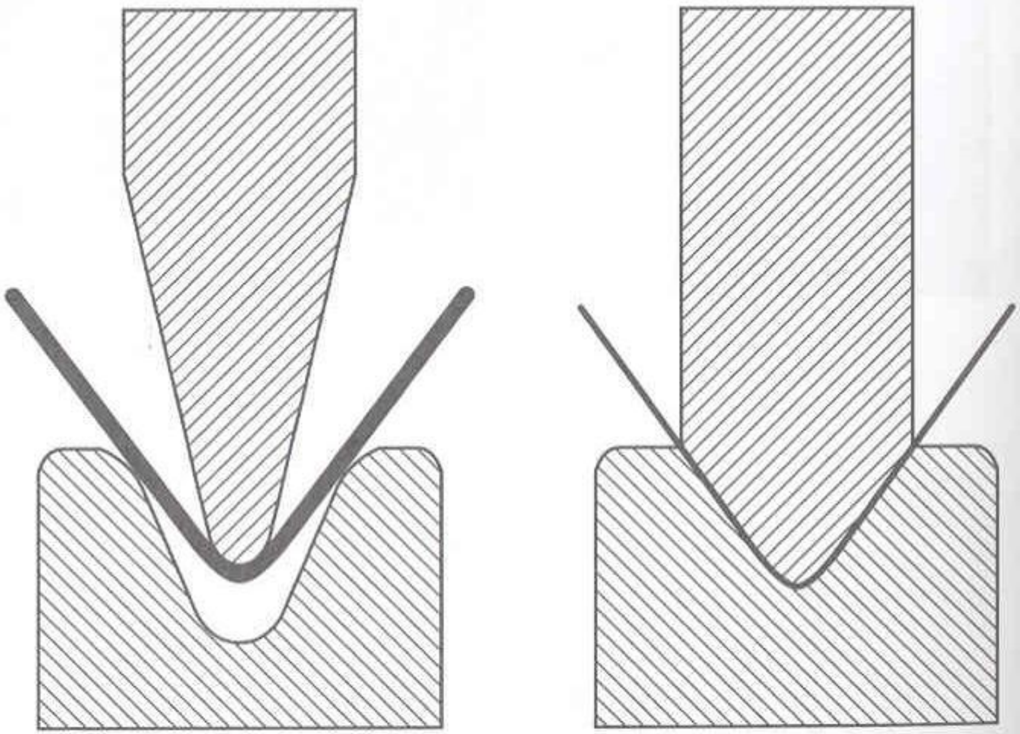


FIGURE 19-27 Comparison of air-bend (*left*) and bottoming (*right*) press brake dies. With the air-bend die, the amount of bend is controlled by the bottoming position of the upper die.

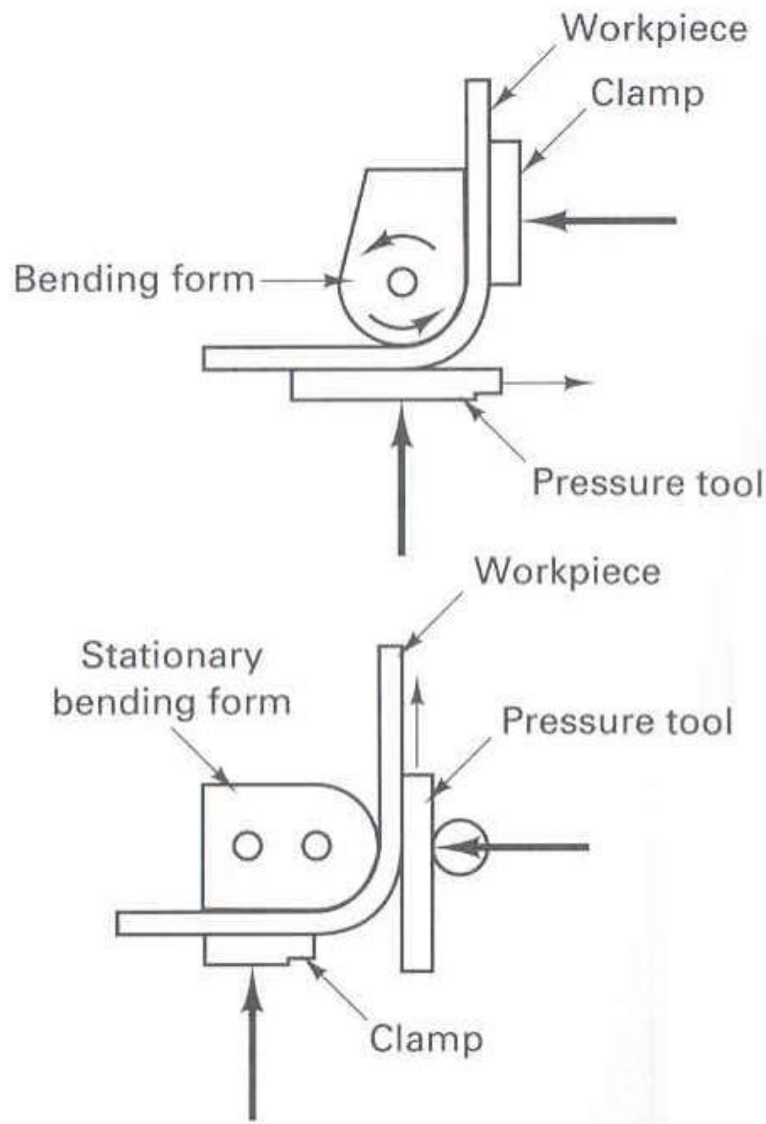


FIGURE 19-29 (*Top*) Draw bending, in which the form block rotates; (*bottom*) compression bending, in which a moving tool compresses the workpiece against a stationary form.

Roll bending →

Three rolls are bending the metal plate depending on their relative positions

Two Lower rolls are driving

Upper roll is adjustable

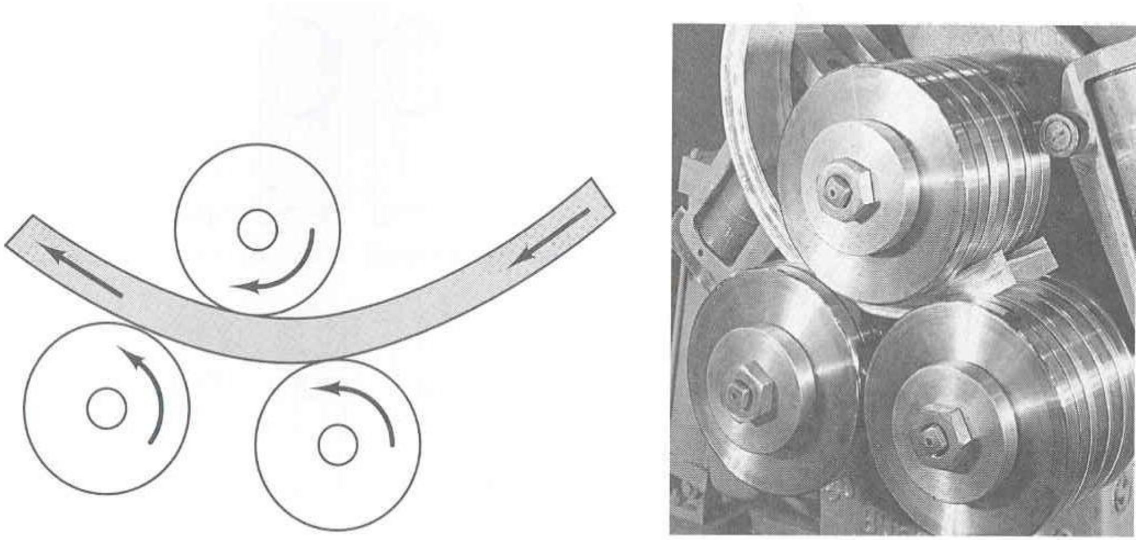


FIGURE 19-28 (*Left*) Schematic of the roll-bending process; (*right*) the roll bending of an I-beam section. Note how the material is continuously subjected to three-point bending. *(Courtesy of Buffalo Forge Company.)*

SHEARING: Mechanical cutting with PUNCH & DIE

- The ***clearance*** between punch & die depends on the hardness of material (for steel 5-8%)

Shearing → deformation and fracture

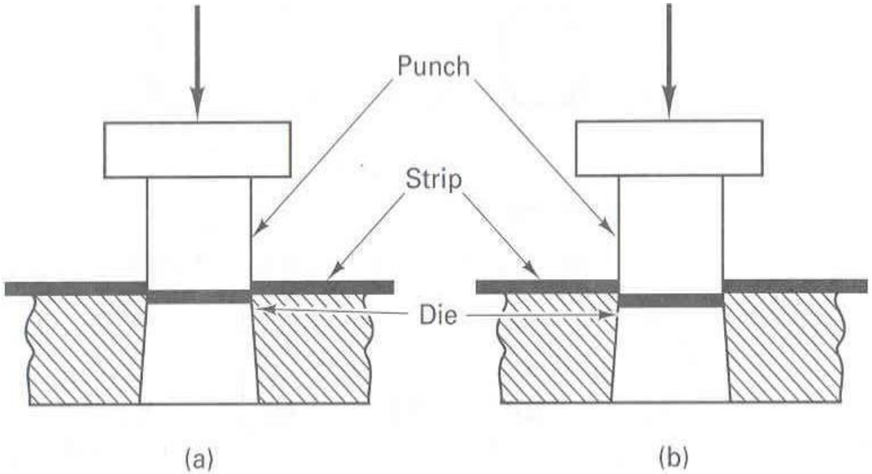


FIGURE 19-34 Simple blanking with a punch and die.

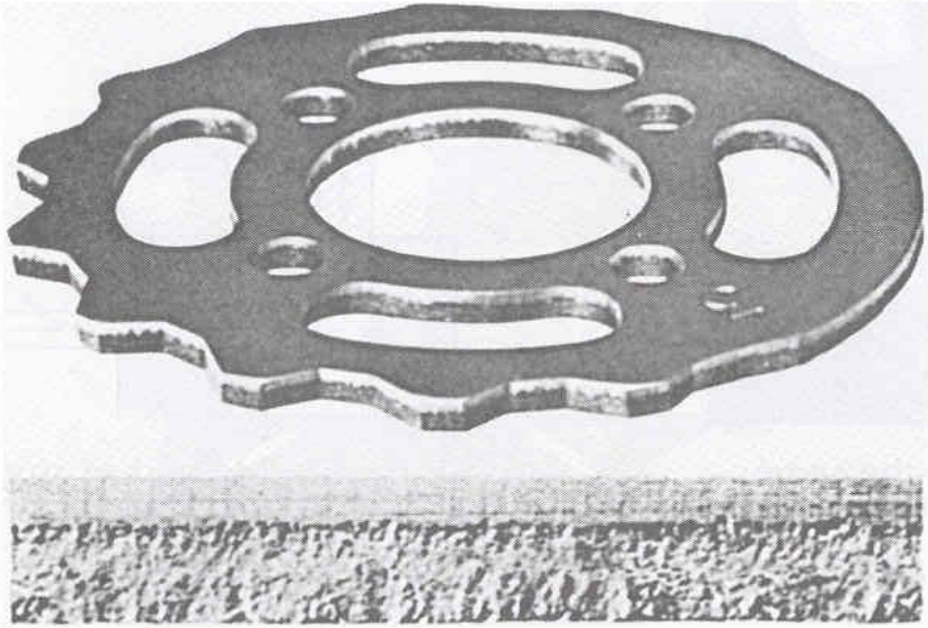


FIGURE 19-35 Conventionally sheared surface showing the distinct regions of deformation and fracture. *(Courtesy of American Feintool Inc.)*

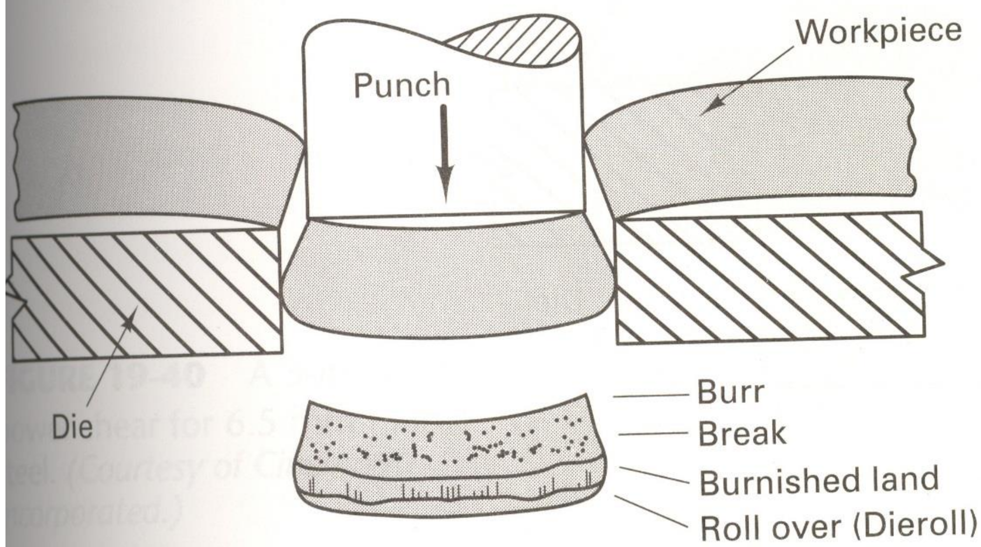
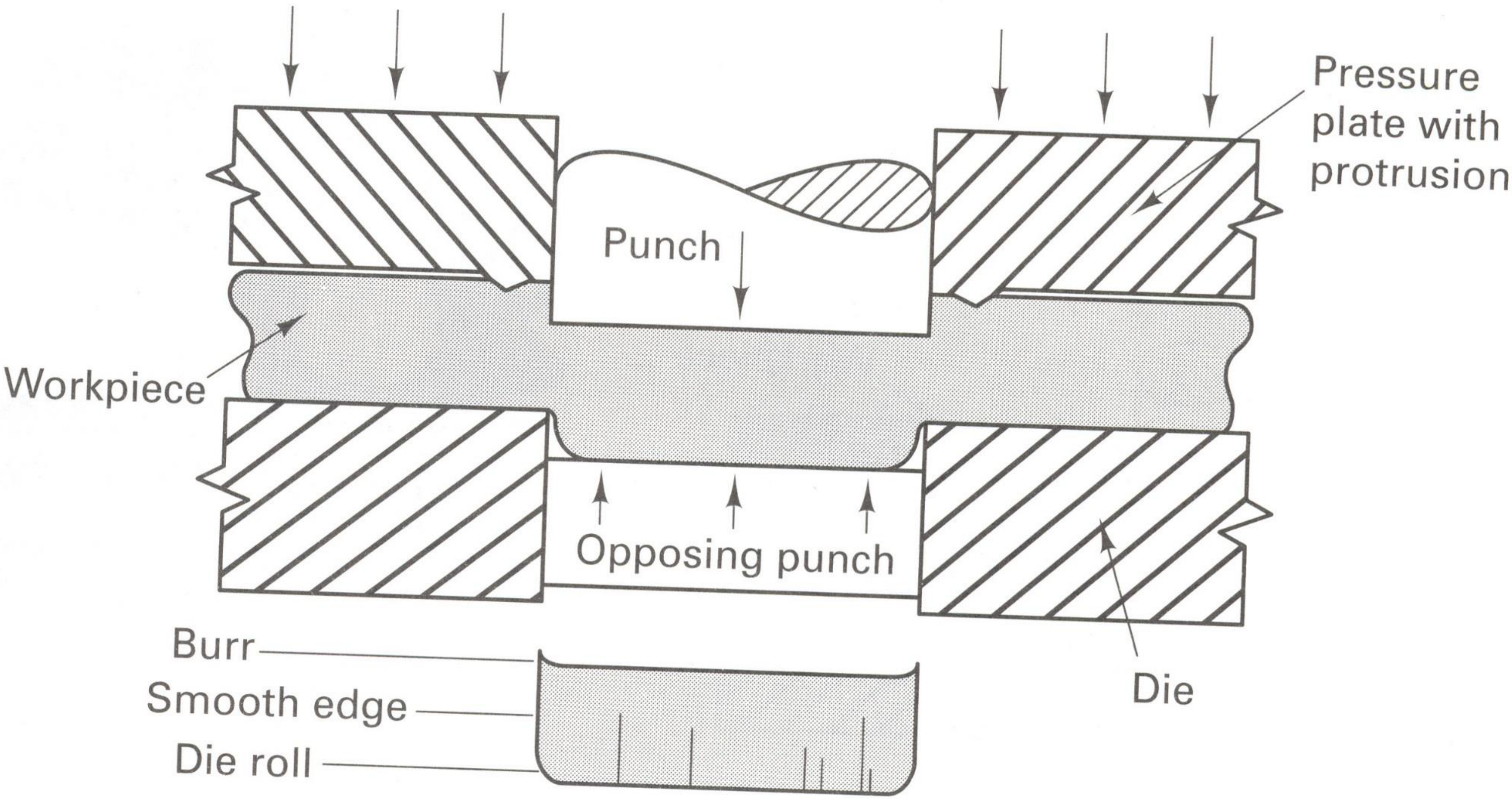


FIGURE 19-35 Simple blanking with a punch and die.



Pressure
plate with
protrusion
Punch
Workpiece
Opposing punch
Burr
Smooth edge
Die roll
Die

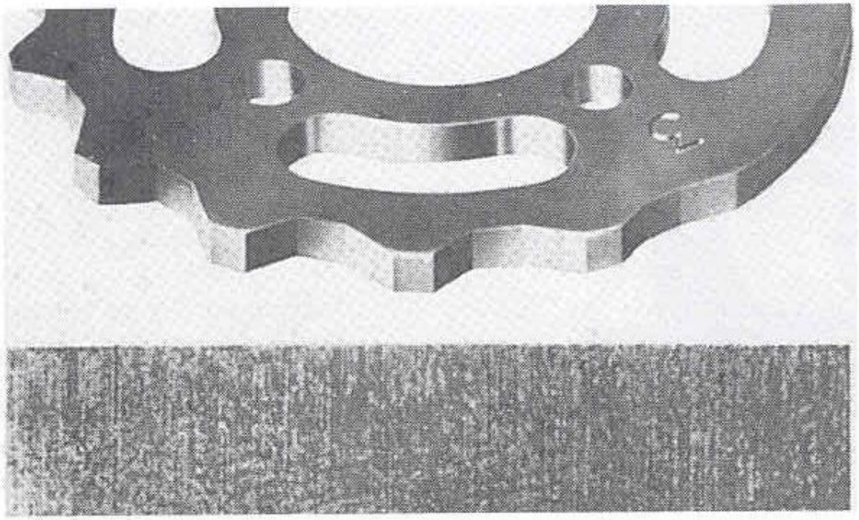


FIGURE 19-37 Fine-blanked surface of the same component as shown in Figure 19-35. *(Courtesy of American Feintool, Inc.)*

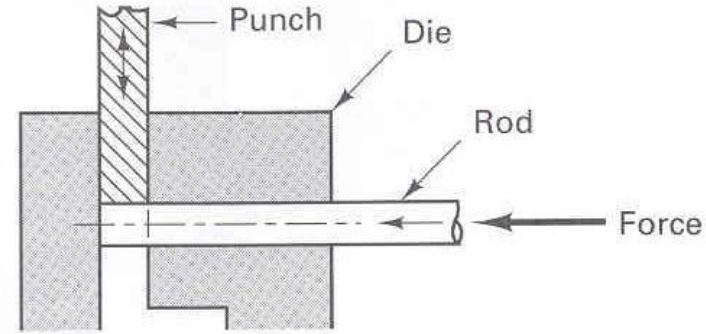


FIGURE 19-38 Method of smooth shearing rod by putting it into compression during shearing.

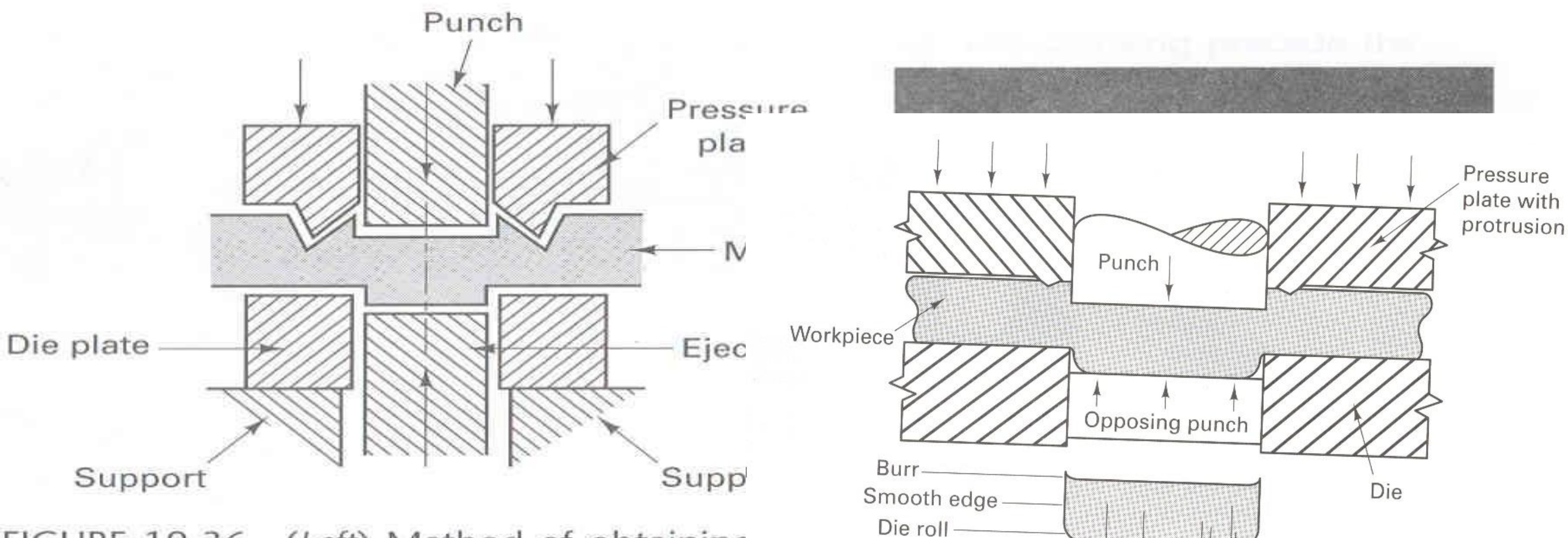


FIGURE 19-36 (*Left*) Method of obtaininc
shaped pressure plate to put the metal int
ejector descending in unison with the punch. *(Courtesy of Metal Progress.)* (*Right*) Stock skeleton after shearing, showing the compressed indentation. *(Courtesy of Clark Metal Products Company.)*

Slitting: Shearing rolls of sheet into several rolls narrower width.

Nibbling: Contour is cut by series of overlapping slits.

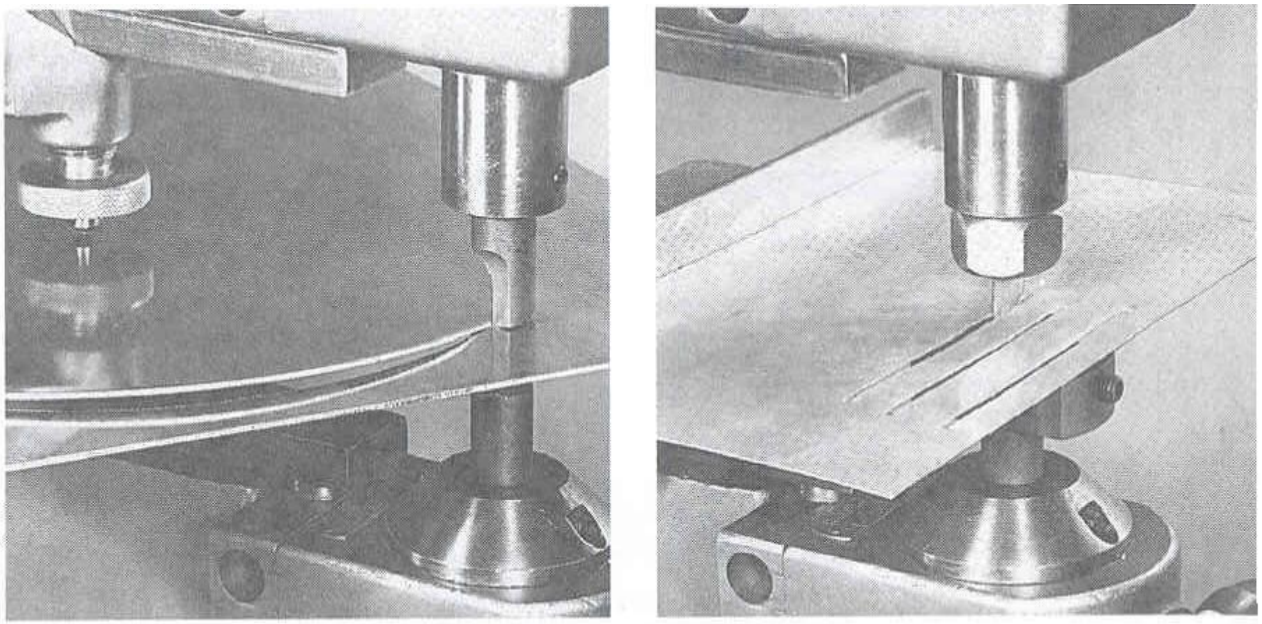


FIGURE 19-42 Shearing operations being performed on a nibbling machine. *(Courtesy of Tech-Pacific.)*

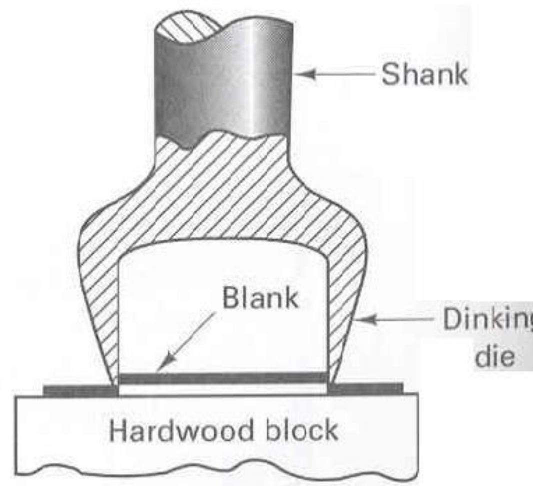


FIGURE 19-43 The dinking proce

Blanking - for thin sheets → flat pieces with flat punch

Punching or piercing- removing some parts of metal from the machines sheet with flat die and inclined punch

Shearing operations where the shear blades are closed or curved lines along the edges of the die or punch.

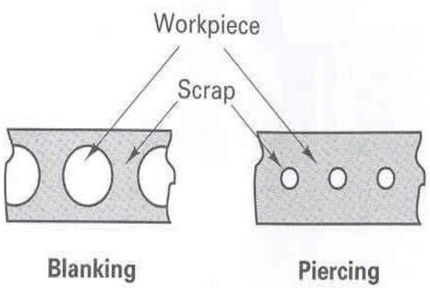


FIGURE 19-40 Schematic showing the difference between piercing and blanking.

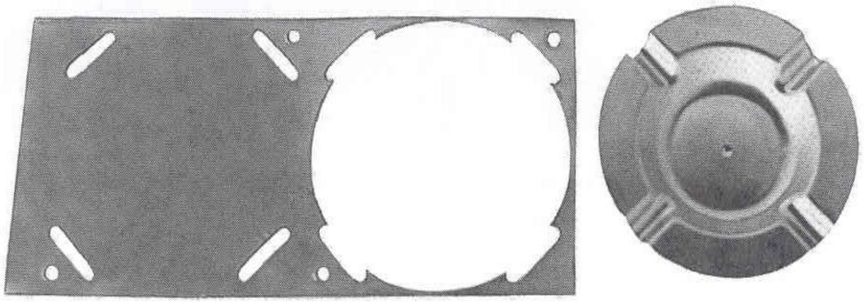


FIGURE 19-41 (*Left to right*) Piercing and lancing, and blanking precede the forming of the final ashtray. The small round holes assist positioning and alignment.

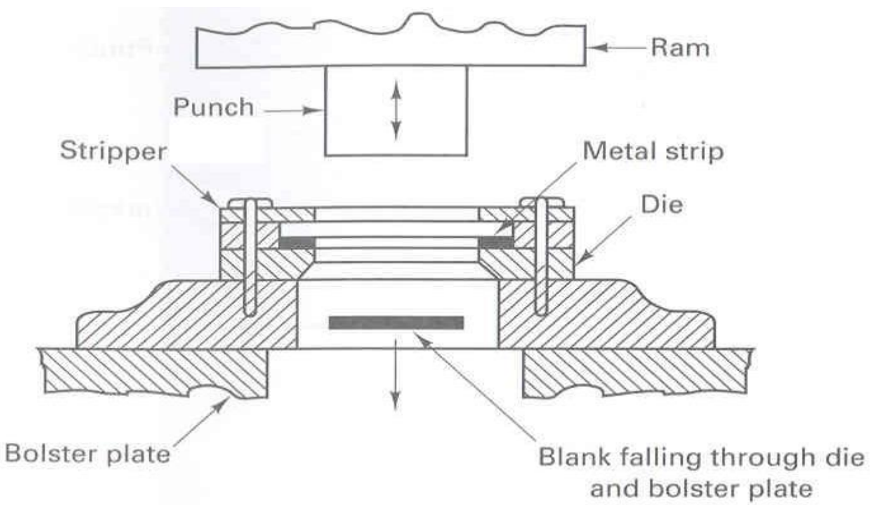


FIGURE 19-44 The basic components of piercing and blanking dies.

- When the punch & die are flat, maximum force is required

→ when the ***tip angle is not 90⁰,*** the cutting starts on one side and the force can be reduced

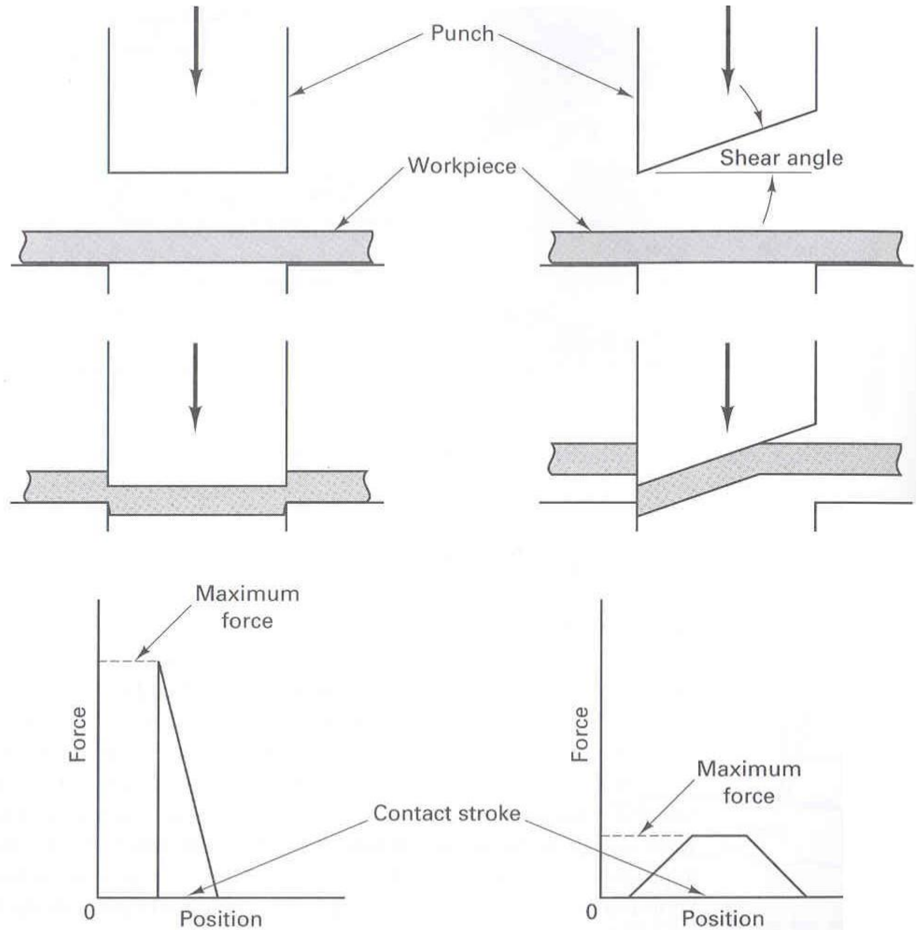


FIGURE 19-45 Blanking with a square-faced punch (*left*) and one containing angular shear (*right*). Note the difference in maximum force and contact stroke. The total work (the area under the curve) is the same for both processes.

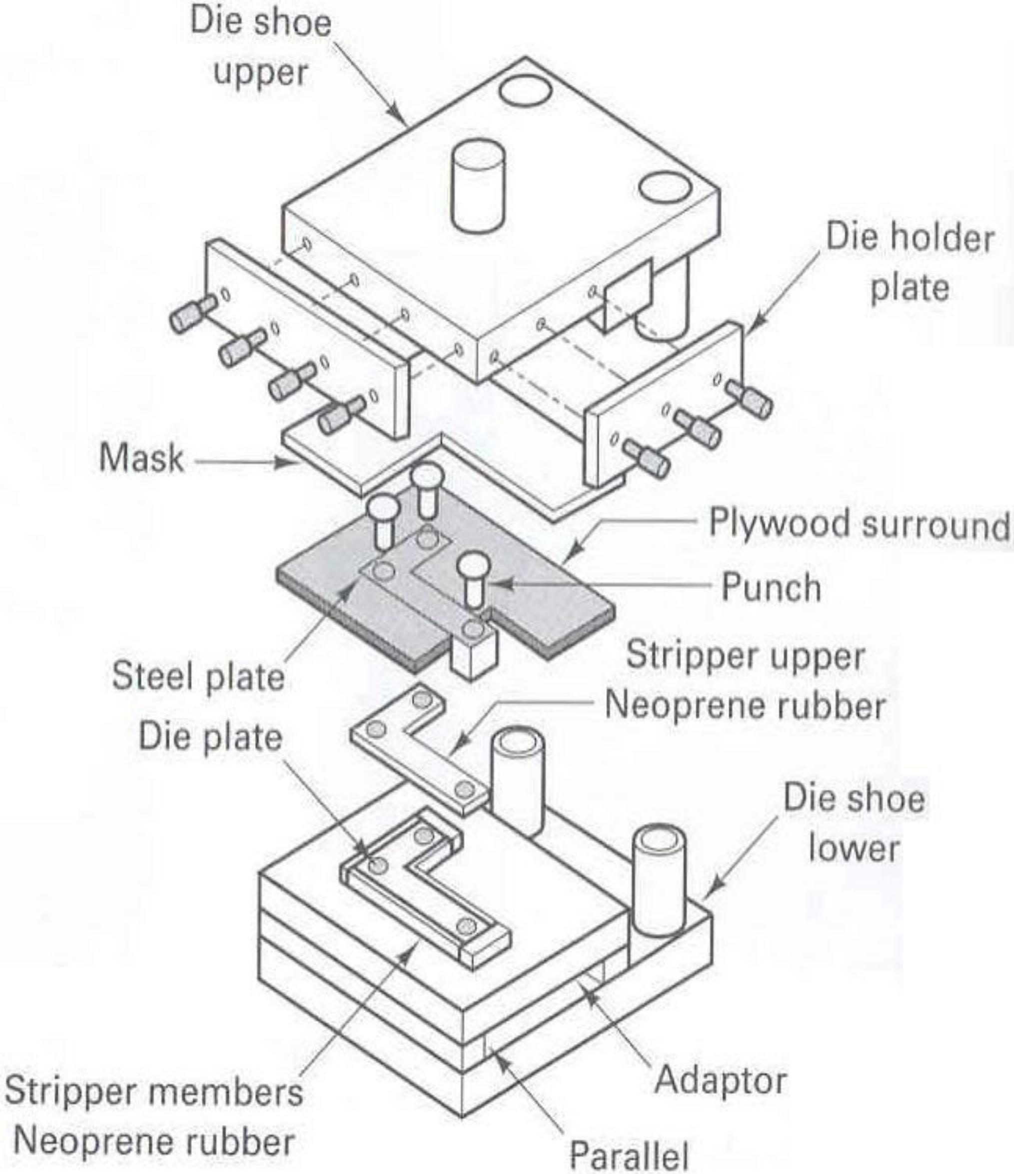


FIGURE 19-49 Construction of a steel-rule die set. *(Courtesy of J. J. Raphael.)*

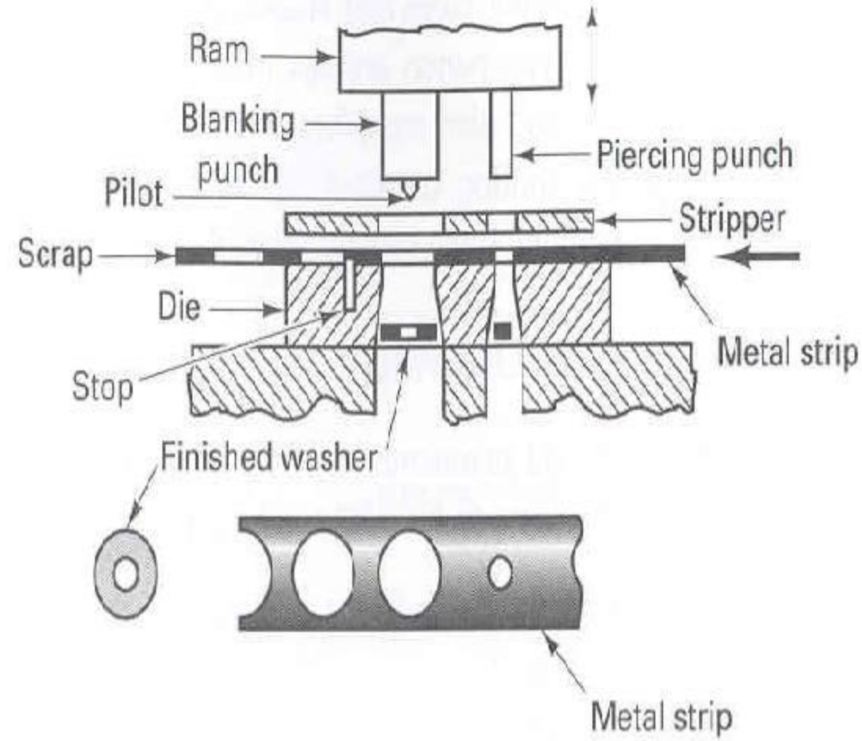


FIGURE 19-50 Progressive piercing and blanking die for making a simple washer.

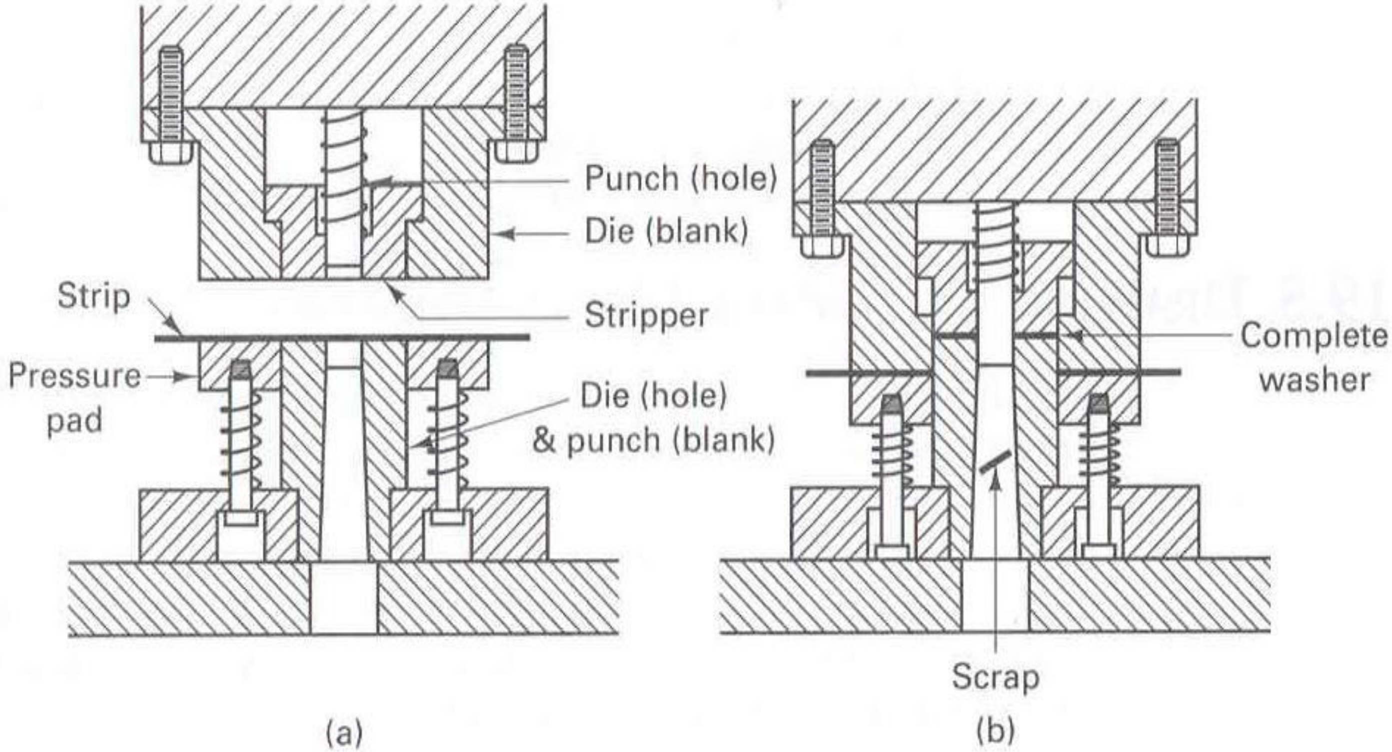


FIGURE 19-51 Method for making a simple washer in a compound piercing and blanking die. Part is blanked (a) and subsequently pierced (b). The blanking punch contains the die for piercing.

FIGURE 19-52 The various stages of an 11-station progressive die. *(Courtesy of the Minster Machine Company.)*

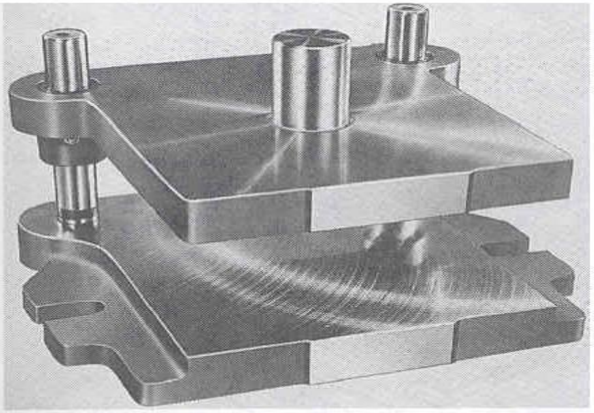


FIGURE 19-46 Typical die set having two alignment guideposts. *(Courtesy of Danly Machine Specialties, Inc.)*

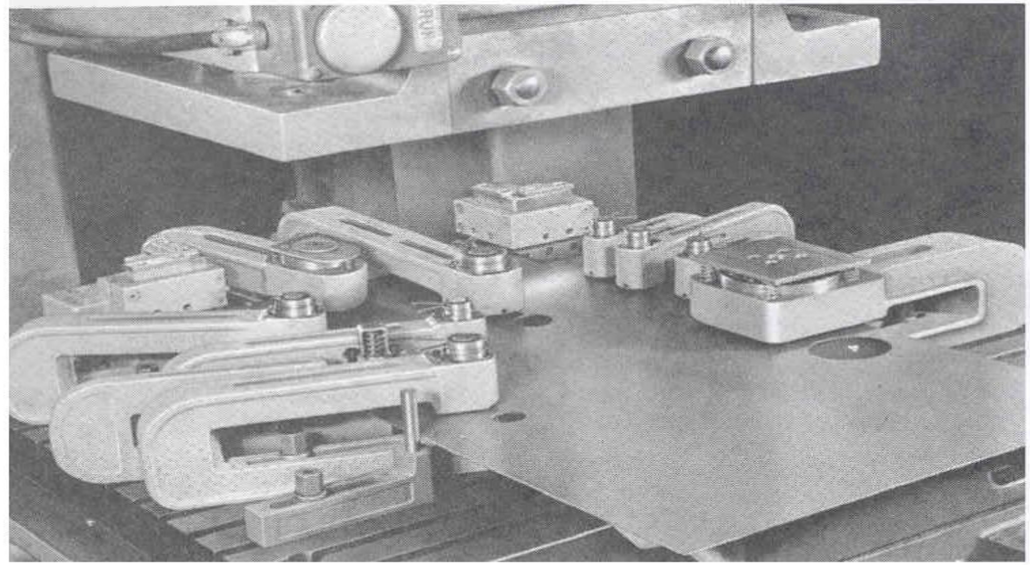


FIGURE 19-47 A piercing and blanking setup using self-contained subpress tool units. *(Courtesy of Strippit Division, Houdaille Industries, Inc.)*

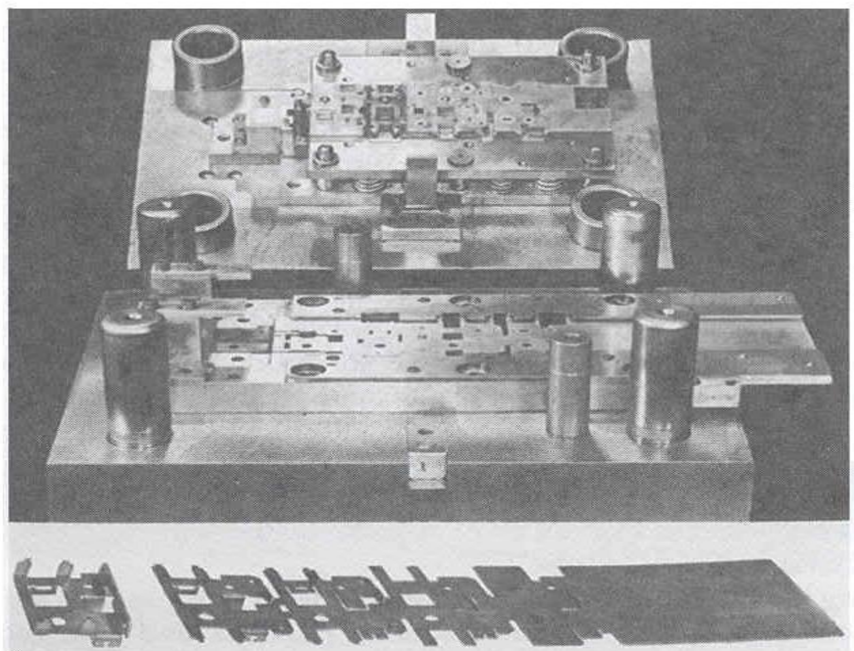


FIGURE 19-48 A progressive piercing, forming, and cutoff die set built up mostly from standard components. The part produced is shown at the bottom. *(Courtesy of Oak Manufacturing Company.)*

COLD DRAWING – Two Types

- Drawing of sheet metal → large metal sheet parts like auto body fenders, hooks – made in this way
- Drawing of wires or tubes – cross section reducing process by forcing the piece through a die
- Longitudinal Shape Drawing – a bar is inserted through a die and pulled by a grip → bar reduces in section →elongates and strain hardens the work
- Ratio of production ~ 30% for one pass → intermediate annealing is required
- Better surface finish and accuracy is obtained than by hot drawing
- Tube and wire drawing are similar to the hot process with similar reductions and larger forces applied.

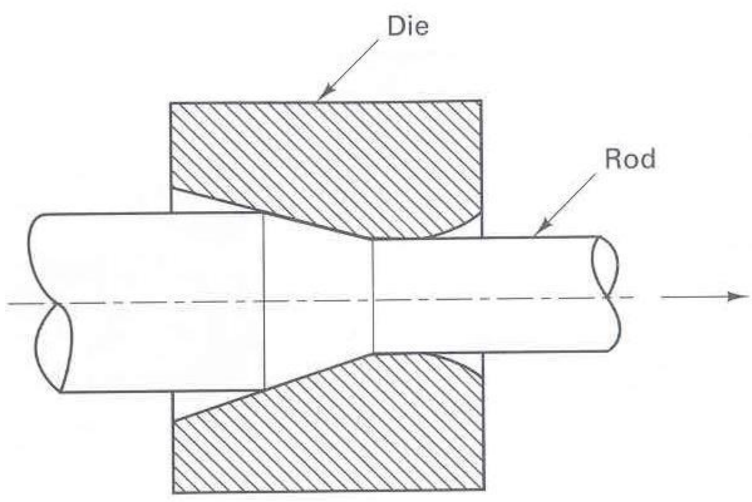


FIGURE 19-53 Schematic diagram of the rod or bar-drawing process.

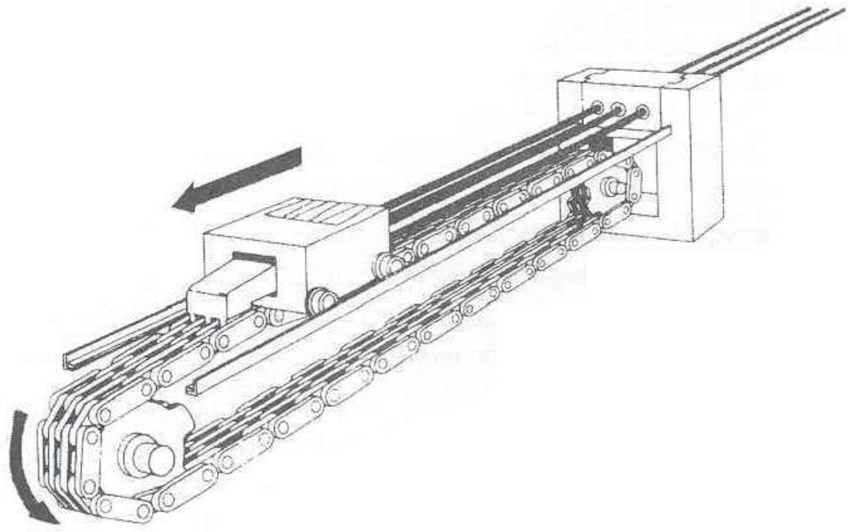


FIGURE 19-54 Schematic diagram of a chain-driven multiple-die draw bench used to produce finite lengths of straight rod or tube. *(Courtesy of Wean United, Inc.)*

Tube drawing

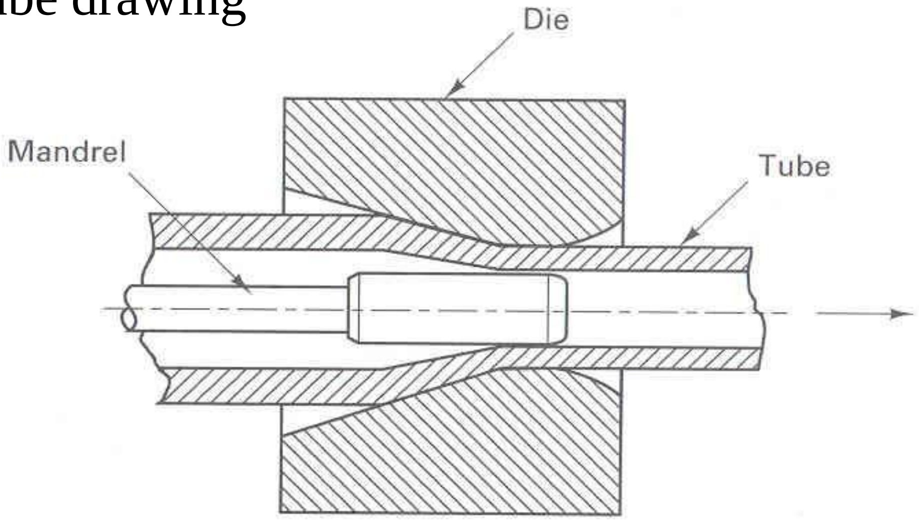


FIGURE 19-55 Cold-drawing smaller tubing from larger tubing. The die sets the outer dimension while the stationary mandrel sizes the inner diameter.

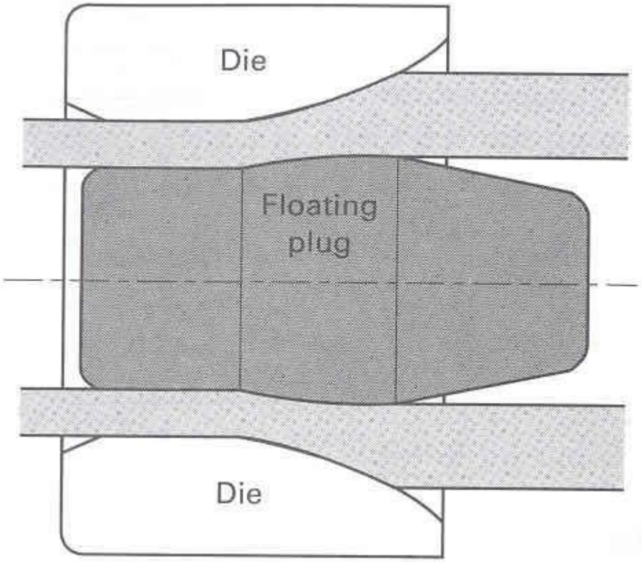


FIGURE 19-56 Tube drawing with a floating plug.

Wire drawing

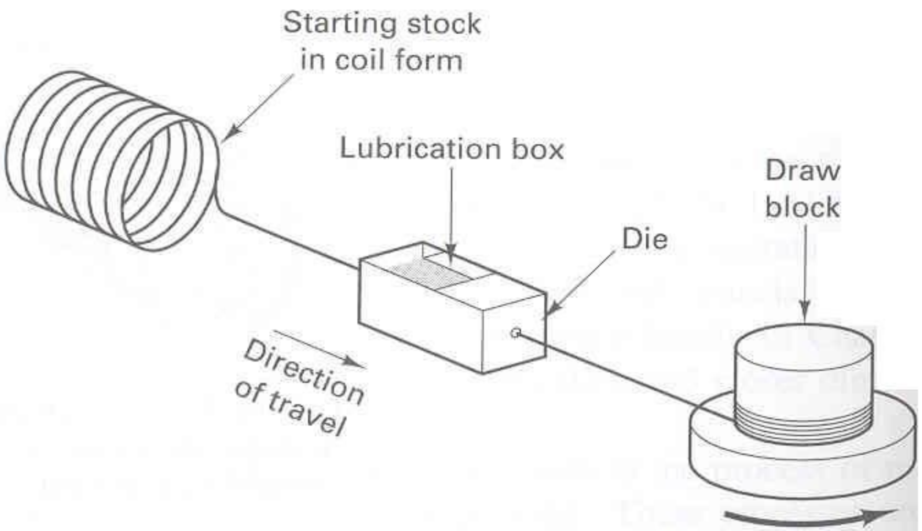


FIGURE 19-57 Schematic of wire drawing with a rotating draw block. The rotating motor on the draw block provides a continuous pull on the incoming wire.

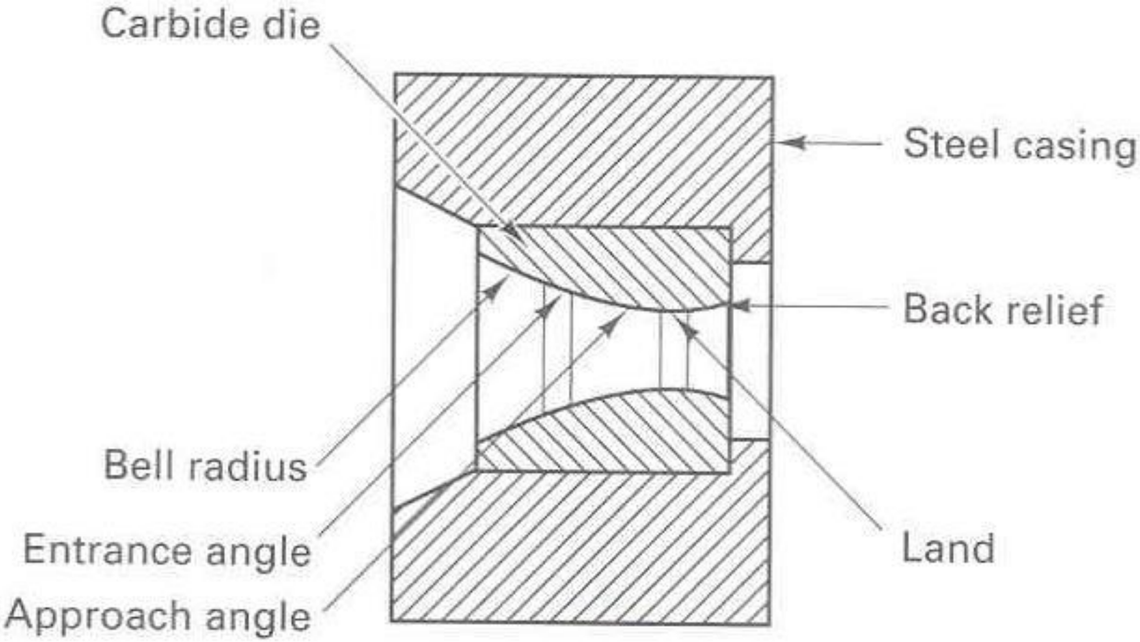
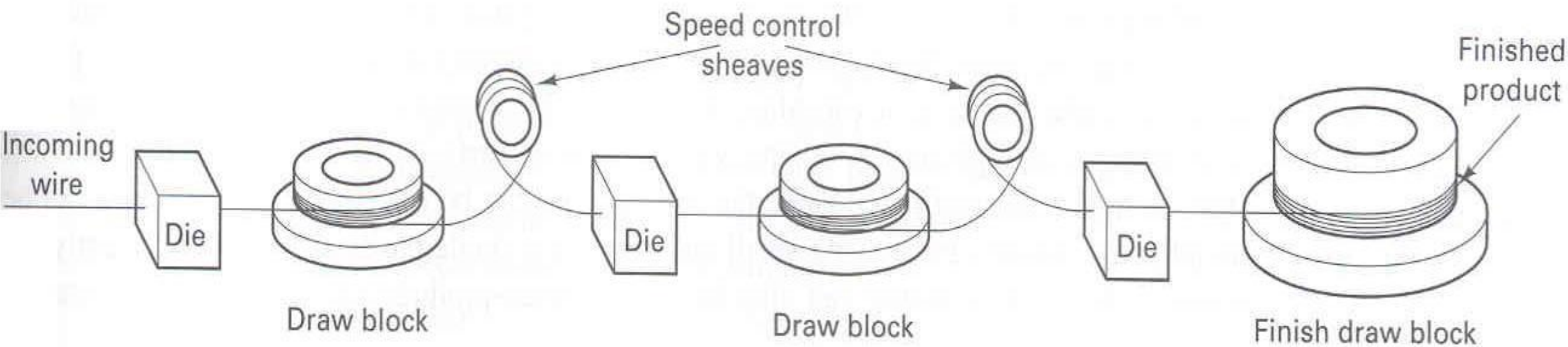


FIGURE 19-58 Cross section through a typical carbide wire drawing die showing the characteristic regions of the contour.

FIGURE 19-59 Schematic of a multistation synchronized wire drawing machine. To prevent accumulation or breakage, it is necessary to assure that the same volume of material passes through each station in a given time. The loops around the sheaves between the stations use wire tensions and feedback electronics to provide the necessary speed control.



SPINNING: ***old process*** – shaping thins metal sheet by pushing it against a form when rotating → symmetrical objects of circular cross section with thickness than 6mm.

- Can be done an ordinary speed lathe or wood lathe where ***a form*** is installed to hold the work piece. The form traditionally is form wood
- Hand tools are usually used
- The tool can be supported by the tool rest on the compound rest and pushed against the work piece that takes the form of the pattern
- Tool friction is reduced by ***lubricants*** (soaps, oils, graphite, lead)
- Small production volume < 5000 pcs. Require low cost equipment

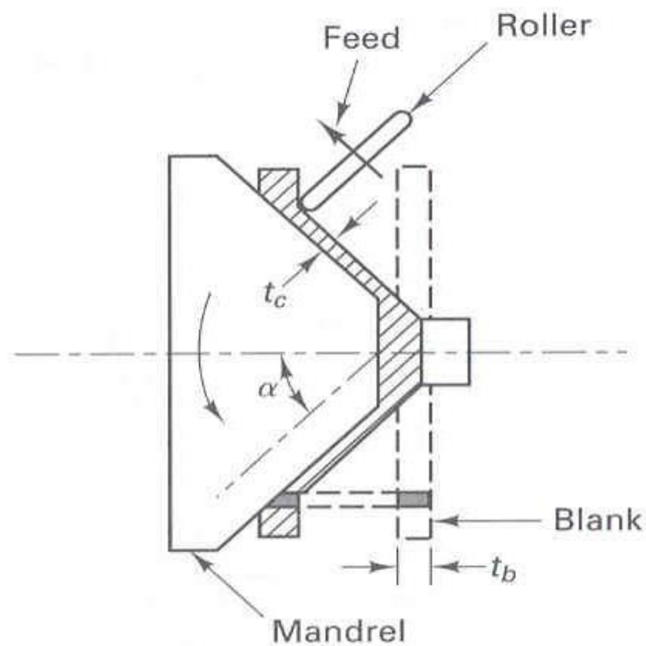


FIGURE 19-62 Schematic representation of the basic shear-forming process.

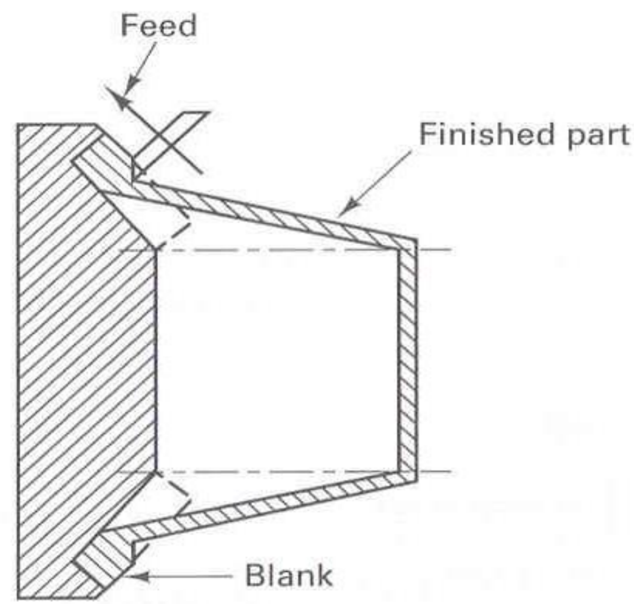


FIGURE 19-63 Forming a conical part by reverse shear forming.

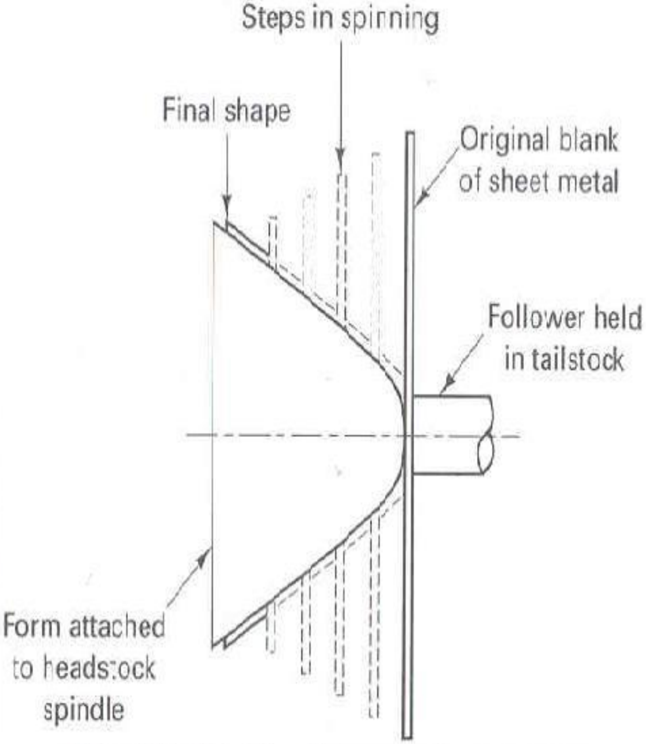


FIGURE 19-60 Progressive stages in the spinning of a sheet metal product.

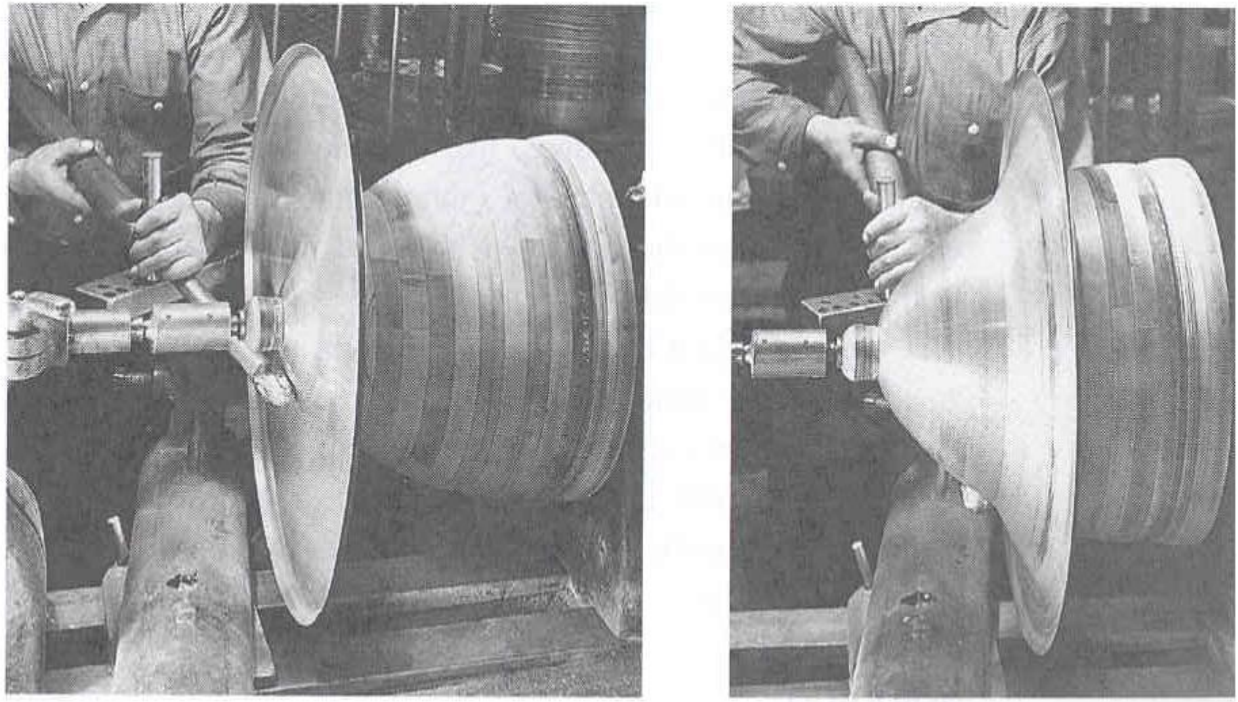


FIGURE 19-61 Two stages in the spinning of a metal reflector. *(Courtesy of Spincraft, Inc.)*

Shear spinning: *metal is flowing*

- Machine spinning using power driven rollers→ reduction of wall thickness up to 80%
- In conventional spinning – thickness ratio is negligible → bending → Reverse shear spinning can be performed
- The formed part can be longer than the model (form)

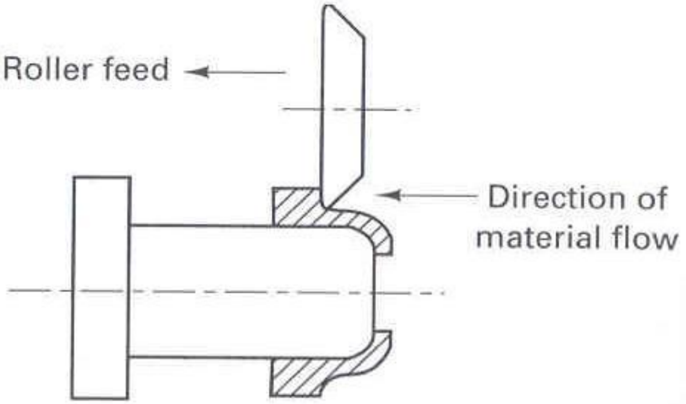
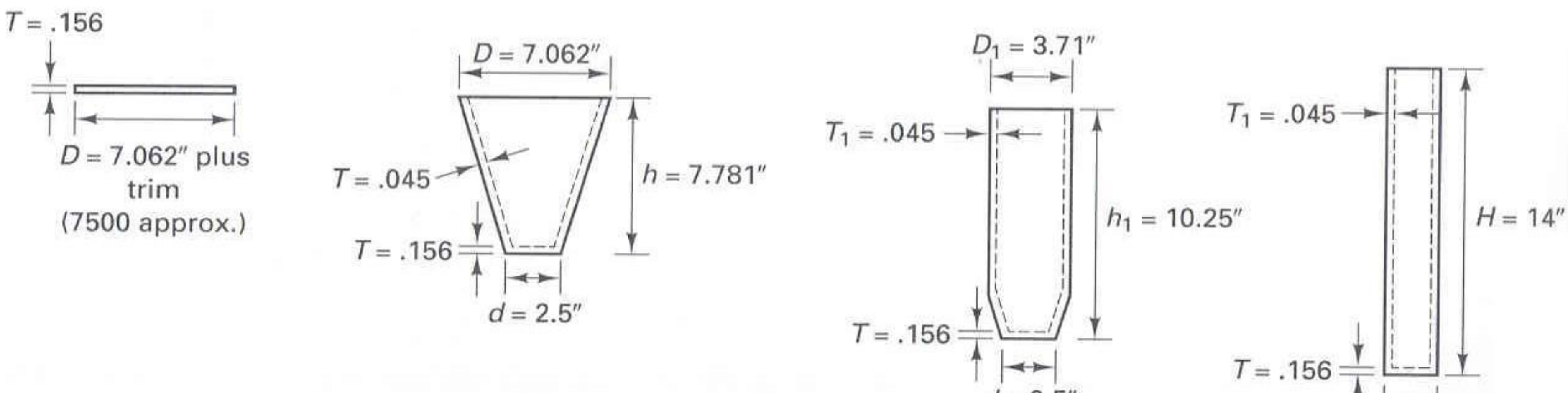


FIGURE 19-64 Shear forming a cylinder by the direct process



STRETCH FORMING

- The metal sheet is formed by pulling it against as single pattern form block
- Stretch: draw forming by stretch press
- Single die is placed between two slides that grip the metal sheet
- Die moves vertically and slides horizontally
- Inexpensive equipment can be used
- Large double curvature parts can be made

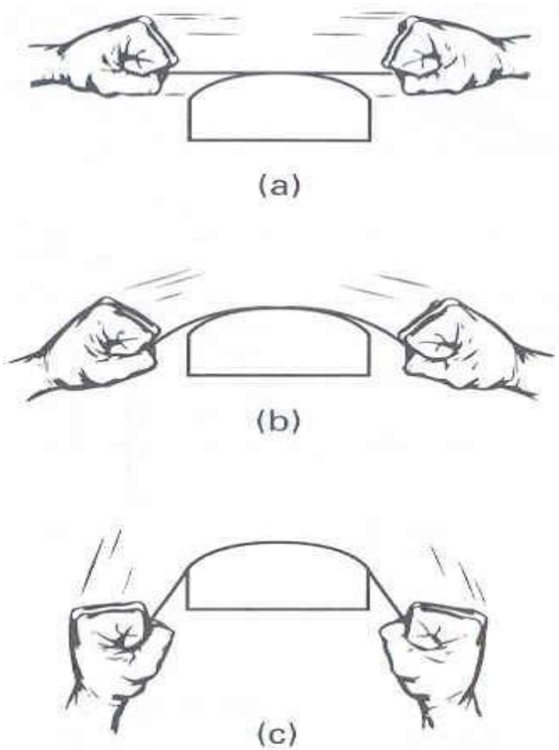


FIGURE 19-66 Schematic representation of the motions and steps involved in stretch-wrap forming.

DRAWING OF PLATES AND SHEETS:

Drawing:

Shallow drawing for depth < DIA

Deep drawing for depth > DIA

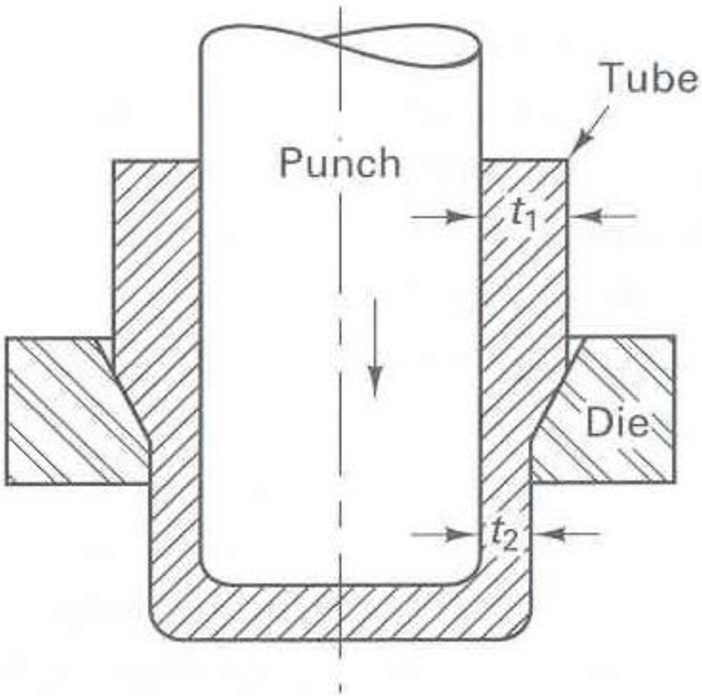


FIGURE 19-82 Schematic of the ironing process.

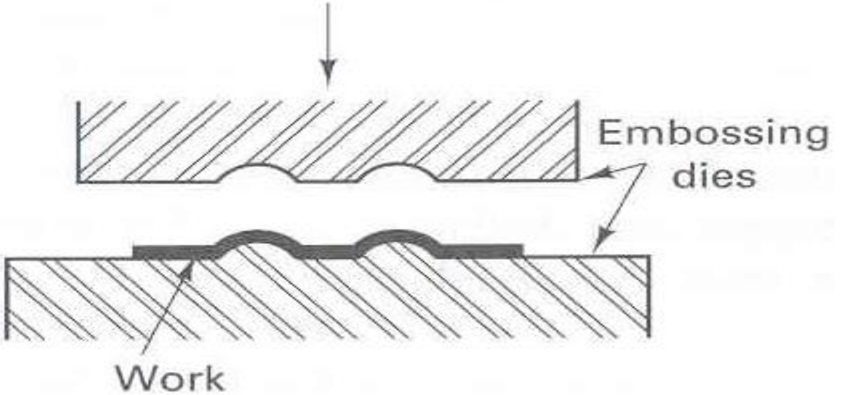


FIGURE 19-83 Embossing.

RUBBER -PAD FORMING – Guerin Process

- Rubber pad – confined in a container → replaces the die or punch
- Under pressure the rubber pad flows around a form and the blank is formed
- Low cost of tooling (only one part of die)
- Mild metal can be formed in this way
- Rubber is not much compressible

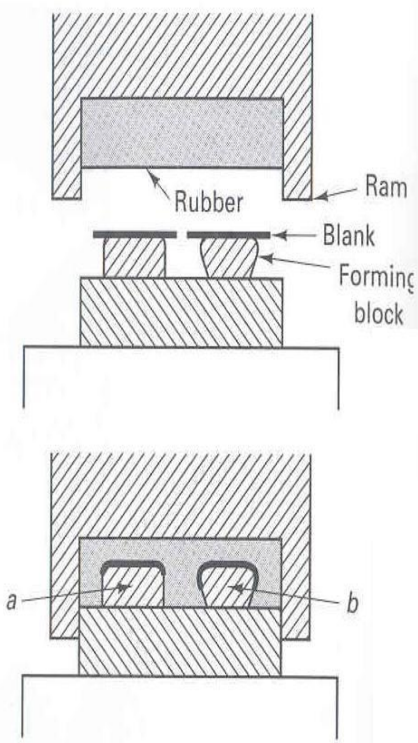


FIGURE 19-72 The Guerin process for forming sheet metal products.

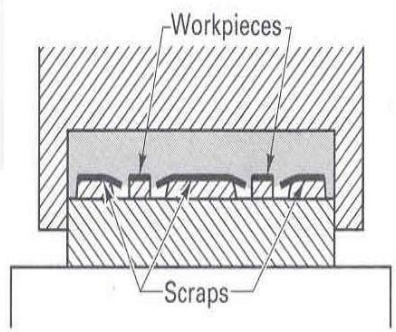


FIGURE 19-73 Method of blanking sheet metal using the Guerin process.

Hydroform process can be also used

* Perform deep drawing using rubber diaphragm
* The rubber chamber is lowered and it clamps the blank
* A punch, pushed by a hydraulic cylinder moves upwards and increase the pressure of the diaphragm on the blank

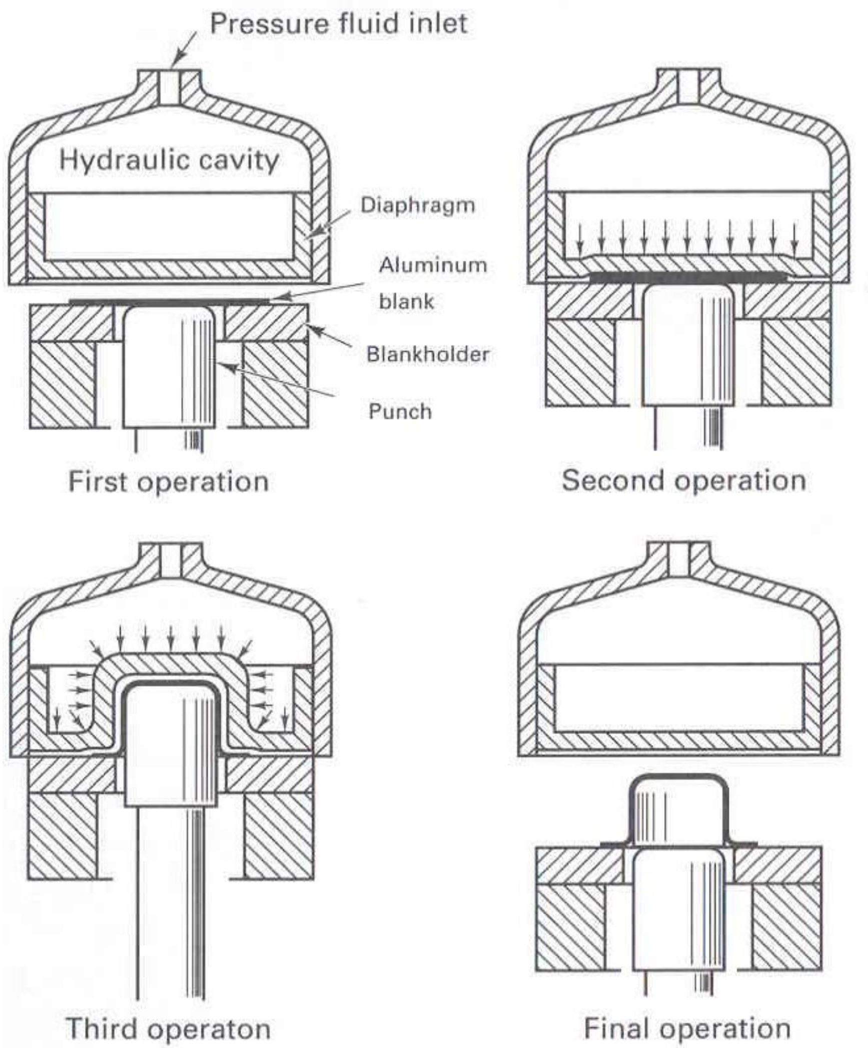


FIGURE 19-74 High-pressure flexible-die forming, showing (1) the blank in place with no pressure in the cavity; (2) press closed and cavity pressurized; (3) ram advanced with cavity maintaining fluid pressure; and (4) pressure released and ram retracted. *(Courtesy of Aluminum Association, New York.)*

EXPLOSIVE FORMING

* High energy rate forming (HERF)
* Pressure up to 7,000 bar can be created with low explosives
* Pressure up to 100,000 bar with high explosives
* The spring back is minimized

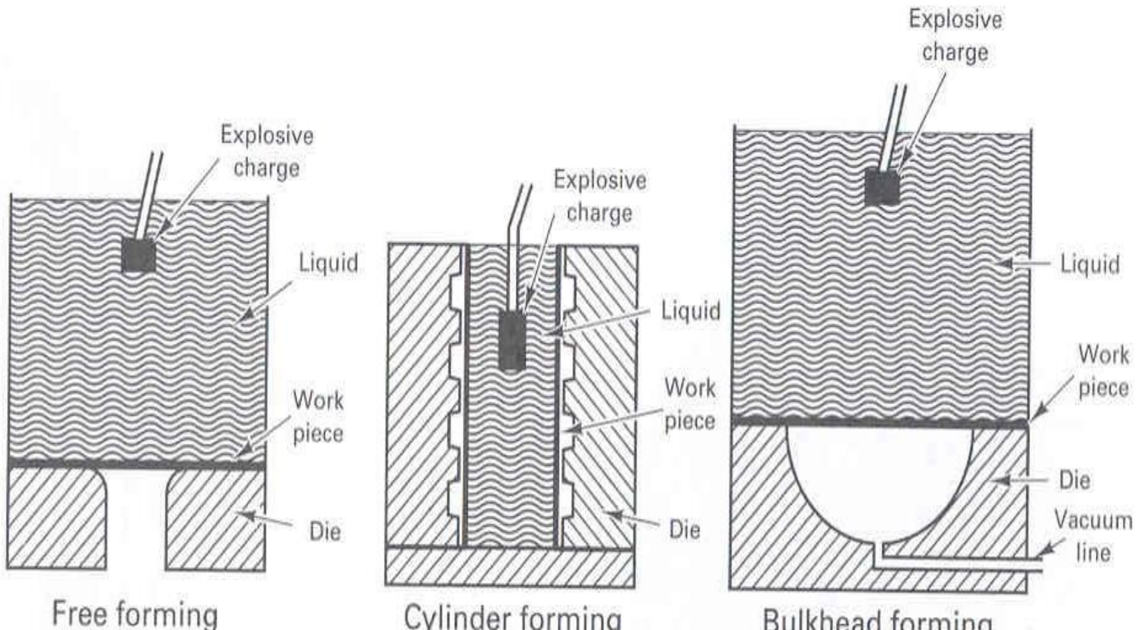


FIGURE 19-77 Three methods of high-energy-rate-forming with explosive charges. *(Courtesy of Materials Engineering.)*

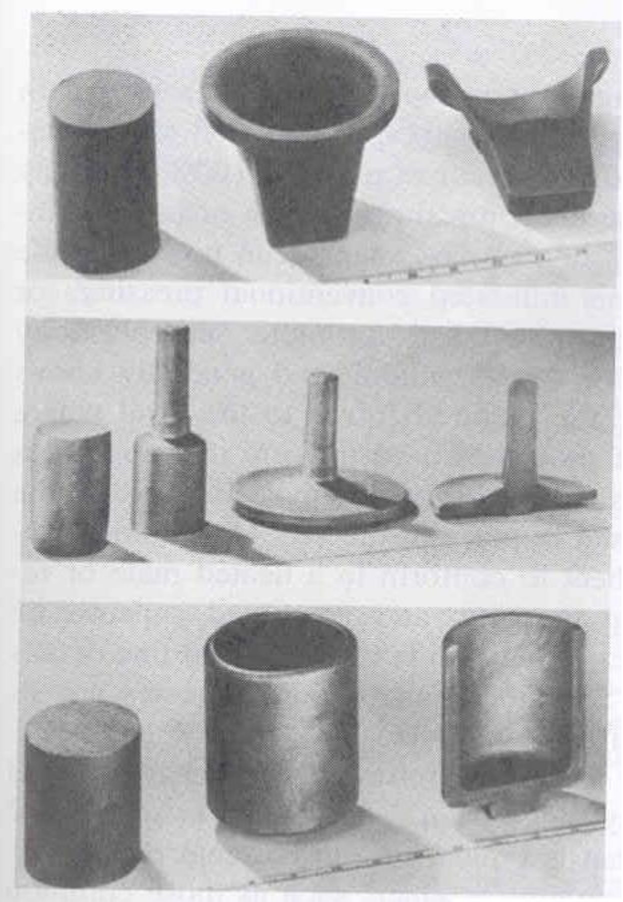


FIGURE 19-80 Typical parts manufactured by the pneumatic–mechanical high-energy-rate forming technique. *(Courtesy of Interstate Drop Forge Inc.)*

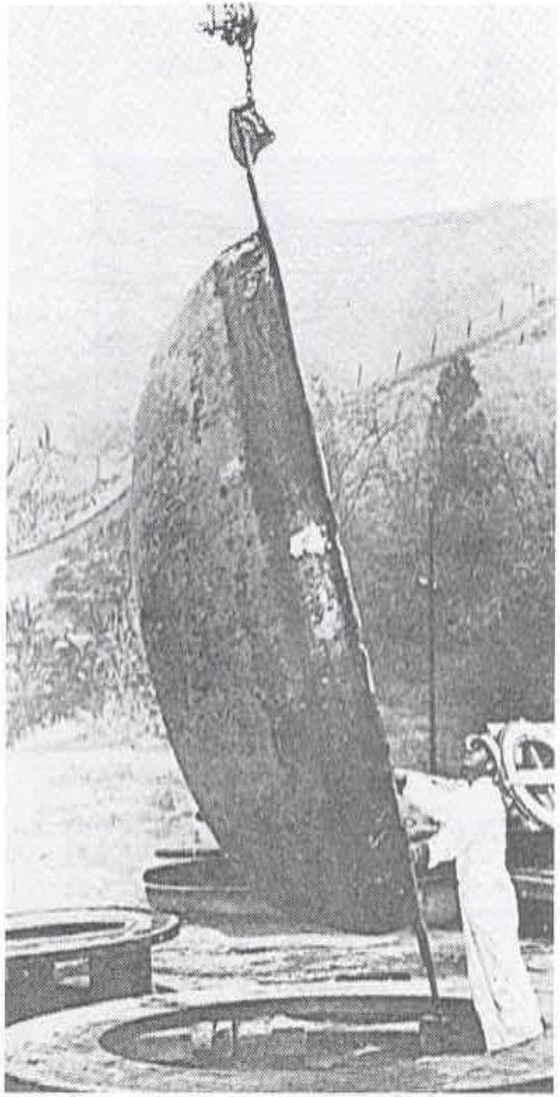


FIGURE 19-78 Explosively formed elliptical dome 10 ft. in diameter being removed from a forming die. *(Courtesy of NASA.)*

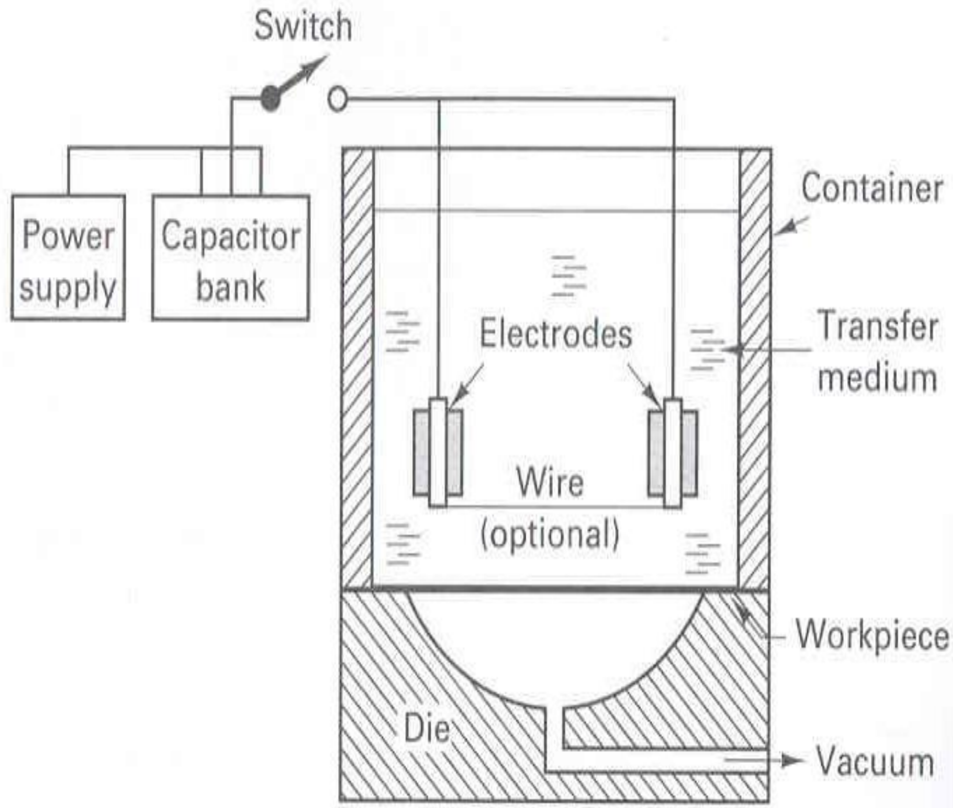


FIGURE 19-79 Components in the spark-discharge method of high-energy-rate forming.

Drawing on a drop hammer

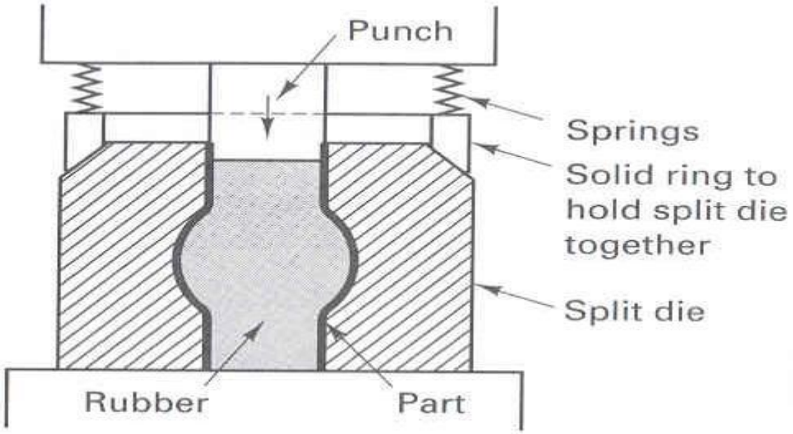


FIGURE 19-75 Method of bulging tubes with rubber tooling.

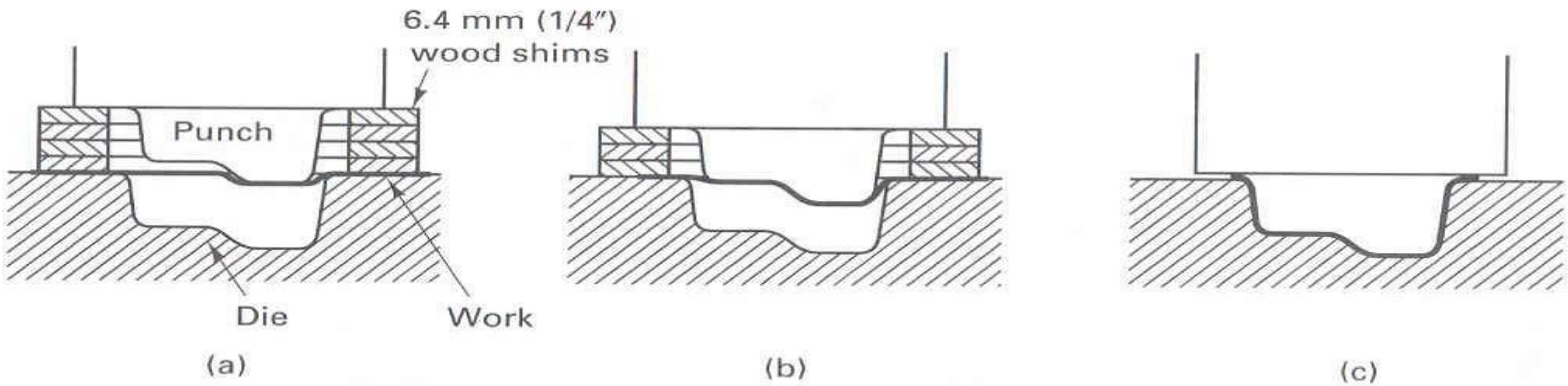


FIGURE 19-76 Method of deep drawing on a drop hammer using inexpensive dies and a stack of shims.

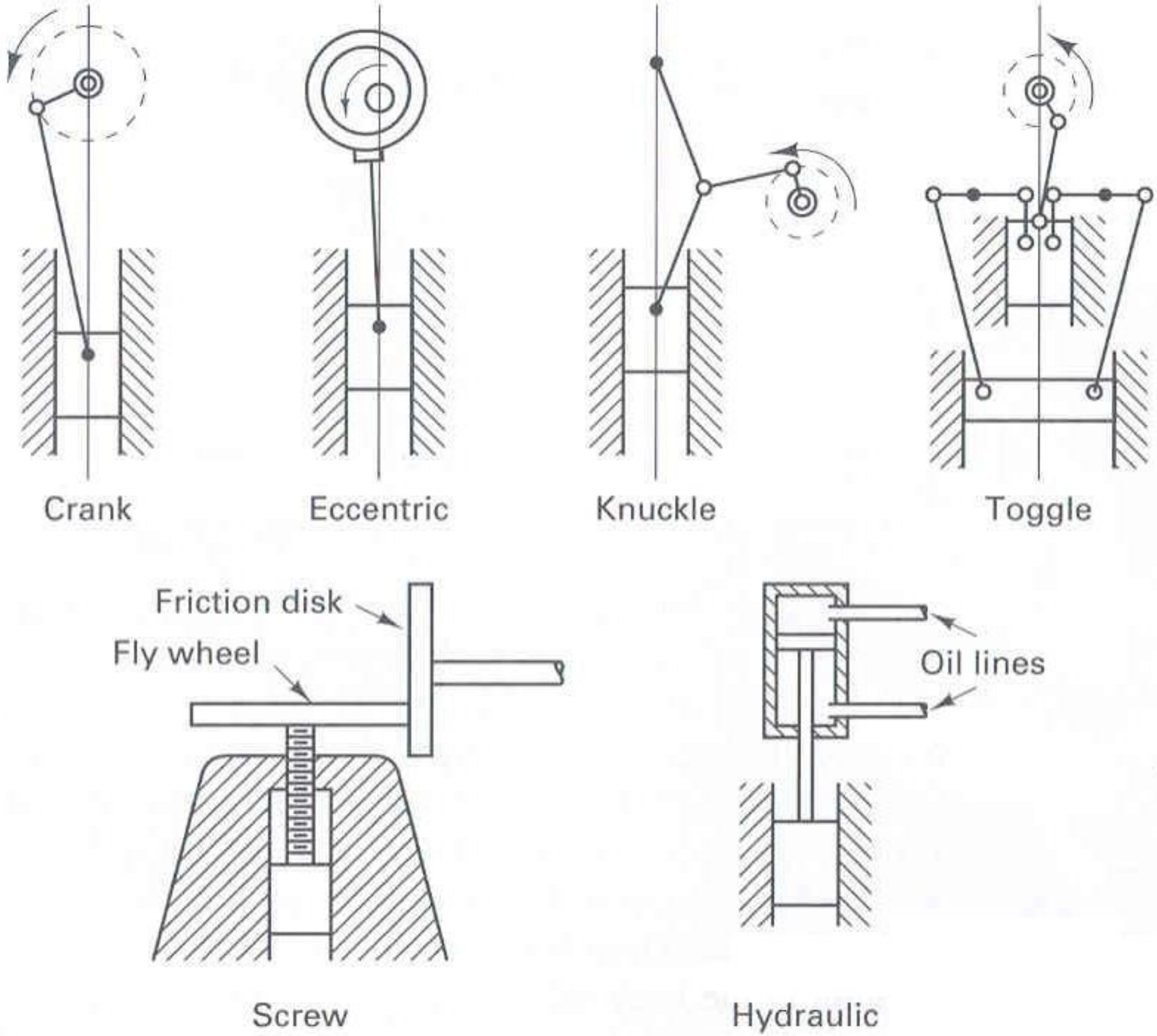


FIGURE 19-85 Schematic representation of the various types of press drive mechanisms.

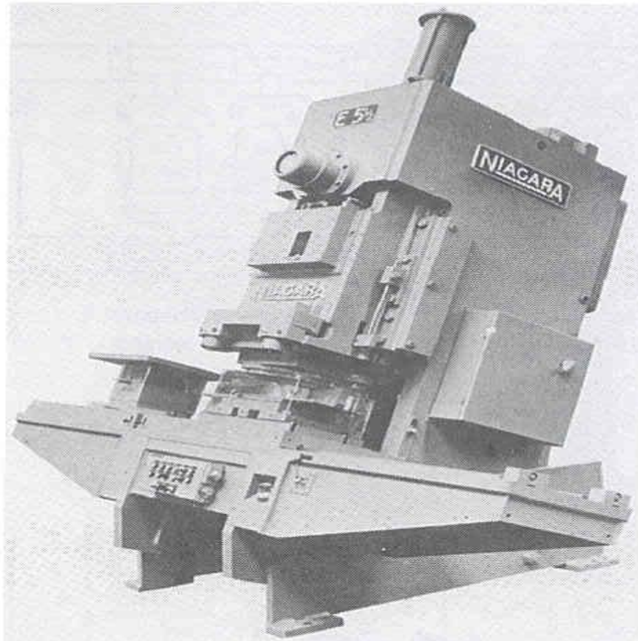


FIGURE 19-86 Inclinable gap-frame press with sliding bolster to accommodate two die sets for rapid change of tooling. *(Courtesy of Niagara Machine & Tool Works.)*

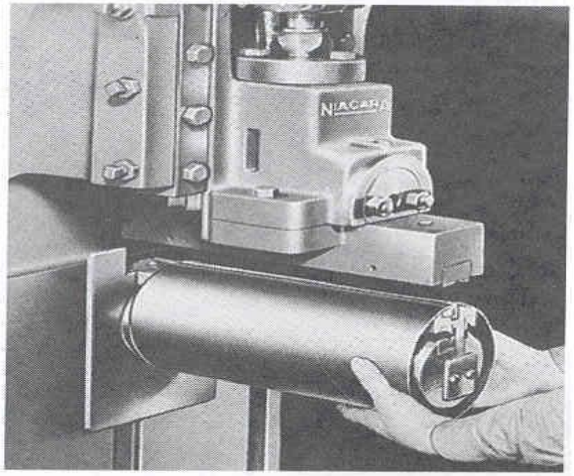


FIGURE 19-87 Making a seam on a horn press. Note the protruding "horn" that replaces the lower press bed. *(Courtesy of Niagara Machine & Tool Works.)*

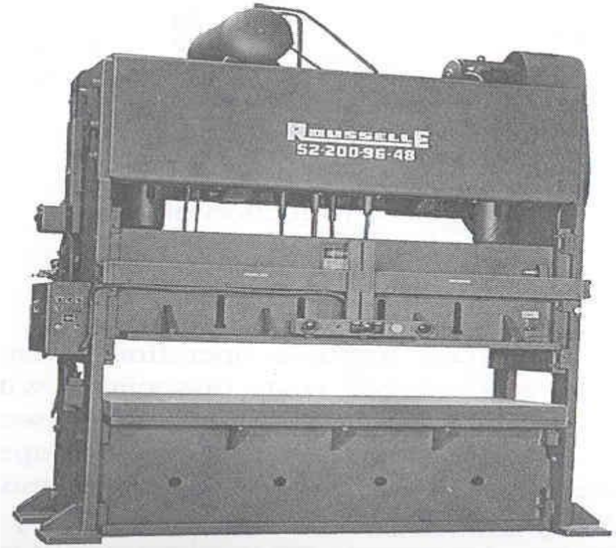


FIGURE 19-88 A 200-ton (1800-kN) straight-side press. *(Courtesy of Rousselle Corporation.)*

Forming production flow:

- Tendency to indicate all process within the same flow to complete a product
- In mass production, very efficient processes

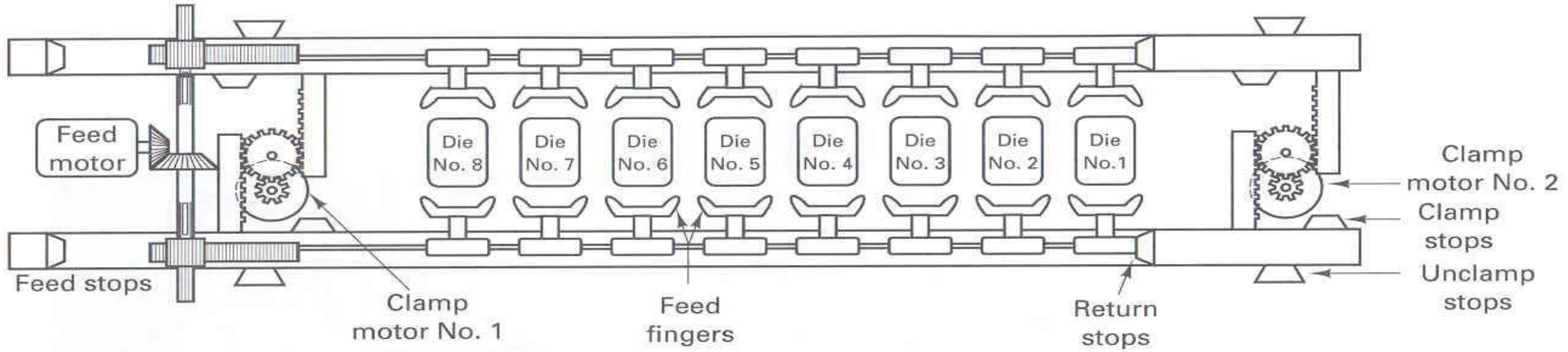


FIGURE 19-89 Schematic showing the arrangement of dies and the transfer mechanism used in transfer presses. *(Courtesy of Verson Allsteel Press Company.)*

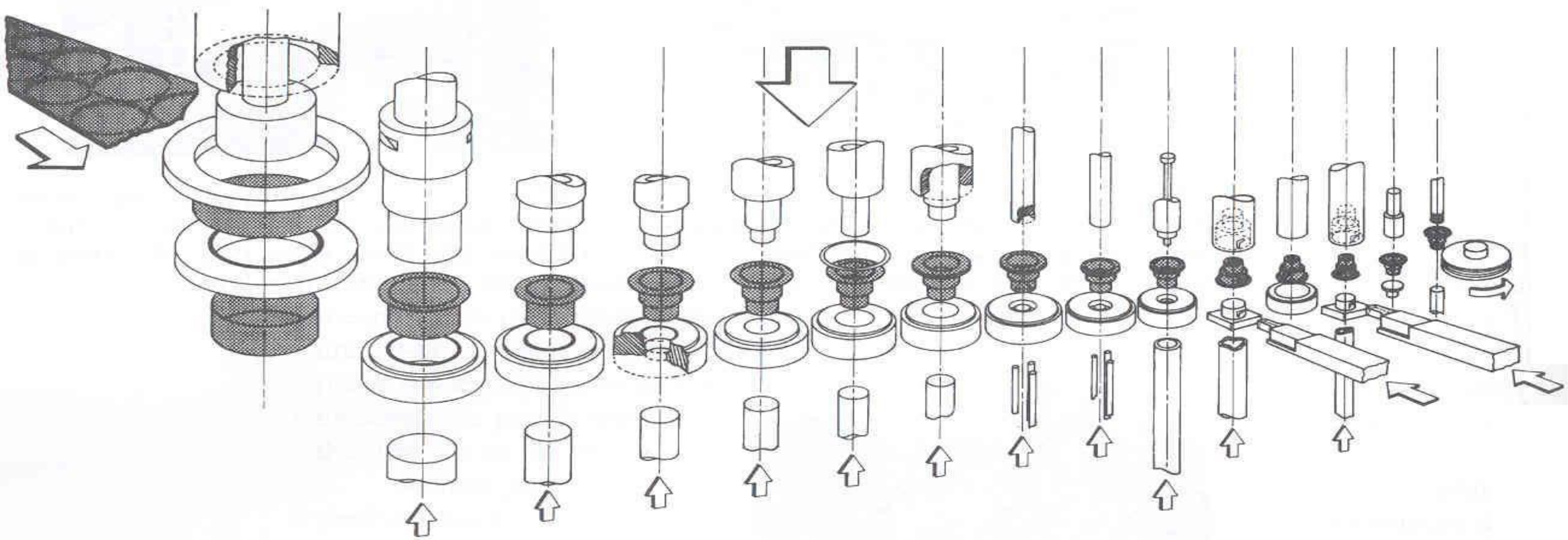


FIGURE 19-90 Various operations that can be performed during the production of stamped and drawn parts on a transfer press. *(Courtesy of U.S. Baird Corporation, Stratford, Conn.)*

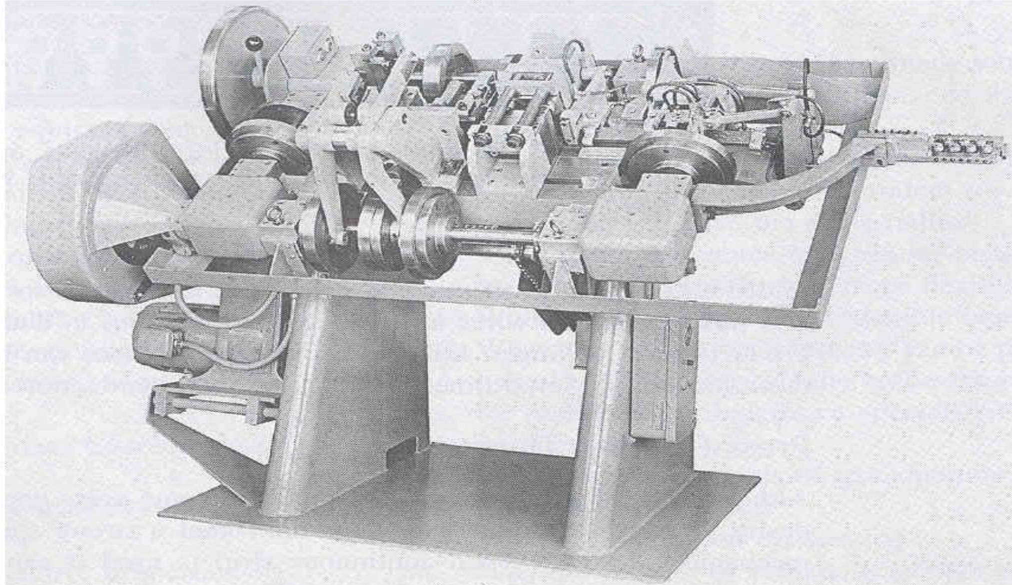


FIGURE 19-91 Multislide machine with guards and covers removed. *(Courtesy of U.S. Baird Corporation, Stratford, Conn.)*

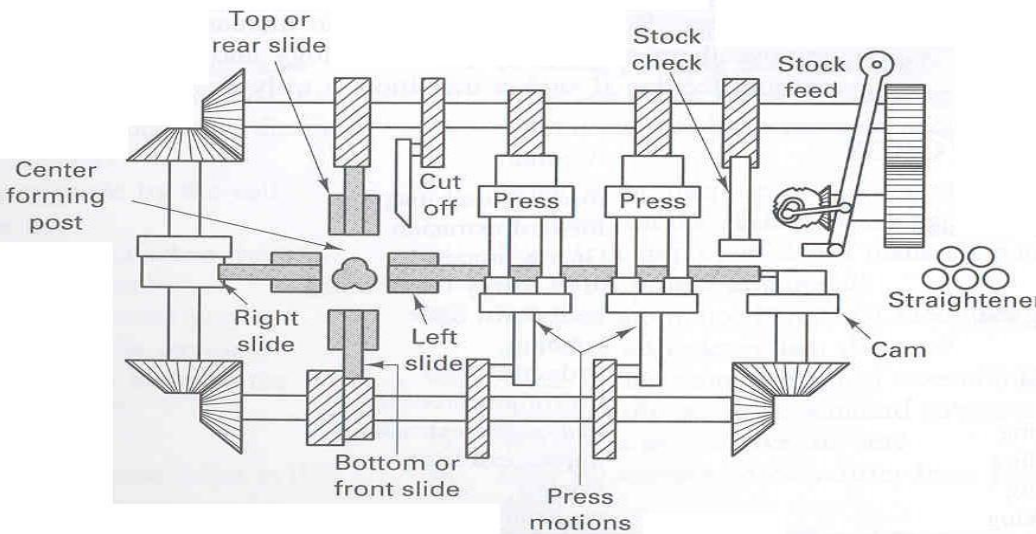


FIGURE 19-92 Schematic of the operating mechanism of a multislide machine. The material enters on the right and progresses toward the left as operations are performed. *(Courtesy of U.S. Baird Corporation, Stratford, Conn.)*