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GIM2042 Manufacturing Processes, Gr. 2, T.301

Lecturer; Assoc. Prof.Dr.Yüksel PALACI
Office ; T403
E-mail ; ypalaci@yildiz.edu.tr

- Book; John Wiley & Sons, Inc. M. P. Groover, "Fundamentals of Modern Manufacturing"
- Chapters:1,10,11,16,18-22,24,30-34
- http://www.bologna.yildiz.edu.tr/index.php?r=course/view&id=1171&aid=35

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SHEET METALWORKING

- Cutting Operations
- Bending Operations
- Drawing
- Other Sheet Metal Forming Operations
- Dies and Presses for Sheet Metal Processes
- Sheet Metal Operations Not Performed on Presses
- Bending of Tube Stock

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Sheet Metalworking Defined

Cutting and forming operations performed on relatively thin sheets of metal
- Thickness of sheet metal = 0.4 mm (1/64 in) to 6 mm (1/4 in)
- Thickness of plate stock > 6 mm
- Operations usually performed as cold working

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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

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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

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Sheet Metalworking Terminology

1. "Punch-and-die"
   - Tooling to perform cutting, bending, and drawing
2. "Stamping press"
   - Machine tool that performs most sheet metal operations
3. "Stampings"
   - Sheet metal products

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Three Major Categories of Sheet Metal Processes

1. Cutting
   - Shearing to separate large sheets; or cut part perimeters or make holes in sheets
2. Bending
   - Straining sheet around a straight axis
3. Drawing
   - Forming of sheet into convex or concave shapes

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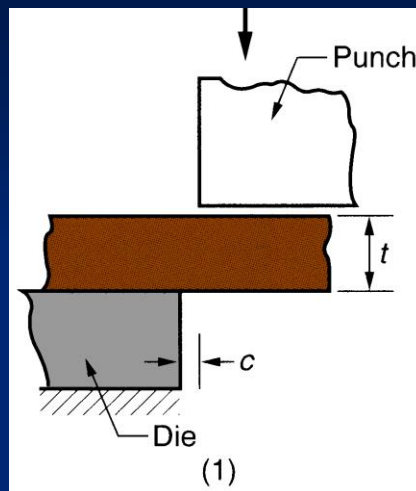

Cutting

Shearing between two sharp cutting edges

Figure 20.1 - Shearing of sheet metal between two cutting edges:

(1) just before the punch contacts work

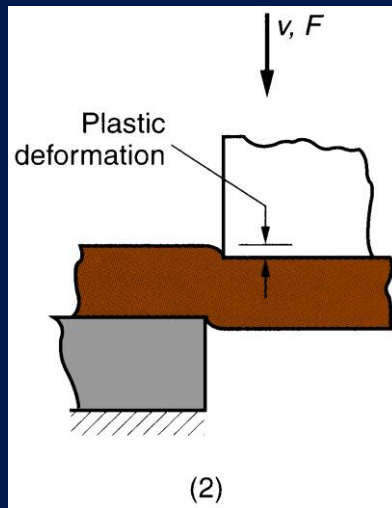*Dept. of Naval Architecture and Marine Engineering*

Figure 20.1 - Shearing of sheet metal between two cutting edges:

(2) punch begins to push into work, causing plastic deformation

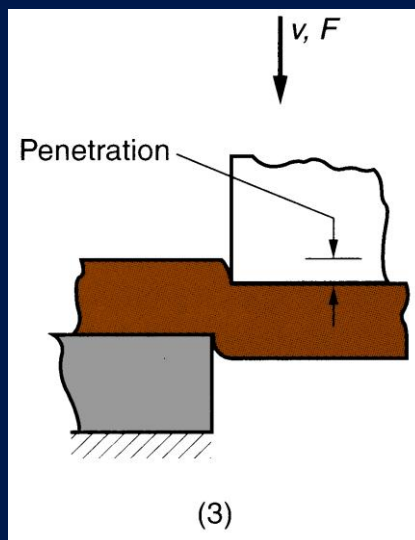*Dept. of Naval Architecture and Marine Engineering*

Figure 20.1 - Shearing of sheet metal between two cutting edges:

(3) punch compresses and penetrates into work causing a smooth cut surface

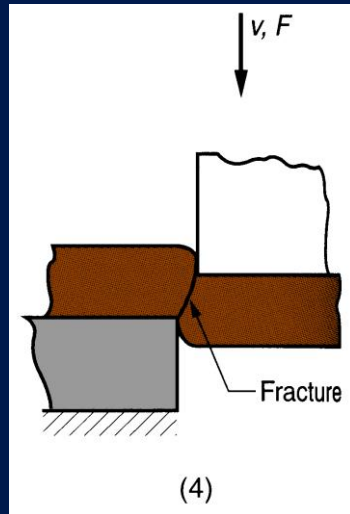*Dept. of Naval Architecture and Marine Engineering*

Figure 20.1 - Shearing of sheet metal between two cutting edges:

(4) fracture is initiated at the opposing cutting edges which separates the sheet

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Shearing, Blanking, and Punching

Three principal operations in pressworking that cut sheet metal:
- Shearing
- Blanking
- Punching

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Shearing

Sheet metal cutting operation along a straight line between two cutting edges
• Typically used to cut large sheets into smaller sections for subsequent operations

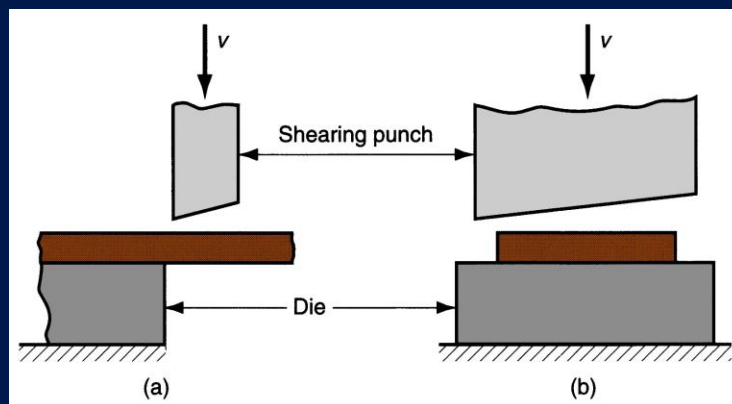*Dept. of Naval Architecture and Marine Engineering*

Figure 20.3 - Shearing operation:
(a) side view of the shearing operation
(b) front view of power shears equipped with inclined upper cutting blade
Symbol *v* indicates motion

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Blanking and Punching

Blanking - sheet metal cutting to separate piece from surrounding stock
- Cut piece is the desired part, called a *blank*

Punching - sheet metal cutting similar to blanking except cut piece is scrap, called a *slug*
- Remaining stock is the desired part
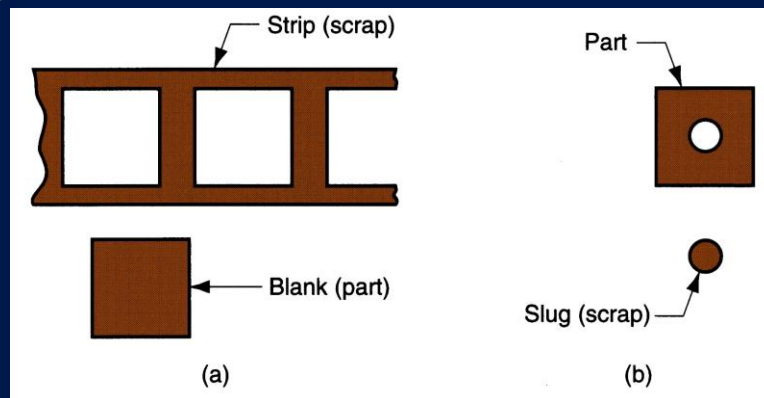
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Figure 20.4 - (a) Blanking and (b) punching

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Clearance in Sheet Metal Cutting

Distance between the punch and die
- Typical values range between 4% and 8% of stock thickness
  - If too small, fracture lines pass each other, causing double burnishing and larger force
  - If too large, metal is pinched between cutting edges and excessive burr results

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Clearance in Sheet Metal Cutting

- Recommended clearance can be calculated by:

$$c = at$$

  where c = clearance; a = allowance; and t = stock thickness

- Allowance a is determined according to type of metal

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Allowance *a* for
Three Sheet Metal Groups

Metal group	*a*
1100S and 5052S aluminum alloys, all tempers	0.045
2024ST and 6061ST aluminum alloys; brass, soft cold rolled steel, soft stainless steel	0.060
Cold rolled steel, half hard; stainless steel, half hard and full hard	0.075

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Punch and Die Sizes for
Blanking and Punching

For a round *blank* of diameter D_b:

Blanking punch diameter = D_b - 2c

Blanking die diameter = D_b

where c = clearance

For a round *hole* of diameter D_h:

Hole punch diameter = D_h

Hole die diameter = D_h + 2c

where c = clearance
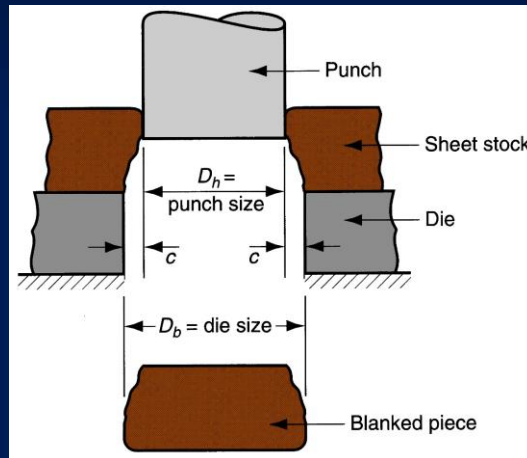
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Figure 20.6 - Die size determines blank size D_b; punch size determines hole size D_h; c = clearance

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Angular Clearance

Purpose: allows slug or blank to drop through die
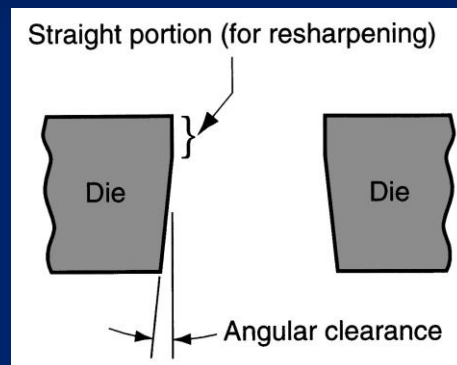- Typical values: $0.25°$ to $1.5°$ on each side

Figure 20.7 - Angular clearance

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Cutting Forces

Important for determining press size (tonnage)

$$F = S\,t\,L$$

where S = shear strength of metal; t = stock thickness, and L = length of cut edge

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Bending

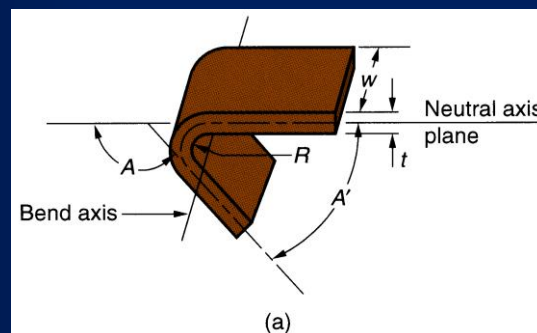Straining sheetmetal around a straight axis to take a permanent bend

Figure 20.11 - (a) Bending of sheet metal

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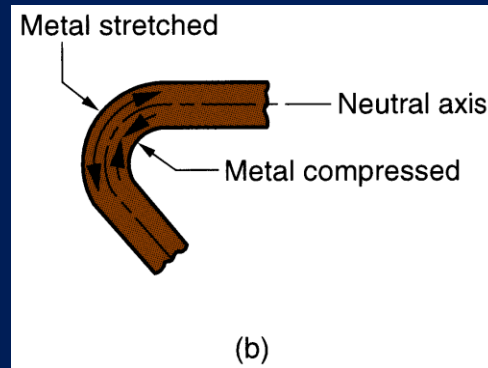Metal on inside of neutral plane is compressed, while metal on outside of neutral plane is stretched

Figure 20.11 - (b) both compression and tensile elongation of the metal occur in bending

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Types of Sheetmetal Bending

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

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V-Bending

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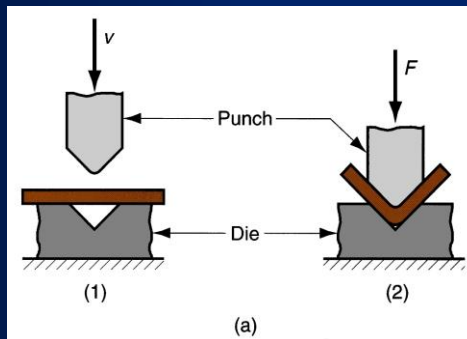- Performed on a *press brake*
- V-dies are simple and inexpensive

Figure 20.12 -
(a) V-bending

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Edge Bending

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

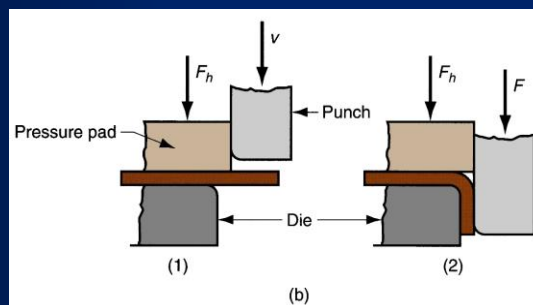
Figure 20.12 - (b) edge bending

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Stretching during Bending

- If bend radius is small relative to stock thickness, metal tends to stretch during bending
- Important to estimate amount of stretching, so that final part length = specified dimension
- Problem: to determine the length of neutral axis of the part before bending

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Bend Allowance Formula

$$BA = 2\pi \frac{A}{360}(R + K_{ba}t)$$

where BA = bend allowance; A = bend angle; R= bend radius; t = stock thickness; and K_{ba} is factor to estimate stretching

- If $R < 2t$, $K_{ba} = 0.33$
- If $R \geq 2t$, $K_{ba} = 0.50$

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Springback in Bending

Springback = increase in included angle of bent part relative to included angle of forming tool after tool is removed

- Reason for springback:
  - When bending pressure is removed, elastic energy remains in bent part, causing it to recover partially toward its original shape

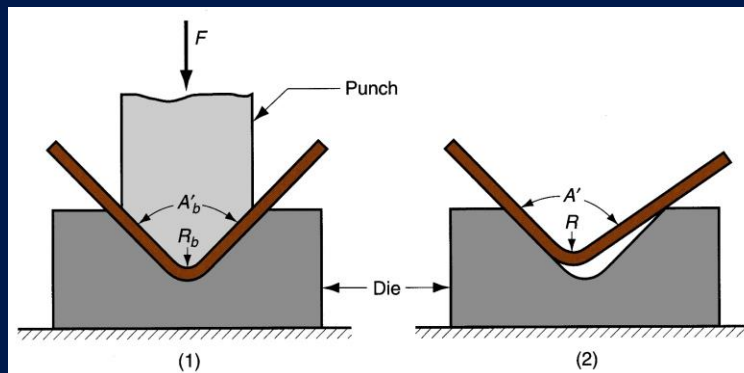*Dept. of Naval Architecture and Marine Engineering*

Figure 20.13 - Springback in bending shows itself as a decrease in bend angle and an increase in bend radius: (1) during bending, the work is forced to take the radius R_b and included 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'

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Bending Force

Maximum bending force estimated as follows:

$$F = \frac{K_{bf}TSwt^2}{D}$$

where F = bending force; TS = tensile strength of sheet metal; w = part width in direction of bend axis; and t = stock thickness. For V- bending, K_{bf} = 1.33; for edge bending, K_{bf} = 0.33
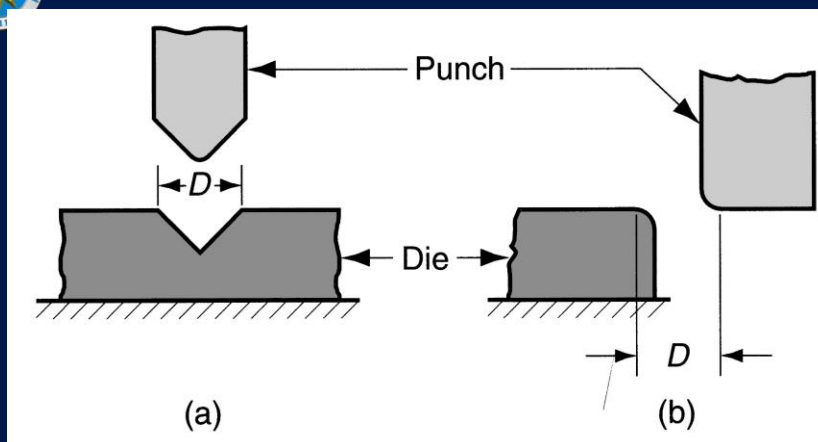
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Figure 20.14 - Die opening dimension D: (a) V-die, (b) wiping die

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Drawing

Sheet metal forming to make cup-shaped, box-shaped, or other complex-curved, hollow-shaped parts
- Sheet metal blank is positioned over die cavity and then punch pushes metal into opening
- Products: beverage cans, ammunition shells, automobile body panels
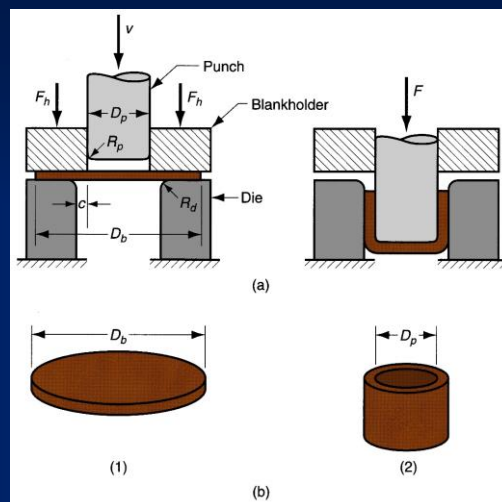
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Figure 20.19 -
- (a) Drawing of a cup-shaped part:
- (1) start of operation before punch contacts work
- (2) near end of stroke

- (b) Corresponding workpart:
- (1) starting blank
- (2) drawn part

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Clearance in Drawing

- Sides of punch and die separated by a clearance c given by:

$$c = 1.1\ t$$

  where t = stock thickness
- In other words, clearance = about 10% greater than stock thickness

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Drawing Ratio *DR*

Most easily defined for cylindrical shape:

$$DR = \frac{D_b}{D_p}$$

where D_b = blank diameter; and D_p = punch diameter
- Indicates severity of a given drawing operation
  - Upper limit = 2.0

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Reduction *r*

- Again, defined for cylindrical shape:

$$r = \frac{D_b - D_p}{D_b}$$

- Value of *r* should be less than 0.50

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Thickness-to-Diameter Ratio

Thickness of starting blank divided by blank diameter
Thickness-to-diameter ratio = t/D_b
- Desirable for t/D_b ratio to be greater than 1%
- As t/D_b decreases, tendency for wrinkling increases

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Blank Size Determination

- For final dimensions of drawn shape to be correct, starting blank diameter D_b must be right
- Solve for D_b by setting starting sheet metal blank volume = final product volume
- To facilitate calculation, assume negligible thinning of part wall

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Shapes other than Cylindrical Cups

- Square or rectangular boxes (as in sinks),
- Stepped cups,
- Cones,
- Cups with spherical rather than flat bases,
- Irregular curved forms (as in automobile body panels)

- Each of these shapes presents its own unique technical problems in drawing

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Other Sheet Metal Forming on Presses

Other sheet metal forming operations performed on conventional presses
- Operations performed with metal tooling
- Operations performed with flexible rubber tooling

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Ironing

- Makes wall thickness of cylindrical cup more uniform
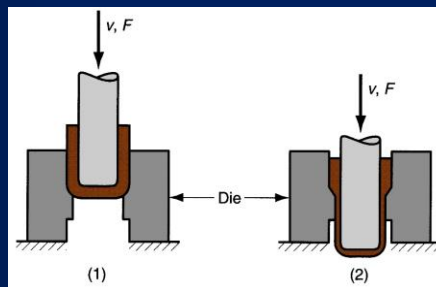- Examples: beverage cans and artillery shells

Figure 20.25 - Ironing to achieve a more uniform wall thickness in a drawn cup: (1) start of process; (2) during process

Note thinning and elongation of walls

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Embossing

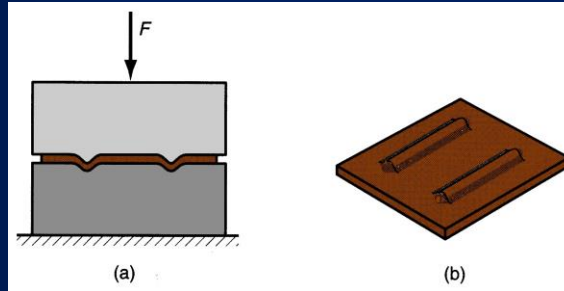- Used to create indentations in sheet, such as raised (or indented) lettering or strengthening ribs

Figure 20.26 - Embossing: (a) cross-section of punch and die configuration during pressing; (b) finished part with embossed ribs

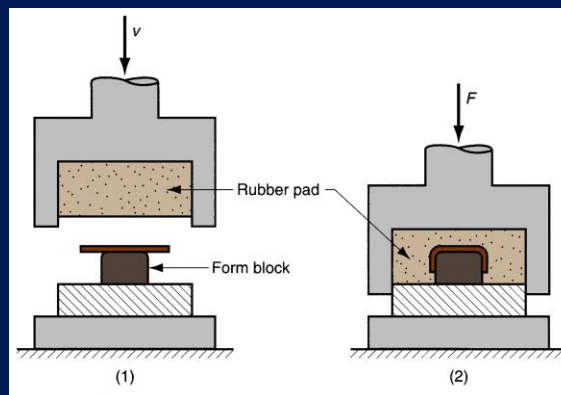*Dept. of Naval Architecture and Marine Engineering*

Guerin Process

Figure 20.28 - Guerin process: (1) before and (2) after
Symbols *v* and *F* indicate motion and applied force respectively

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Advantages of Guerin Process

- Low tooling cost
- Form block can be made of wood, plastic, or other materials that are easy to shape
- Rubber pad can be used with different form blocks
- Process attractive in small quantity production

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Dies for Sheet Metal Processes

Most pressworking operations performed with conventional *punch-and-die* tooling
- Custom-designed for particular part
- The term *stamping die* sometimes used for high production dies
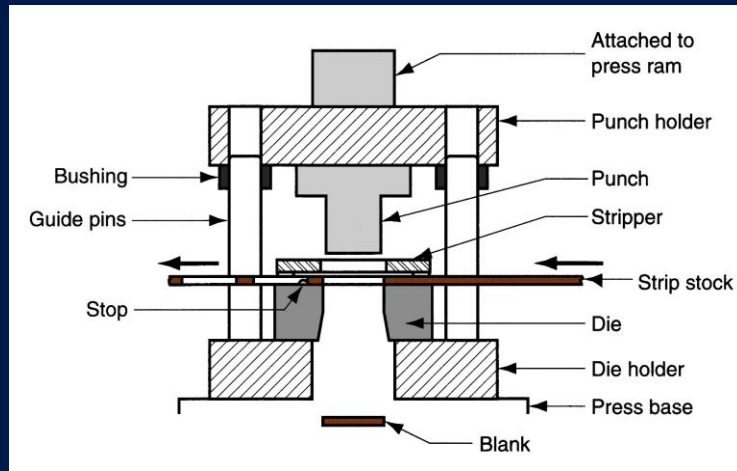
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Figure 20.30 - Components of a punch and die for a blanking operation
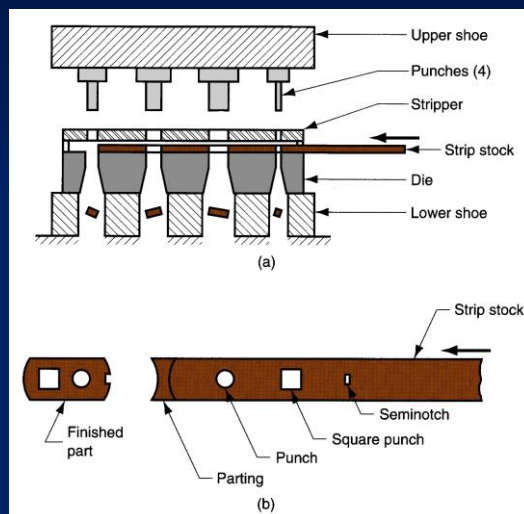
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Figure 20.31 -
(a) Progressive die;
(b) associated strip development
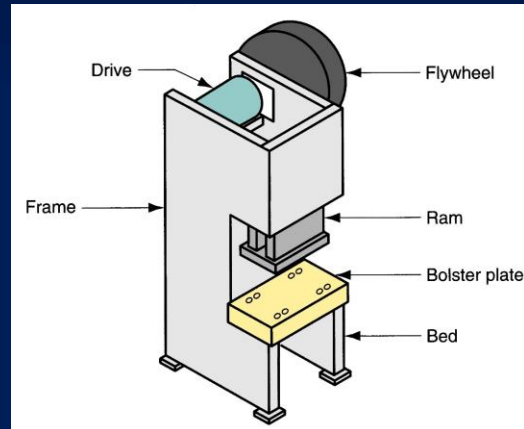
"" *Dept. of Naval Architecture and Marine Engineering*

Figure 20.32 - Components of a typical mechanical
drive stamping press

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Types of Stamping Press Frame

- *Gap frame* – configuration of the letter C and often referred to as a *C-frame*
- *Straight-sided frame* – box-like construction for higher tonnage

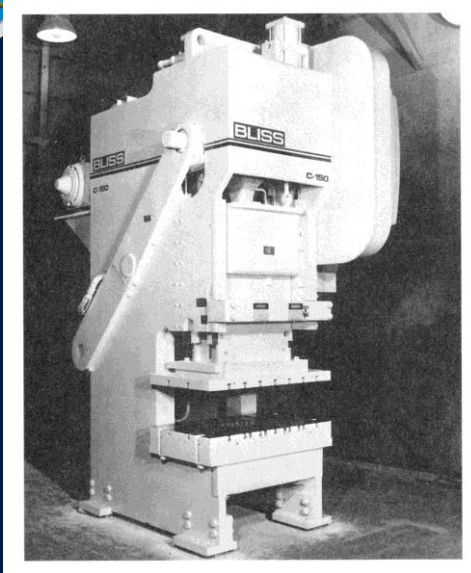*Dept. of Naval Architecture and Marine Engineering*

Figure 20.33 - Gap frame press for sheet metalworking

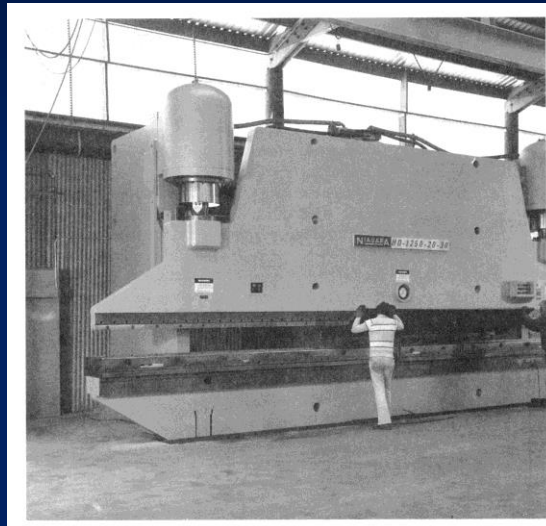(photo courtesy of E. W. Bliss Company)

Capacity = 1350 kN (150 tons)

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Figure 20.34 -

Press brake with bed width of 9.15 m (30 ft) and capacity of 11,200 kN (1250 tons); two workers are positioning plate stock for bending

(photo courtesy of Niagara Machine & Tool Works)

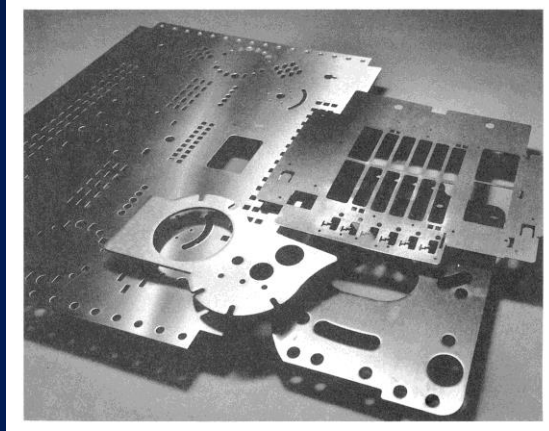*Dept. of Naval Architecture and Marine Engineering*

Figure 20.35 - Several sheet metal parts produced on a turret press, showing variety of hole shapes possible
(photo courtesy of Strippet, Inc.)

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Figure 20.36 - Computer numerical control turret press
(photo courtesy of Strippet, Inc.)

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Figure 20.37 -
Straight-sided frame press
(photo courtesy Greenerd
Press & Machine
Company, Inc.)

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Power and Drive Systems

- Hydraulic presses - use a large piston and cylinder to drive the ram
  - Longer ram stroke than mechanical types
  - Suited to deep drawing
  - Slower than mechanical drives
- Mechanical presses – convert rotation of motor to linear motion of ram
  - High forces at bottom of stroke
  - Suited to blanking and punching

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Sheet Metal Operations
Not Performed on Presses

- Stretch forming
- Roll bending and forming
- Spinning
- High-energy-rate forming processes.

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Stretch Forming

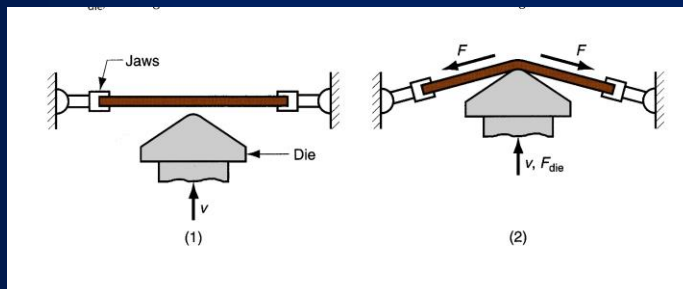Sheet metal is stretched and simultaneously bent to achieve shape change

Figure 20.39 - Stretch forming: (1) start of process; (2) form die is pressed into the work with force F_{die}, causing it to be stretched and bent over the form. F = stretching force

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Force Required in Stretch Forming

$$F = LtY_f$$

where F = stretching force; L = length of sheet in direction perpendicular to stretching; t = instantaneous stock thickness; and Y_f = flow stress of work metal

- Die force F_{die} can be determined by balancing vertical force components

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Roll Bending

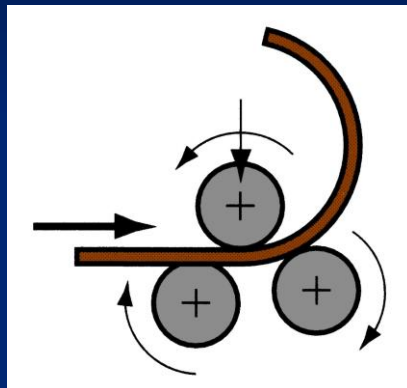Large metal sheets and plates are formed into curved sections using rolls

Figure 20.40 - Roll bending

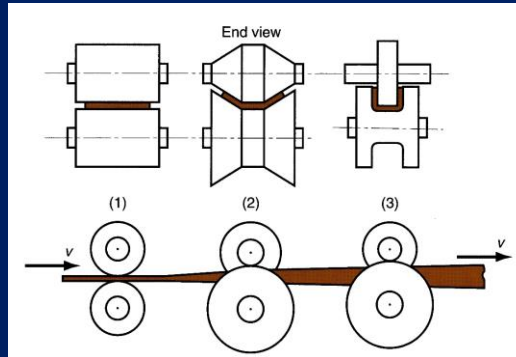*Dept. of Naval Architecture and Marine Engineering*

Roll Forming

Continuous bending process in which opposing rolls produce long sections of formed shapes from coil or strip stock

Figure 20.41 - Roll forming of a continuous channel section:

(1) straight rolls
(2) partial form
(3) final form

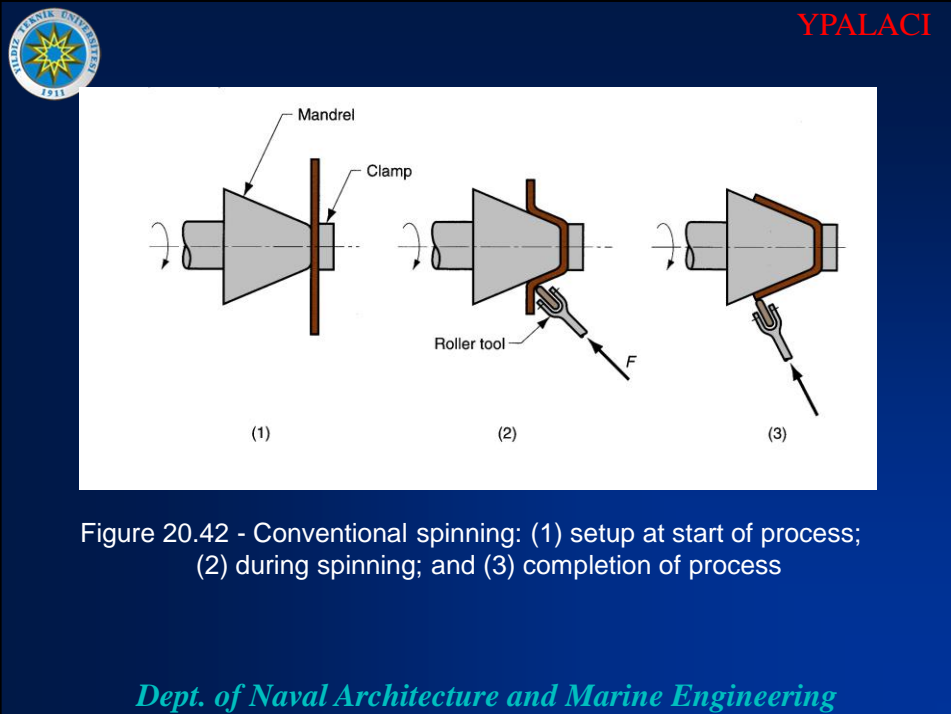*Dept. of Naval Architecture and Marine Engineering*

Spinning

Metal forming process in which an axially symmetric part is gradually shaped over a rotating mandrel using a rounded tool or roller

- Three types:
    1. Conventional spinning
    2. Shear spinning
    3. Tube spinning

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Figure 20.42 - Conventional spinning: (1) setup at start of process; (2) during spinning; and (3) completion of process

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High-Energy-Rate Forming (HERF)

Processes to form metals using large amounts of energy over a very short time
- HERF processes include:
  - Explosive forming
  - Electrohydraulic forming
  - Electromagnetic forming

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Explosive Forming

Use of explosive charge to form sheet (or plate) metal into a die cavity
- Explosive charge causes a shock wave whose energy is transmitted to force part into cavity
- Applications: large parts, typical of aerospace industry

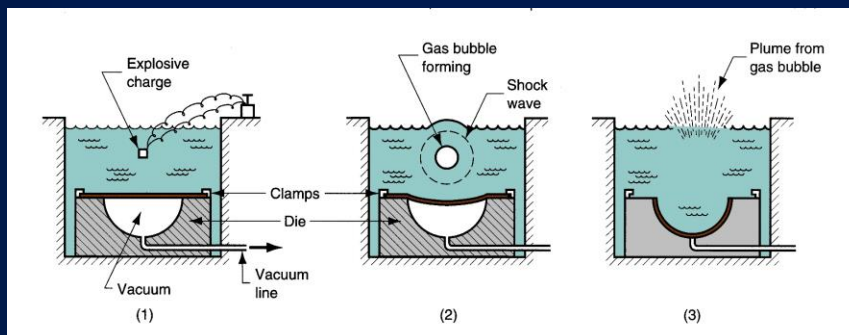*Dept. of Naval Architecture and Marine Engineering*

Figure 20.45 - Explosive forming:
(1) setup, (2) explosive is detonated, and
(3) shock wave forms part and plume escapes water surface

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Electromagnetic Forming

Sheet metal is deformed by mechanical force of an electromagnetic field induced in workpart by an energized coil

- Presently the most widely used HERF process
- Applications: tubular parts

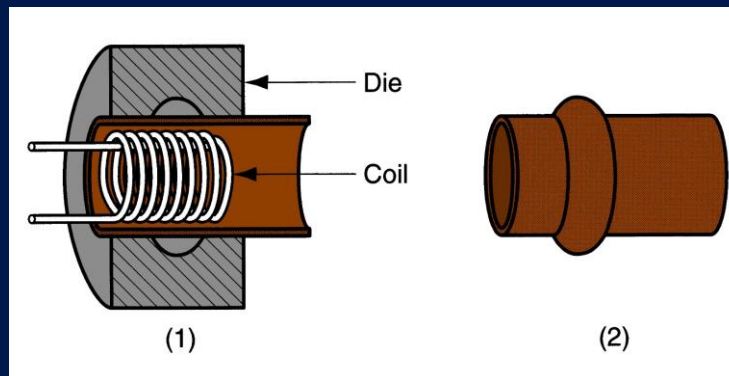*Dept. of Naval Architecture and Marine Engineering*

Figure 20.47 - Electromagnetic forming: (1) setup in which coil is inserted into tubular workpart surrounded by die; (2) formed part

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