MODULE 5

SHEET METAL OPERATIONS
SHEET METALWORKING
Cutting and forming thin sheets of metal usually performed as cold working

Sheet metal = 0.4 (1/64) to 6 mm (1/4in) thick

Plate stock > 6 mm thick

Advantage - High strength, good dimensional accuracy, good surface finish, economical mass production (low cost).

Cutting, bending, drawing
PARTS MADE BY SHEET METAL FORMING

- Car bodies
- Aircraft fuselages
- Trailers
- Office furniture appliances
- Fuel tanks
- Cookware
Sheet Metalworking Terminology

“Punch-and-die” Tooling to perform cutting, bending, and drawing

“Stamping press” Machine tool that performs most sheet metal operations

“Stampings” Sheet metal products
A set of die and punch

Press working of sheet metal
SHEET METAL OPERATIONS

- SHEARING
- BLANKING
- PUNCHING (PIERCING)
- BENDING
- STAMPING
- DRAWING
- DEEP DRAWING
- EMBOSsing
- SPINNING
- ROLL FORMING
SHEET METAL CHARACTERISTICS

Characteristics of metals important in sheet forming

1. Elongation
2. Yield point elongation
3. Anisotropy ➔ Crystallographic anisotropy
   Mechanical fibering
4. Grain Size
5. Residual stresses
6. Spring back
7. Wrinkling
8. Quality of sheared edges
9. Surface condition of sheet
Cutting Operation

• **Shearing** - using a machine called power shear or square shear.

• **Blanking** - shearing a closed outline (desired part called blank)

• **Punching** - sheared part is slag (or scrap) and remaining stock is a desired part
CUTTING OPERATION

Punch

Die

C

t
SHEARING

Diagram showing a process involving a punch, sheet, clearance, and die.
Analysis

Clearance -4-8% but sometime 1% of thickness

Too small –fracture does not occur requiring more force. Too large –Get pinched and cause an excessive burr

**Clearance: c=a*t**

**Metal group**

- 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
Factors affecting shearing operation

- Shape and material of the punch
- Die, speed of punching, lubrication
- Clearance between punch & die
Die, blank and punch size

- For a round blank,
  Blank punch diameter = \(D_b - 2c\)
  Blank die diameter = \(D_b\)

- For a round hole,
  Hole punch diameter = \(D_h\)
  Hole die diameter = \(D_h + 2c\)

- Angular clearance of 0.25° to 1.5°

- Cutting forces: \(F = S \times t \times L = 0.7 \times TS \times t \times L\)
  where \(S\) = Shear strength
  \(t\) = thickness
  \(L\) = length of cutting edge
  \(TS\) = Ultimate tensile strength
STAGES IN SHEARING ACTION

1. Plastic Deformation
2. Fracture
3. Shear
FEATURES OF PUNCHED HOLE

- Rollover depth
- Penetration depth
- Burnish depth
- Sheet thickness
- Fracture depth
- Burr height
- Fracture angle
- Breakout dimension
FEATURES OF SLUG

- Burr
- Burr height
- Dishing
- Flattened portion under the punch
- Rough surface
- Smooth surface (burnished)
- Ideal slug
Control of hole and blank sizes by clearance location.
Shearing Operations

(a)

Discarded

Punching

Blanking

Punching (piercing) and blanking.
Blanking and punching
Other Cutting Operations

- Cutoff and Parting
- Slotting, Perforating and Notching
- Trimming, Shaving and Fine Blanking
NOTCHING OPERATION
LANCING OPERATION
Maximum force, \( P \) required to be exerted by the punch to shear out a blank from the sheet can be estimated as

\[
P = t \cdot L \cdot \tau
\]

- \( t \) – Sheet thickness
- \( L \) – Total length sheared
- \( \tau \) – Shear strength of the sheet material
Shearing force, $SF = 0.02 \ Lt$

$SF$ – Shearing force in KN

$L$ – Length of cut in mm

$t$ – Thickness of material in mm
Clearance between die and punch,

\[ c = 0.003t.\tau \]
Example: A circular blank of 30 mm diameter is to be cut from 2 mm thick 0.1 C steel sheet. Determine the die and punch sizes. Also estimate the punch force and the stripping force needed. You may assume the following for the steel: Tensile strength: 410 MPa; shear strength: 310 MPa

Solution: - For cutting a blank, die size = blank size

\[ \therefore \text{Die size} = 30 \text{mm} \]

Clearance = \(0.003 \times t \times \tau = 0.003 \times 2 \times 310\)

= 1.86 mm

Punch size = blank size – 2 clearance

= 30 – 2 \times 1.86 = 26.28 mm

Punch force needed = \(L \times t \times \tau = \pi \times 30 \times 2 \times 310\)

= 58.5 kN

Stripping force needed = 0.02 \(L \times t\)

= 0.02 \times \pi \times 30 \times 2

= 3.77 kN
Fig 5.33 Shaving and Trimming Operations

(a) Shaving

(b) Trimming
PROGRESSIVE AND COMPOUND DIES
Figure 16.11 Schematic illustrations: (a) before and (b) after blanking a common washer in a compound die. Note the separate movements of the die (for blanking) and the punch (for punching the hole in the washer). (c) Schematic illustration of making a washer in a progressive die. (d) Forming of the top piece of an aerosol spray can in a progressive die. Note that the part is attached to the strip until the last operation is completed.
PROGRESSIVE DIE

A simple progressive die
COMPOUND DIE

Compound die for making a washer
Fig 5.21 Compound Die for blanking & drawing operation in one go of the press
Yield-Point Elongation

(a)

Load

Elongation

Y_{upper}

Y_{lower}

Yielded metal

Lueder's bands

Unyielded metal
Forming-Limit Diagram

A grid pattern of circles, typically 2.5 to 5mm in diameter, produced by electrochemical or photoprinting.

After drawing, the circles are observed for failure. The major strain is on the major direction and magnitude of strain.
Erichsen and Bulge-Tests

(a) Punch force

Sheet specimen

d
Bending Operations
• V-bending

• Edge Bending
In **V-bending**, the sheet metal is bent between a V-shaped punch and die set up. The included angles range from very obtuse to very acute values.
In **edge bending**, cantilever loading of the sheet is seen. A pressure pad is used to apply a force to hold the sheet against the die, while the punch forces the sheet to yield and bend over the edge of the die.
Other Bending Operations

- Flanging
- Hemming
- Seaming
- Curling
- Channel,

- U-bending
- Offset bending,
  and Tube forming

- Air bending,
  Corrugating
Straight flanging  stretch flanging  shrink flanging

Hemming  seaming  curling
Other bending operations
BENDING OPERATION

Fig 5.34 Bending a cantilevered job in a punch press

Angle relieved to allow for overbending and spring-back
Sheet bending

Sheet bending is defined as the straining of the metal around a straight axis.

During bending operation, the metal on the inner side of the neutral plane is compressed, and the metal on the outer side of the neutral plane is stretched.

Bending causes no change in the thickness of the sheet metal.
Fig 5.35 Making a 90° bend in a V die and press
Fig. 5.36 Bending operation (showing spring back)
SPRING BACK

At the end of the bending operation, the bent part retains some of its elasticity which is recovered after the punch is removed.

PREVENTING METHODS

1. Stretch forming
2. Overbending
3. Bottoming
4. Ironing
Drawing
Basic drawing operation - a cup-shape part
Detail Steps of Drawing

1. Initial Contact

2. Bending
Detail Steps of Drawing....

3. Straightening

4. Friction & Compression
Detail Steps of Drawing...

5. Final Shape
Fig. 5.37 Drawing operation with blank holder

- Blank holding ring
- Punch
- Blank
- Die
- Draw ring
- Holding ring exerting pressure on blank
- Cup partially drawn
Other Drawing Operation

- Redrawing
- Drawing without a Blankholder
Fig. 5.38 Sheet-metal drawing operations, (a) ironing is the operation in which wall thickness of a drawn part is made constant by pushing the drawn part through ironing rings, (b) deep drawing with double action drawing, (c) embossing is stretching the sheet-metal blank into desired shape under a punch and die.
Fig. 5.39. Embossing
Defects in drawing

- Wrinkling in the flange
- Wrinkling in the wall
- Tearing
- Earing – Anistropy in sheet metal
- Surface scratch
- **Wrinkling in flange and cup wall:** This is like ups and downs or waviness that is developed on the flange. If the flange is drawn into the die hole, it will be retained in cup wall region.

- **Tearing:** It is a crack in the cup, near the base, happening due to high tensile stresses causing thinning and failure of the metal at this place. This can also occur due to sharp die corner.

- **Earing:** The height of the walls of drawn cups have peaks and valleys called as earing. There may be more than four ears. Earing results from planar anisotropy ($\Delta R$), and ear height and angular position correlate well with the angular variation of $R$.

- **Surface scratches:** Usage of rough punch, dies and poor lubrication cause scratches in a drawn cup.
Stretching/stretch forming

Stretch forming is a sheet metal forming process in which the sheet metal is intentionally stretched and simultaneously bent to have the shape change.

Sheet is held by jaws or drawbeads at both the ends and then stretched by punch, such that the sheet is stressed above yield strength.
When the tension is released, the metal has been plastically deformed. The combined effect of stretching and bending results in relatively less springback in the part.
Stretching/stretch forming
$h_o =$ initial stock thickness

Thinning

$t < h_o$

die

$t = h_o$

Forming punch

Stretcher jaw

Platten

Hydraulic cylinder

Stretch forming
Stretch-wrap forming

Form block

Start

Stretching
Work part
Horn (Anvil)
Bending Curvilinear Bending
Angular Bending
(I) Bonding in a 4-slide machine

(II) Roll Bonding
METAL SPINNING

Metal Spinning process is a cold forming process in which the blank metal appears to flow somewhat like a piece of clay on a potter's wheel.
CLASSIFICATION OF METAL SPINNING TECHNIQUES

Metal Spinning

Manual (Conventional) Spinning
- Practiced by pressing a tool against a circular metal preform.
- Involves no significant thinning of work metal; essentially a shaping process.
- Used for prototype manufacture or in production runs less than 1000 pieces.

Power Spinning
- Metal is deformed using high shear forces.
- Use of automated CNC machines.
- Significant thinning of metal preforms.
- Suitable for high production runs.

Tube Spinning
- Thickness of cylindrical parts reduced by spinning them on cylindrical mandrel rollers.
PROCESS OF METAL SPINNING

External shape of the mandrel corresponds to the internal contour of the part to be produced.

- The blank is clamped between spinning mandrel and a follower on the tailstock spindle.
- The mandrel, blank, and follower are then set in rotation at controlled speeds.
**STEPS IN SPINNING PROCESS**

**Step 1 : Metal Forming**
- This step involves the laying down of the material onto the mandrel.
- It is accomplished with short inside to outside moves.
- Material gets easier to form as the part is closer to completion.
Step 2: Trimming Parts having been spun are trimmed at the end to blunt sharp edges and also to bring the component to the desired length.

Step 3: Finishing

• Finishing is done at very high RPMs (1200+) so that a minimum of force need be applied and very smooth strokes can be used.
• The flat side of spinning tool is used for straight surfaces and rounded side for curves and radii.
Metal Spinning.

- Final shape
- Blank
- Chuck
- Head stock
- Tool rest
- Pin
- Hand tool
- To hold blank in place
Shear Spinning

Schematic illustration of the conventional spinning process (b) Types of parts conventionally spun. All parts are antisymmetric.
Progressive forming in shear spinning.
Schematic illustration of the shear spinning process for making conical parts. (a) The mandrel conical parts. (b) The mandrel can be shaped so that curvilinear parts can be made.
Tube Spinning Process

- Forward
- Roller
- Workpiece
- Mandrel
- External
TUBE SPINNING

- Thickness of cylindrical parts are reduced by spinning them on a cylindrical mandrel rollers.

- Parts can be spun in either direction.

- Large tensile elongation up to 2000 % are obtained within certain temperature ranges and at low strain rates.
COMPARISON WITH OTHER FORMING PROCESSES

- Low tooling cost compared to other forming techniques.

- Conventional spinning also wastes a considerably smaller amount of material than other methods.

- The standard method of press forming the part requires many steps, as opposed to only three steps for spinning.
Rubber forming

In bending and embossing of sheet metal, the female die is replaced with rubber pad.

- **Rubber pad forming (RPF)** is a metalworking process where sheet metal is pressed between a die and a rubber block, made of polyurethane.

- Under pressure, the rubber and sheet metal are driven into the die and conform to its shape, forming the part.
Rubber pads can have a general purpose shape, like a membrane. Alternatively, they can be machined in the shape of die or punch.