Forming Processes:
shaping solid materials by plastic deformation w/o melting.; sheet metal forming, forging, extrusion, rolling

Plasticity:
ability of a material to flow as a solid w/o deterioration of props.

Deformation: requires large forces

Yield Strength: stress which deform. begins

Ductility: ability to elongate before fracture

Strain Hardening: ↑ in resistance to deform. w/ plastic strain

States of Stress:

Uniaxial Stress: single normal stress (tension / compression)

Biaxial Stress: sheet metal forming processes where in-plane stresses (σ_x, σ_y) exist; shear stress τ_{xy} too sometimes.

Triaxial Stress: when all 3 normal stresses $(\sigma_x, \sigma_y, \sigma_z)$ are present; forging /extrusion

General Parameters:
-> strength or resistance for deform
-> conditions at diff. temp.
-> formability limits
-> reaction to lubricants
-> speed of deform. & its effects
-> speed-sensitive materials requires more energy to produce same results

Bulk Deformation Process:
involve significant volume change of workpiece;
bulk: work parts w/ relatively low surface-to-volume ratios
starting work shapes: cylindrical billets & rectangular bars.
E.g. forging, rolling, extrusion, & drawing

Drawing Optical Fibers:

Optical Fiber: thin transparent strands of glass / plastic that transmit light signals; telecommunications, medical imaging, & industrial sensing

Pros: higher bandwidth, lower signal loss, & immunity to EM interference

Principle:
- light travels through fiber core by reflecting off cladding;
- diff. in refractive index: light reflects btwn. core & cladding;
- total internal reflection: minimal loss.

Manufacturing:
- reactive gases -> inside a glass tube;
- heating: chemical reaction;
- composition of inner tube changes;
- outer side (lower IOR): cladding
- inner side: higher IOR;
- tube pulled until inner sides converge in the center: uniform & no holes

Total Internal Reflection (TIR):
occurs b/c of Snell's Law (how light bends when passing btwn. mat. w/ diff. refractive index). $\frac{\sin\theta_2}{\sin\theta_1} = \frac{n_1}{n_2} = \frac{v_2}{v_1}$

angle of light hitting cladding > critical°: insufficient bend to enter cladding (slower) -> TIR. -> traps & transmits light

Rolling:
reduces thickness & refines grain structure of metal sheets / bar stocks by passing it through rollers.

Flat Rolling: creates metal sheet of various thickness

Shape Rolling: produce specific shapes like I-beams or angles

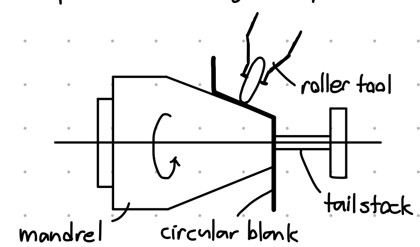
Forging:
shaping metals by compressive forces btwn dies.

Open-die forging: no closed die cavity; shape changes in multiple directions

Closed-die forging: use matched dies to form specific shapes

Isothermal Forging: high-temp to improve material props. & reduce forces

Shear Spinning:
a sheet metal disc pressed against a rotating mandrel & roller tool; creates axisymmetric cups, cones, & bowls; suitable for thin-walled parts w/ high depth-to-diameter ratios



Tube Spinning:
similar to shear spinning but uses tubular blanks; close / open-ended tubular parts; high material utilization & good surface finish

Swagging (Kneading):
reduces diameter & increases length of solid / tubular pieces; hammering / comp. forces btwn. dies; improves strength & surface finishes

Stretching:
thinning of a metal sheet by applying tensile forces; specific shapes / reduce weight; req. control of blank dimensions & tooling geometry.

Extrusion:
extrusion forces a heated metal billet through a die to create continuous profile

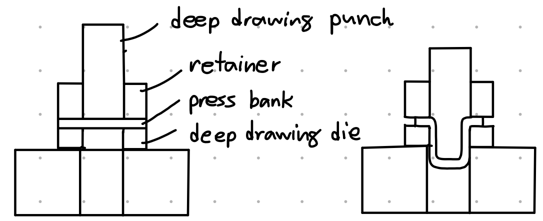
Direct Extrusion: ram pushes billet directly through a die.

Indirect Extrusion: container holds billet & ram pushes against container's bottom to extrude material.

Hydrostatic Extrusion: fluid pressure transmits force to billet, reducing friction & enabling complex shapes

Drawing

Deep Drawing: sheet metal blank is drawn over a punch into a die cavity; cup-like shapes; req. careful control of blank holder force & lubrication



Tube / Wire Drawing: cont. reduce diameter & increase length; uses multiple dies w/ decreasing diameters; high strength & precise tolerance

Straight Bending:
creates linear bends in sheet metals using bending tools; req. consider springback & material prop.

Contoured Flanging:
bends sheet metal along a curved edge to create flanges; strengthening, stiffening, & joining parts; specialized tooling & careful process control

Independent Variables:
aspects of processes engineers/operators have direct control over
- temp., strain rate, tooling geometry, lubrication, product geometry

Dependent Variables.
outcomes of a forming process/influenced by indep. vars.; optimization, QC, predicting prop.'s
- force/power consump., product prop., exit temps, surface finish, dimensional precision, material flow details.

Experience:
trial & error / can be slow/costly, often lacks quantitative data

Experiment:
direct observation of cause & effect relationships

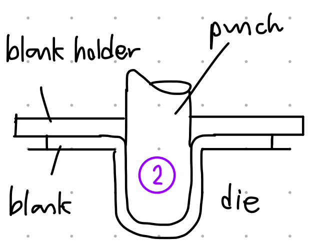
Process Modeling:
enables analysis of complex scenarios/interaction btwn. vars.

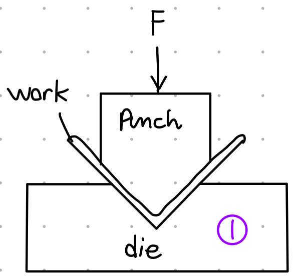
Simulation Techniques.

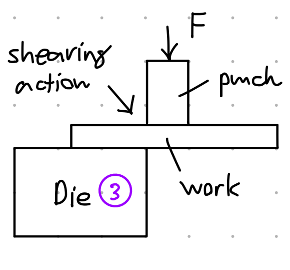
Finite Element Method (FEM):
numerically solves equations to analyze stress, strain, & deform.

Analytical Modeling:
simplified equations to predict specific aspects of process

Computational Fluid Dynamics (CFD):
models fluid flow behavior in processes







Essential Material Properties (Metal Forming):
desirable prop: low Y.S. & high ductility

Yield Strength: stress which plastic deform. starts
lower Y.S. = better formability.

Ductility: ability to elongate before fracture
higher ductility = higher complexity shapes

Strain Hardening: ↑ in Y.S. w/ plastic deform.
can limit formability & req. higher forming forces

Strain Rate Sensitivity: mat.'s dependence on deform. speed: careful process control if sensitive

Anisotropy: variation in prop. depending on direction; can affect forming behav.

Sheet Metal Working:
steel / aluminum / brass

any forming performed on metal sheets/strips/coils
- high surface area-to-volume ratio of starting mat.
- AKA press working / parts called stampings
- Usual tool: punch & die

Pros: lightweight & high strength: weight, formability (complex shapes), cost effective (large scale prod.), good surface finish & recyclability (e.g. automotive/aerospace comp., enclosures, & building + HVAC).

1 Bending Sheet Metal:
Factors: material props, sheet thickness, bend radius & angle, tooling selection & setup

2 Drawing Sheet Metal:
Factors. material props., blank holder force & lubrication, tooling design/geometry

3 Shearing Sheet Metal:
Edge Quality & Burr Control: tool sharpness, clearance, & material prop.; imperfect-shearing → burr

Minimizing Burr: proper tool maintenance /sharpening, lubrication/coatings, specialized shearing techniques (lasercutting / water jet).

Material Behavior for Optimal Forming Processes
Material's response to force.
predicting final shape/props., avoiding defects, ensure functionality, optimizing correct process/params.

Flow Curve: true stress & strain account for ↓ in cross-sec A. as mat deforms; more accurate v.s. engineering stress-strain curves
primary interest: plastic region where mat's behav is expressed by:

$\sigma = K\varepsilon^n$ K: strength coeff., n = strain hardening exponent

Lubrication:
reduces friction btwn tool & workpiece