

Sheet Metal Forming Fundamentals

Shearing, blanking, bending, flanging, stretch forming, deep drawing and troubleshooting

Key Equations (standard textbook forms)

Max punch force	$F_{\max} = 0.7 \cdot \text{UTS} \cdot t \cdot L$	t = sheet thickness, L = total length sheared (perimeter).
Bending force	$F = k \cdot \text{UTS} \cdot L \cdot t^2 / W$	W = die opening; k ≈ 0.3 wiping, 0.7 U-die, 1.3 V-die.
Limiting drawing ratio	$\text{LDR} = D_0 / D_p$	Max blank diameter ÷ punch diameter that draws without tearing.
Punch-die clearance	c ≈ 2-10% of t	Too large a clearance pulls material into the die instead of shearing it.
Min bend radius	$R_{\min} \geq t$ (rule of thumb)	Expressed as a multiple of thickness; depends on material and method.

Shearing Operations

Operation	What it does
Shearing	Cut a sheet along a straight line
Slitting / roll slitting	Cut a coil into narrower strips
Blanking	Cut out a contoured part; the removed piece is the part
Punching / piercing	Cut a hole; the removed slug is scrap
Trimming	Remove excess material from drawn parts
Shaving	Remove a thin edge layer for tighter tolerance and no burr
Fine blanking	Very tight clearance; burr-free, tight-tolerance edge with no secondary ops
Rotary shearing	Rotating cutter cuts continuously, like a can opener

Forming Operations

Bending	Deform along a bend line into a V or U shape, usually on a press brake. Watch stringer direction vs rolling direction and Poisson narrowing at the bend.
Flanging	Fold an edge to stiffen it by raising the buckling load; pierced flanges leave rough, thinned edges.
Stretch forming	Clamp edges and stretch over a form block; common for aircraft skins.
Draw bead	Restraint in the die that controls metal flow into the cavity; trimmed off afterward.
Fabrication vs forming	Fabrication = design, cut, form, join, finish. Forming = only the plastic shaping step.

Troubleshooting

Defect	Fixes
Springback	Overbend, or use a smaller bend angle
Wrinkling	Add blank holder, smaller punch, adjust draw speed for uniform flow
Tearing	Adjust draw ratio, lubricate, use a more ductile material
Cracking	Larger bend radius, slower forming, more ductile material, maintain tooling
Distortion	Symmetric tooling, even forming load, slower speed, proper clamping

Worked deep-draw example: AKDQ steel, R = 1.7, LDR = 2.4; 220 mm blank, 100 mm punch → $D_0/D_p = 2.2 < 2.4$, so the cup can be drawn in one step. Best practices: right material and gauge, design to min bend radius and tool clearance, respect tolerances, lubricate punch and die.