

Sheet Metal Stamping & Forming Design

Stamping operations, tailor-welded blanks, defects, anisotropy, springback and FLDs

Key Concepts

Stamping	Matched dies in a press cut and form sheet; often several operations in one die or a progressive line.
Stamping steps	Blanking → piercing → bending → drawing → flanging. Types: progressive, transfer, compound.
Bypass notches	Notches in a progressive-die carrier strip that clear tooling and pilots and control part separation.
Sheet vs bulk forming	Sheet: mainly tensile, high area/volume, fails by necking or wrinkling. Bulk (forging, rolling, extrusion): mainly compressive.
Superplastic forming	Some Al, Ti and Ni alloys stretch up to ~300% without breaking; paired with diffusion bonding.
Tailor-welded blank	Blanks of different thickness or grade welded before stamping. Used for body side outers, front rails, floor pans.

Anisotropy Equations

Volume constancy	$\epsilon_l + \epsilon_w + \epsilon_t = 0$	True strains sum to zero.
Normal anisotropy	$R = \epsilon_w / \epsilon_t$	High R resists thinning; better deep drawability.
Average anisotropy	$R_{avg} = (R_0 + 2R_{45} + R_{90}) / 4$	Higher R_{avg} → higher LDR.
Planar anisotropy	$\Delta R = (R_0 - 2R_{45} + R_{90}) / 2$	$\Delta R \neq 0$ causes earing in drawn cups.
n and m	$n \propto$ uniform strain; $m \propto$ post-necking strain	Strain-hardening exponent and strain-rate sensitivity.

Worked example: stopped at $\epsilon_l = 0.15$; $\epsilon_w = -0.090$ (0°), -0.075 (45°), -0.080 (90°). Then $\epsilon_t = -(\epsilon_l + \epsilon_w)$ gives $R_0 = 1.50$, $R_{45} = 1.00$, $R_{90} = 1.14 \rightarrow R_{avg} \approx 1.16$, $\Delta R \approx +0.32$ (ears form at 0° and 90°). Calculated with the standard formulas above.

Defects

Defect	Cause / description	Prevention
Local necking	Excess localized thinning at high curvature or constrained areas	Tooling design, lubrication; neck angle via Mohr's circle of strain
Tearing / cracks	Strain beyond the forming limit	Stay inside the FLD; material, gauge, lubrication
Springback	Elastic recovery; bend radius usually grows	Overbend, pre-bend, air bend, bottoming, larger radius
Wrinkling	Compressive buckling; worse with anisotropy	Draw beads, blank holder, material choice
Earing	Planar anisotropy gives uneven metal flow	Low- ΔR material, tooling compensation
Orange peel	Large grains after heavy deformation	Finer-grain material
Lüders bands	Visible strain markings on panels	Material and process control

Forming Limit Diagram (FLD)

- Plots major vs minor strain at failure, built from tests such as the punched dome test.
- Major strain is always positive; minor strain can be positive or negative.
- Used for process design, material comparison and quality control.
- Other formability tests: Erichsen cupping test and bulge test.