

Leaf Spring Design

Parts, types, leaf vs coil, design steps and a semi-elliptic light-truck spring worked example

Parts of a Leaf Spring

Main (master) leaf	Longest, topmost leaf with an eye at each end that attaches to the frame.
Graduated leaves	Progressively shorter leaves beneath the main leaf; add stiffness and share load.
Spring pack	The complete leaf stack, held by a center bolt and alignment clips.
Shackle	Pivoting bracket that lets the spring lengthen and shorten as it flexes.
U-bolts & center bolt	U-bolts clamp the pack to the axle; the center bolt keeps leaves aligned.
Hangers & bushings	Brackets and rubber or polyurethane bushings mounting the eyes and shackle to the frame.

Leaf vs Coil Springs

	Leaf spring	Coil spring
Load capacity	Higher, less deflection; spreads load over the chassis	Transfers load to a single point
Ride comfort	Harsher: interleaf friction causes stickiness	Smoother, no interleaf friction
Axle location	Locates the axle itself (no trailing arms / Panhard rod)	Needs separate links
Typical use	Rear of trucks, vans, large SUVs; rail cars	Most passenger cars

Design Rules & Facts

- Types: **mono-leaf** (single leaf) and **multi-leaf** (symmetrical or unsymmetrical stack-up).
- Mount the spring seat as close to the axle centerline as possible; a longer lever increases **axle wind-up**.
- Leaf springs carry vertical forces plus horizontal forces and torques; wind-up comes from longitudinal force above or below the seat.
- Functions: support weight, provide springiness, damp via interleaf friction, keep tire grip, locate the axle.
- Ends can be squared-off or diamond-pointed; virtually no modern vehicle uses leaf springs at the front.
- Replace when sagging, cracked, broken or leaning.

Standard Beam Relations Used in Sizing

Leaf moment of inertia	$I_{\text{total}} = \sum b t^3 / 12$	b = leaf width, t = leaf thickness, summed over leaves.
Bending stress	$\sigma = M c / I$, $c = t / 2$	Thicker leaves raise stress for the same deflection.
Spring rate	$K = F / \delta$	Target rate is checked with the center clamp in place.

Design Steps

Step	Action
1	Find the total moment of inertia required for the specified rate and length.
2	Find the maximum permissible leaf thickness within the stress limit at the corresponding load.
3	Select candidate leaves (here from the SAE spring design manual, 1995) and calculate stress.
4	Estimate steel mass and compare options; pick the lightest that meets rate and stress.

Worked Example: Symmetrical Semi-Elliptic Light-Truck Spring

17.5 N/mm

Target rate (tested with center clamp)

≤ 6.39 mm

Max permissible leaf thickness, 4 leaves

1000 N/mm²

Max allowable stress (options 4 and 5 exceeded it)

Option C

3 × (6.3 × 75 mm) + 1 × (6.3 × 56 mm): lowest mass, rate within 1%

History: carriage springs appeared in France in the mid-1600s and spread to England and Germany by ~1750. Automotive use declined in the 1970s with front-wheel drive and coil springs.