

EV Braking System Explained

Regenerative + friction braking, braking forces, UNECE R13 constraints and EV-specific issues

Braking Force Equations

Front longitudinal	$F_{x,f} = M a_x \gamma$	Share of braking force on the front axle.
Rear longitudinal	$F_{x,r} = M a_x (1 - \gamma)$	
Front vertical	$F_{z,f} = (b_f/L) M g - (h/L) M a_x$	Static share plus load transfer term (sign convention as in the article).
Rear vertical	$F_{z,r} = (b_r/L) M g + (h/L) M a_x$	
Brake distribution	$\gamma = F_{x,f} / F_{x,tot}$	Front axle force ÷ total braking force demand.
Braking intensity	$z = F_{x,tot} / (M g)$	Total braking demand ÷ vehicle weight.
Adhesion utilization	$k = F_x / F_{x,max}$ (per axle)	Braking force ÷ maximum braking force at that axle.
Kinetic energy	$E = \frac{1}{2} M v^2$	Energy friction brakes turn into heat, or regen recovers.

Symbols

M, g, a_x	Vehicle mass · gravity · longitudinal deceleration.
L, h	Wheelbase · CG height.
b_f, b_r	Distances from CG to the front / rear axle.

UNECE Regulation 13 Constraints

- Rear wheels locking first makes the vehicle unstable (oversteer). R13 limits how braking force is split front to rear.
- Condition A:** $k_f \geq k_r$: front adhesion utilization at least equal to rear.
- Condition B:** $0.85 k \leq z + 0.07$ for braking intensities z from 0.1 to 0.61.

Regenerative vs Friction Braking

	Regenerative	Traditional friction
How it slows the car	Electric motor reversed to act as a generator	Pads clamp rotors (or shoes in drums)
Energy	Kinetic energy returned to the battery	Kinetic energy turned into wasted heat
Wear	Very low, no pad-to-rotor contact	Wears pads and rotors
Best for	Everyday, gradual slowing	Hard stops, emergencies, full battery, low speed

EV-Specific Concepts

Blended braking	Car combines regen and friction automatically when the pedal is pressed so it feels like one stop.
One-pedal driving	Strong regen stops the car when the accelerator is lifted. Tesla regen mode, Nissan e-Pedal; Kia/Hyundai use steering-wheel paddles.
Brake lights	Still activate under regen, as they would with the pedal.
Pad corrosion	Infrequent friction braking lets moisture sit; pad backing can rust and adhesive can fail, so pads may wear out faster on EVs.
"Lot rot"	Surface rust on rarely used rotors causing NVH when braking.

Engineering Trade-off: FNC Rotors

Benefit	Penalty
Hardened surface, resists rust and lot rot	Added process cost
Fixes corrosion-related NVH	Cannot be turned / resurfaced at service
Longer rotor life	Lower friction coefficient → less torque → larger caliper or rotor needed

FNC = ferritic nitrocarburizing, a thermochemical surface treatment for iron rotors.

Key Facts

up to 90%

Braking energy captured in most hybrids

1899 / 1902

Daimler's drum-brake concept / Renault's first mechanical drum brake

All US EVs/PHEVs

Feature regenerative braking

Friction

Still required: hard stops, low speed, full battery