Pitch and Bounce Frequencies and Oscillation Centres

Natural frequencies and oscillation centres (nodes) of the coupled pitch and bounce modes of a vehicle body from its mass, pitch inertia and axle ride rates.

Method: Bounce–pitch model of the sprung mass

Input parameters

Unit system: SI

Parameter	Value	Unit
Sprung mass	1,350.0	kg
Pitch moment of inertia	1,900.0	kg·m²
Front ride rate (both wheels)	48.000	N/mm
Rear ride rate (both wheels)	56.000	N/mm
CG to front axle	1.2000	m
CG to rear axle	1.5000	m

Calculated results

Parameter	Value	Unit
Lower natural frequency	1.3218	Hz
Higher natural frequency	1.6749	Hz
Node of mode 1 (ahead of CG positive)	-2.4266	m
Node of mode 2 (ahead of CG positive)	0.58000	m
Dynamic index k² /ab	0.78189	

Notes for this case

• With body heave z and pitch θ, a point x ahead of the CG moves z + xθ, the springs store ½k_f(z + aθ)² + ½k_r(z − bθ)², and the frequencies follow from det(K − ω²M) = 0. Each mode rotates about a node where z + xθ = 0; the mode whose node lies outside the wheelbase is mainly bounce, the one inside mainly pitch. Olley's guidance: front frequency a little below the rear so the car settles rather than pitches after a bump, and a dynamic index near 1 (then the axles act independently).

Formula and method

$$\begin{vmatrix} k_f + k_r - m\omega^2 & k_f a - k_r b \\ k_f a - k_r b & k_f a^2 + k_r b^2 - I_y \omega^2 \end{vmatrix} = 0, \quad x = \frac{k_f a^2 + k_r b^2 - I_y \omega^2}{k_f a - k_r b}$$

Variables

m	Sprung mass	kg
I_y	Pitch moment of inertia	kg·m²
k_f	Front ride rate (both wheels)	N/m
k_r	Rear ride rate (both wheels)	N/m
a	CG to front axle	m
b	CG to rear axle	m
f_1	Lower natural frequency	1/s
f_2	Higher natural frequency	1/s
x_1	Node of mode 1 (ahead of CG positive)	m
x_2	Node of mode 2 (ahead of CG positive)	m
D_r	Dynamic index k² /ab	-

Method and standards

Pitch and bounce.

Assumptions and limits

- Linear, undamped, rigid body on two axle springs.

References

Bounce–pitch model of the sprung mass

Report details

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Results are for engineering estimation. Verify critical designs against the referenced standards and your own data.

This calculator online

https://calc.firecad.com/automotive/vehicle-dynamics/pitch-bounce-frequencies

Open this case on calc.firecad.com →

Reopens the calculator with the inputs of this report.