Wheel Hop and Ride Frequencies of a Quarter Car

Wheel hop (unsprung) natural frequency, body ride frequency with tyre compliance, their ratio and the critical damping of the unsprung mass for one corner.

Method: Two-degree-of-freedom quarter-car model (decoupled approximation)

Input parameters

Unit system: SI

Parameter	Value	Unit
Sprung mass per corner	380.00	kg
Unsprung mass per corner	42.000	kg
Suspension wheel rate	28.000	N/mm
Tyre vertical stiffness	220.00	N/mm

Calculated results

Parameter	Value	Unit
Wheel hop frequency	12.230	Hz
Body ride frequency (spring and tyre in series)	1.2867	Hz
Frequency separation	9.5045	
Critical damping of the unsprung mass	6,454.8	

Notes for this case

• Because the wheel is light and the tyre stiff, the two modes of a quarter car separate: the body bounces on the spring and tyre in series, f_ride = (1/2π)√(k_r/m_s) with k_r = k_sk_t/(k_s + k_t), and the wheel hops between the spring and the tyre, f_hop ≈ (1/2π)√((k_s + k_t)/m_u). Typical values are 1–1.5 Hz and 10–15 Hz. Heavy unsprung mass lowers hop frequency and worsens road holding; dampers are a compromise between controlling both modes. Critical damping is given in N·s/m.

Formula and method

$$f_{hop} = \frac{1}{2\pi}\sqrt{\frac{k_s + k_t}{m_u}}, \quad f_{ride} = \frac{1}{2\pi}\sqrt{\frac{k_s k_t}{(k_s + k_t)m_s}}$$

Variables

m_s	Sprung mass per corner	kg
m_u	Unsprung mass per corner	kg
k_s	Suspension wheel rate	N/m
k_t	Tyre vertical stiffness	N/m
f_{hop}	Wheel hop frequency	1/s
f_{ride}	Body ride frequency (spring and tyre in series)	1/s
f_{hop}/f_{ride}	Frequency separation	-
c_{cr}	Critical damping of the unsprung mass	-

Method and standards

Wheel hop.

Assumptions and limits

- Linear springs; modes decoupled; undamped natural frequencies.

References

Two-degree-of-freedom quarter-car model (decoupled approximation)

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/wheel-hop-frequency

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Reopens the calculator with the inputs of this report.