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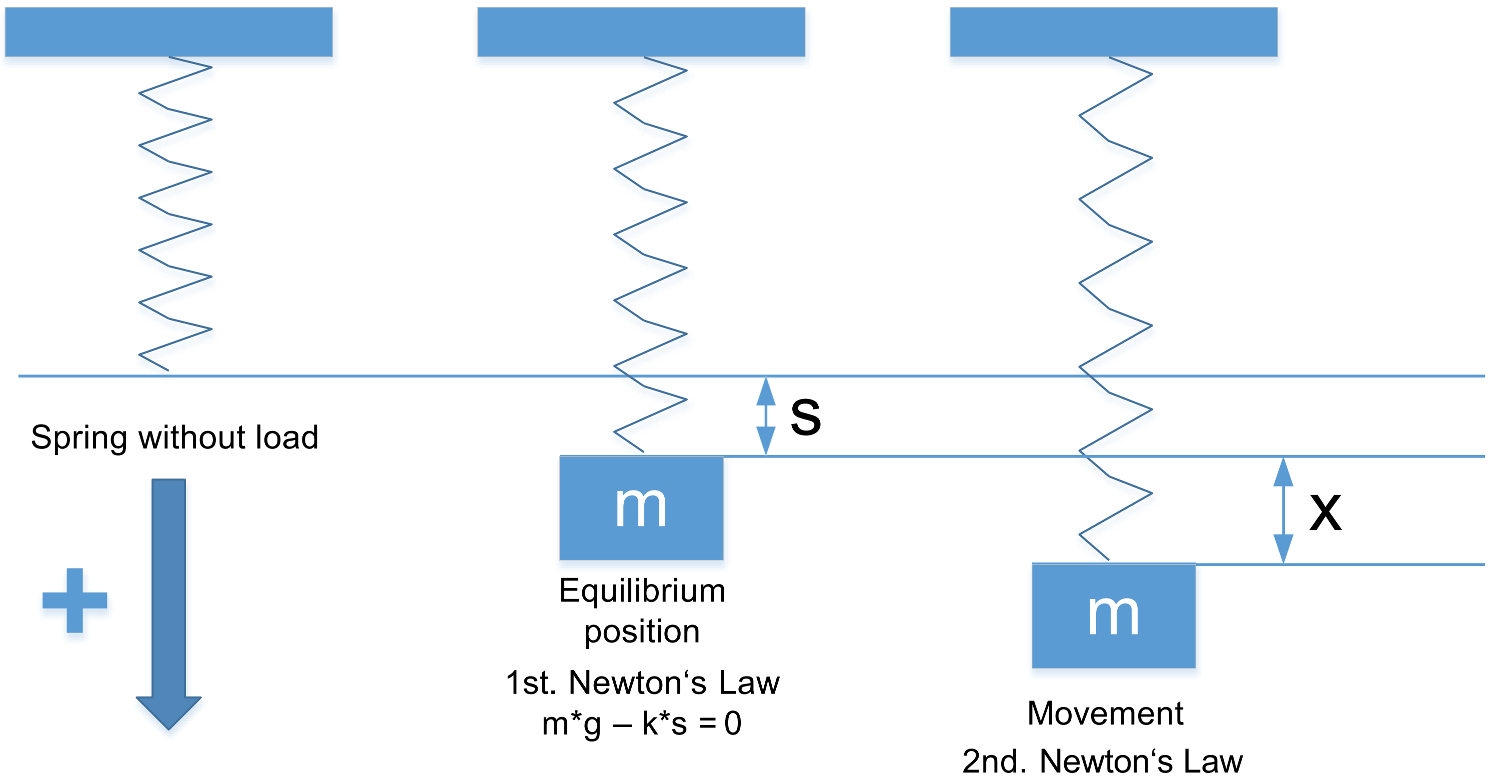
Spring and Damper

Course PDF

Working principle - Spring



2nd Newton's Law

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$$m \cdot x'' = -k (s + x) + m \cdot g$$
$$m \cdot x'' = -k \cdot s - k \cdot x + m \cdot g$$
$$m \cdot x'' = m \cdot g - k \cdot s - k \cdot x$$
$$m \cdot x'' = -k \cdot x$$

$$x'' + k/m \cdot x = 0$$
$$\omega^2 = k/m$$
$$x'' + \omega^2 = 0$$

$$x(t) = C1 \cdot \cos(\omega \cdot t) + C2 \cdot \sin(\omega \cdot t)$$

Notes:
ω = natural frequency
Period $T = 2 \cdot pi / \omega$
Frecuency $f = 1 / T$

Differential Equation

Differential equation of free amortized motion:

$$x'' + 2*\lambda * x' + \omega^2 * x = 0$$

Note: $\beta / m = 2*\lambda$

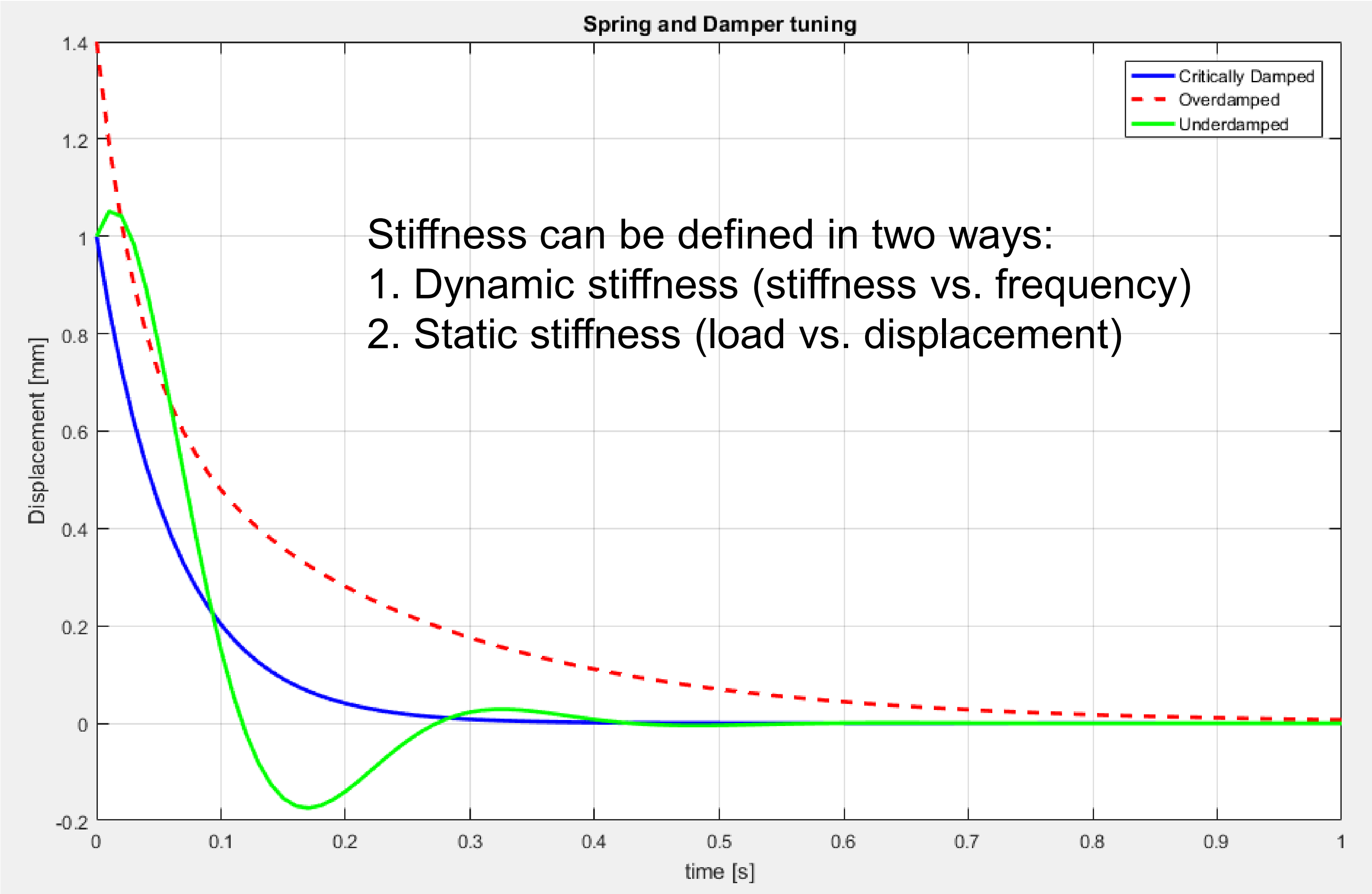
$$m^2 + 2*\lambda * m + \omega^2 = 0$$

$$m1 = -\lambda + (\lambda^2 - \omega^2)^\wedge(½)$$
$$m2 = -\lambda - (\lambda^2 - \omega^2)^\wedge(½)$$

3 cases:

$\lambda^2 - \omega^2 > 0$ Overdamped
$\lambda^2 - \omega^2 =$ Critically damped
$\lambda^2 - \omega^2 < 0$ Underdamped (complex roots)

Behavior of a spring-damper



Stiffness can be defined in two ways:

1. Dynamic stiffness (stiffness vs. frequency)
2. Static stiffness (load vs. displacement)

Design considerations

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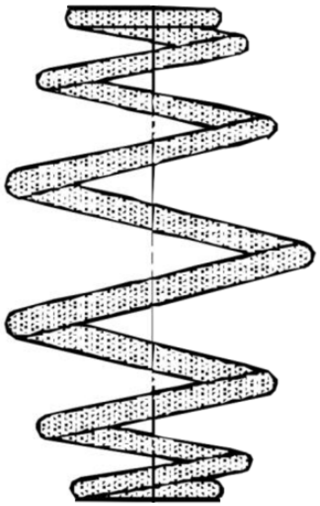

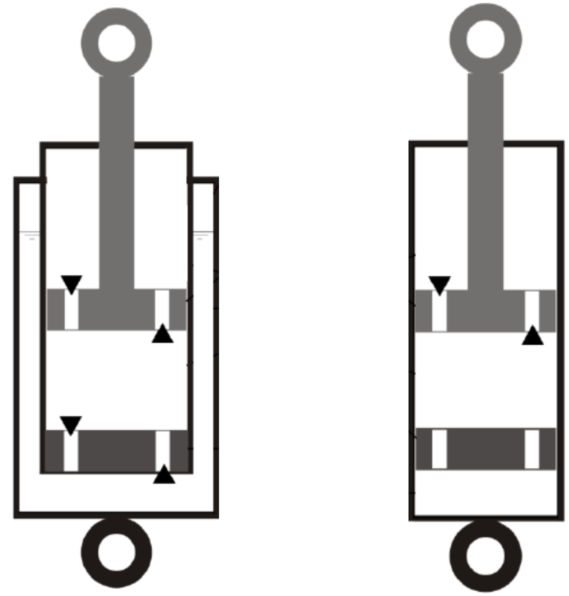

Considerations in spring/shock absorber design (compression and rebound):

Avoid the natural frequency of the human body so as not to cause passenger discomfort (motion sickness).

Vehicle weight change, road and speed have an impact on the theoretical design.

Vehicle purpose: off-road, sport, comfort? Vertical displacement desired?

Iterations between mathematical models, tests and vehicle evaluations are fundamental to improve prediction models.