Vehicle Dynamics and Simulation

Ride Dynamics

Dr B Mason
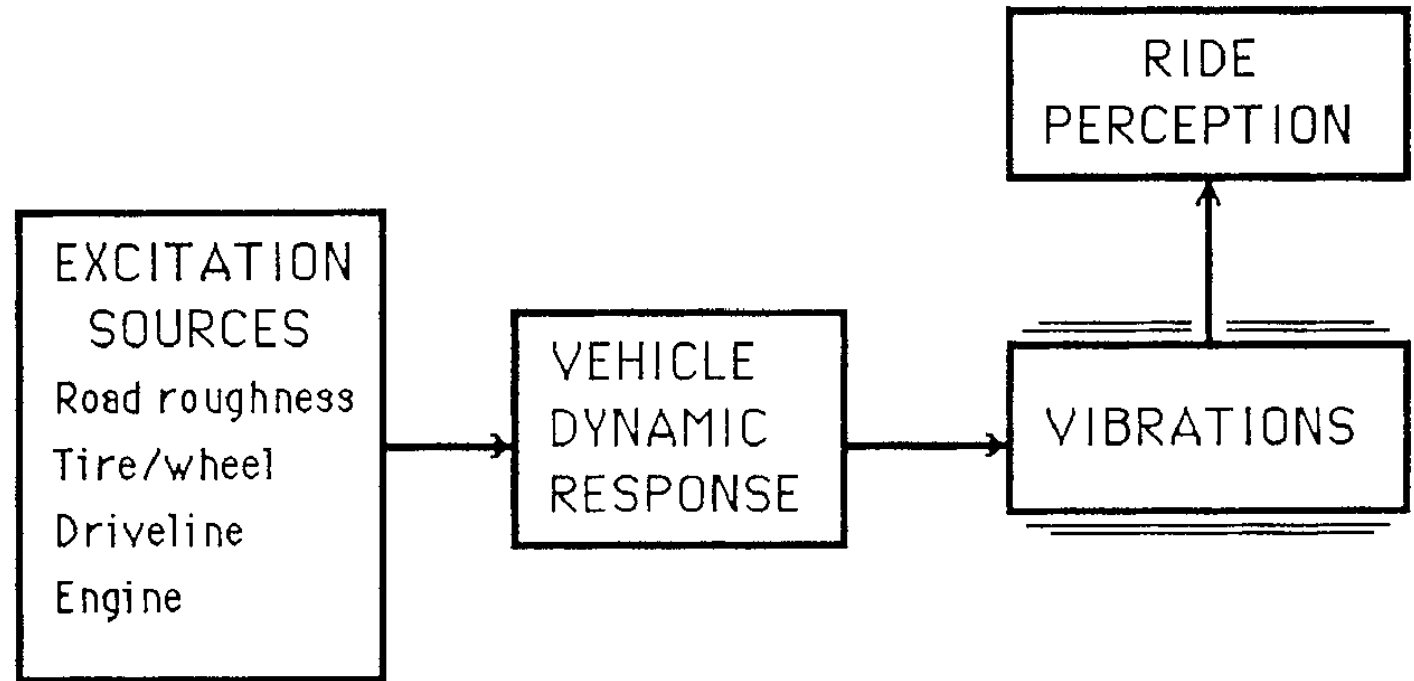
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Lecture overview

- Excitation input

- Quarter car model
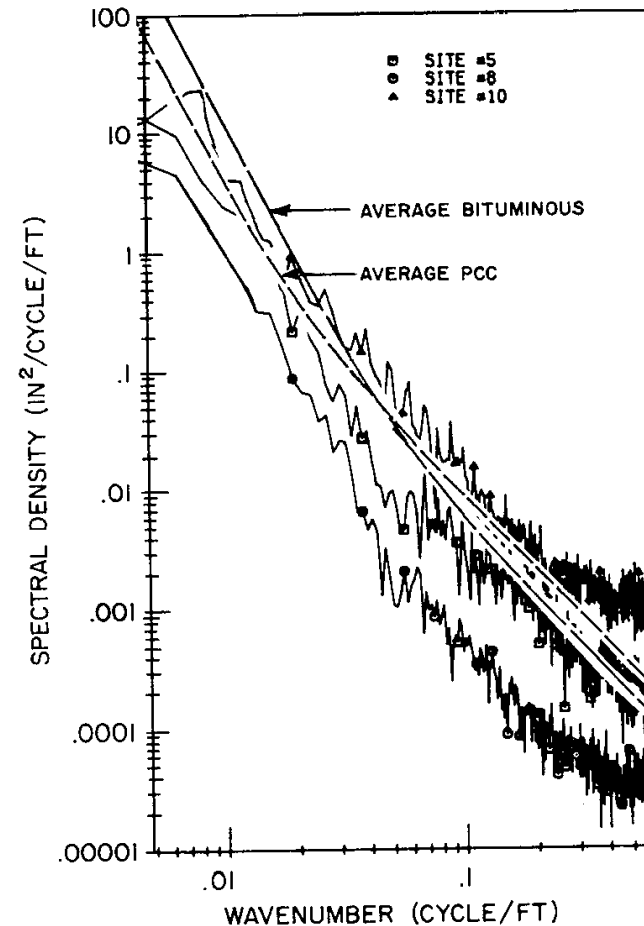
- Ride response
  - Active suspension

- Human perception

The Ride System

- The Ride System
  - Excitation
  - Response
  - Vibration
  - Perception

- Analyses in time or frequency domains

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Excitation: Road Roughness

- The road surface is the most significant excitation source.

Excitation: Road Roughness

- A model for generating excitation input
- Generator source: random sequence
- Described using;

$$G_Z(\upsilon) = G_O\left[1 + (\upsilon_O/\upsilon)^2\right]/(2\pi\upsilon)^2 \qquad [1]$$

where;

$G_Z(\upsilon)$ = PSD amplitude (feet^2/cycle/foot)

υ = Wavenumber (cycles/foot)

G_O = Roughness magnitude parameter (1.25×10^5 for rough roads, 1.25×10^6 for smooth)

υ_O = Cutoff wavenumber (0.02 cycles/foot for rough roads, 0.05 cycles/foot for smooth)
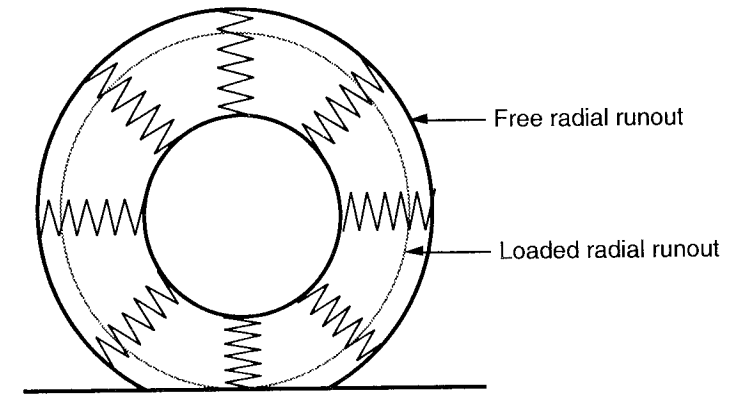
Excitation: Road Roughness

- Simulated roads can be created using [1] or a random number sequence (coloured noise)
- Multiplying cycles/distance (cyc/ft, cyc/m) by vehicle speed gives frequency -> from which PSD can be plotted.
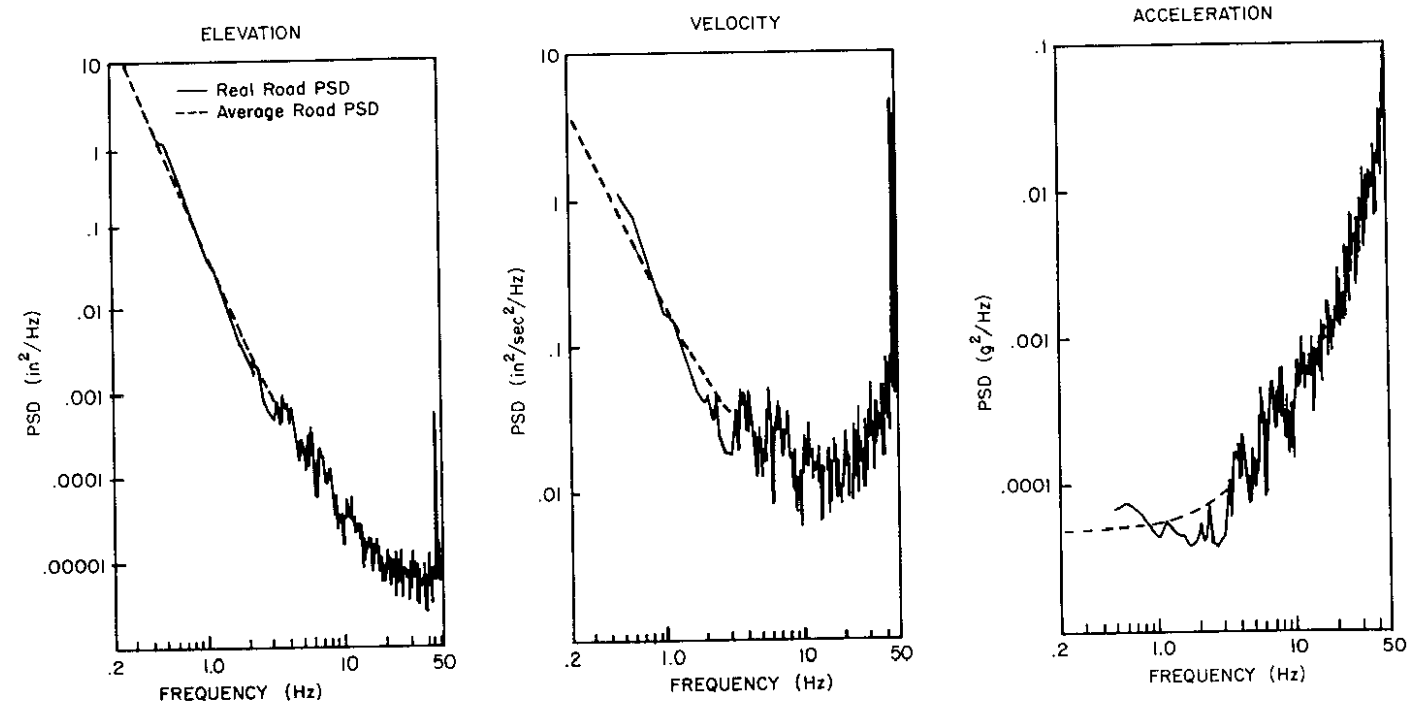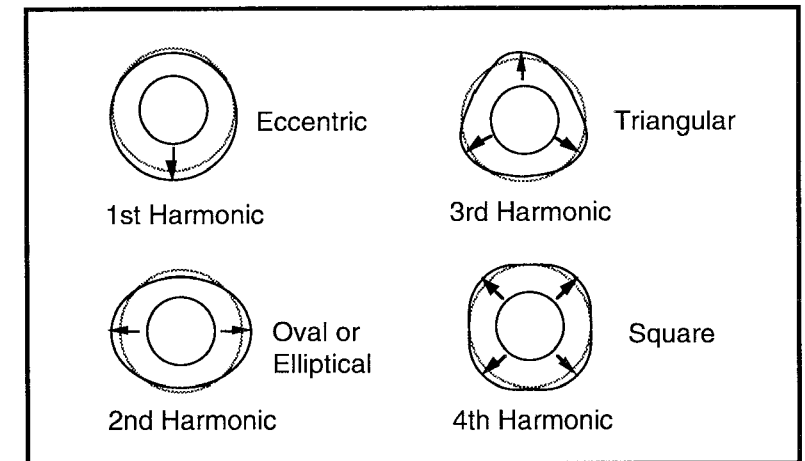

Frequency [cyc/s] = wave number [cyc/m] x speed [m/s]

Excitation: Secondary Effects

- Secondary effects include vibration
  - Driveline
  - Engine
  - Wheel/tyre
- Typically at higher frequency that primary excitation sources
- Runout occurs due to deformation of the tyre. Imperfections result in different harmonics i.e. mode shapes
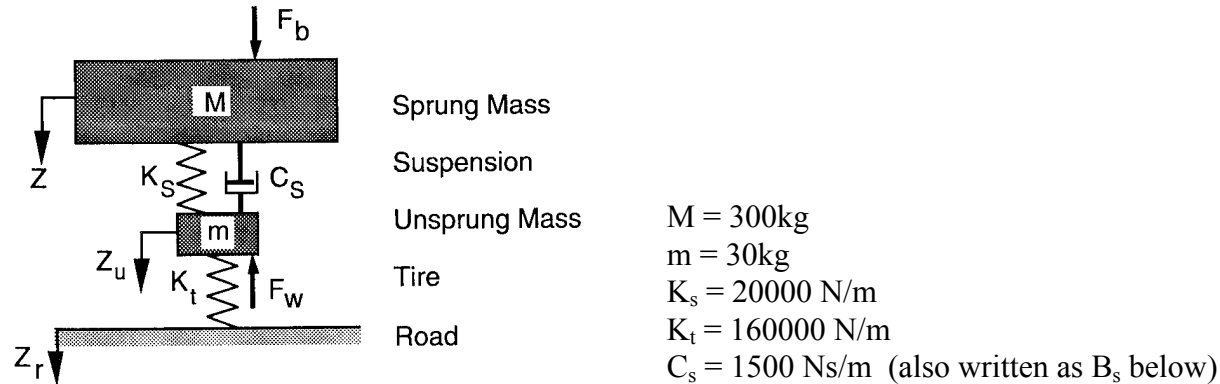
Free radial runout

Loaded radial runout

Fig. 5.5 Tire radial spring model.

'Runout' due to tyre deformation

Eccentric
1st Harmonic

Triangular
3rd Harmonic

Oval or Elliptical
2nd Harmonic

Square
4th Harmonic
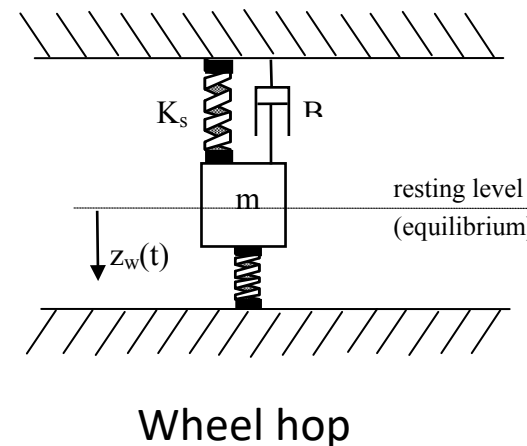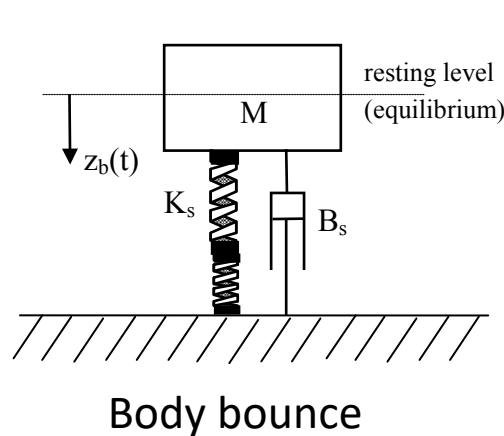
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The Quarter Car Model

- The simplest 'useful' representation of vertical ride dynamics

- More simple representations (for quick calcs) is possible considering different modes in isolation.

Body bounce

Wheel hop

Modal simplifications of the quarter car :

Modal simplifications of the quarter car :

resting level

The Quarter Car Model: Body bounce

- Considering body bounce;

$$K_{bb} = \frac{K_s K_t}{K_s + K_t}$$

- The natural frequency, ω_n;

$$\omega_n = \sqrt{\frac{K_{bb}}{M}}$$

- The actual response is damped by the damping ratio, ζ (typically $0.2 - 0.4$)

$$\omega_d = \omega_n \sqrt{1 - \zeta} \text{ with } \zeta = \frac{B_s}{\sqrt{4K_{bb}M}}$$

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The Quarter Car Model: Wheel hop

- For wheel hop;

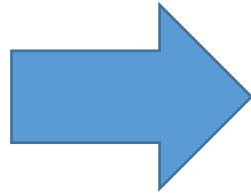$$K_{wh} = K_s + K_t$$
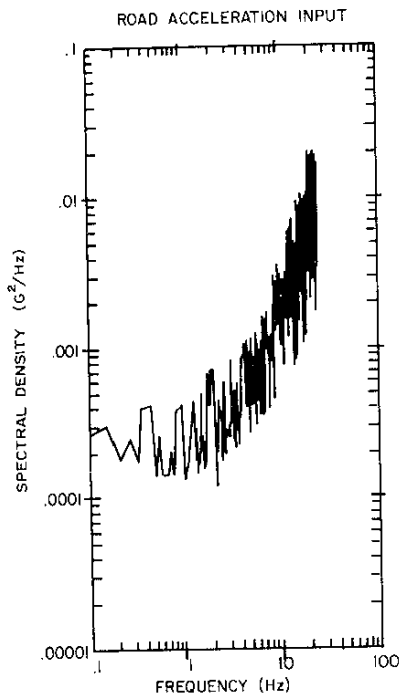
- So that the natural frequency, ω_n

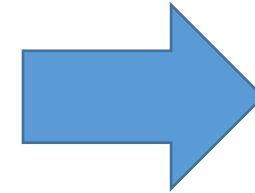$$\omega_n = \sqrt{\frac{K_{wh}}{m}}$$

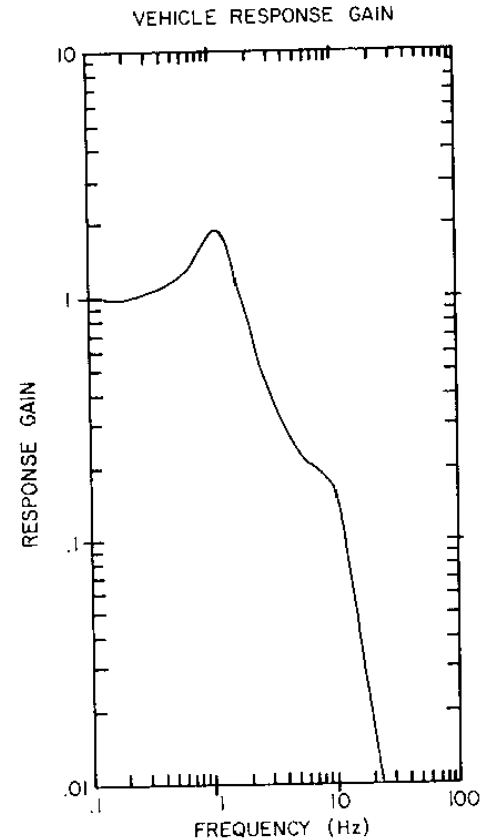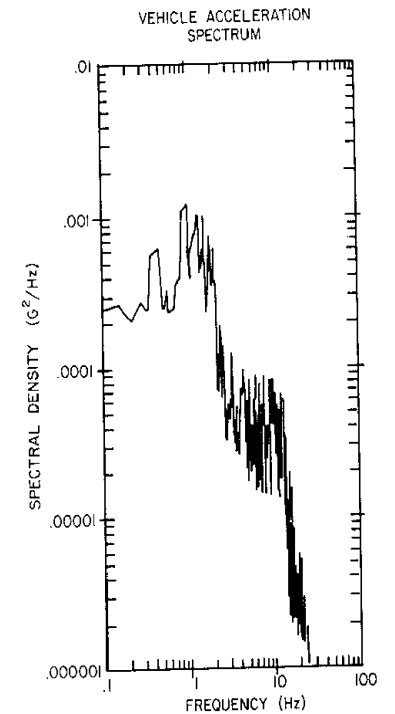- Calculate the wheel hop frequency;
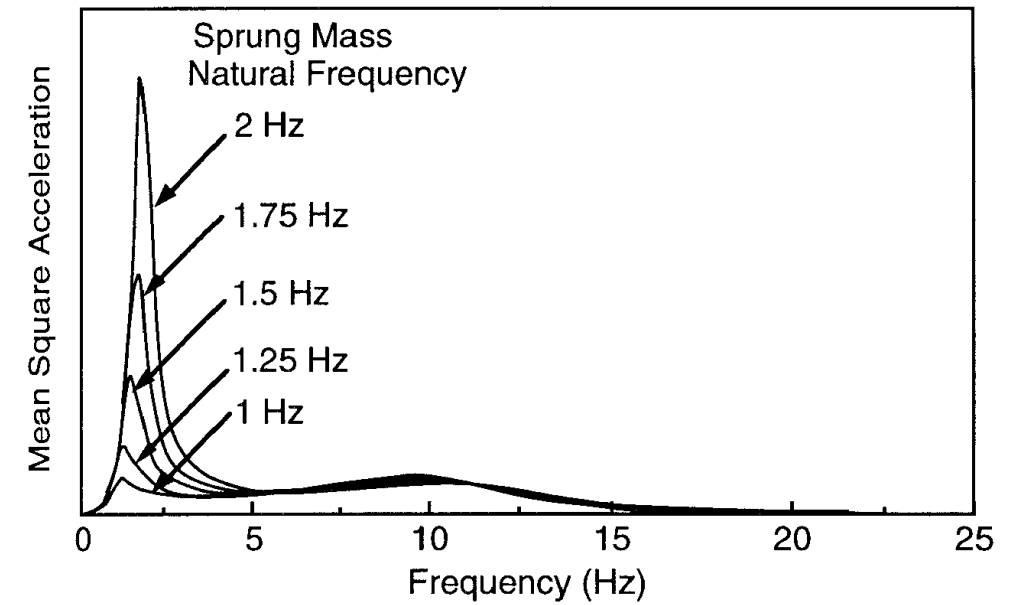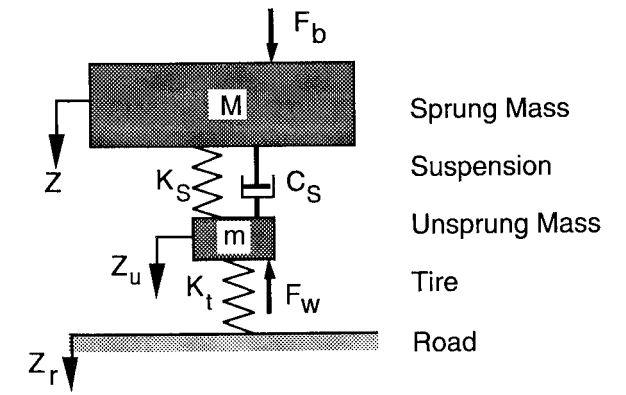
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Ride Response

Modelled system

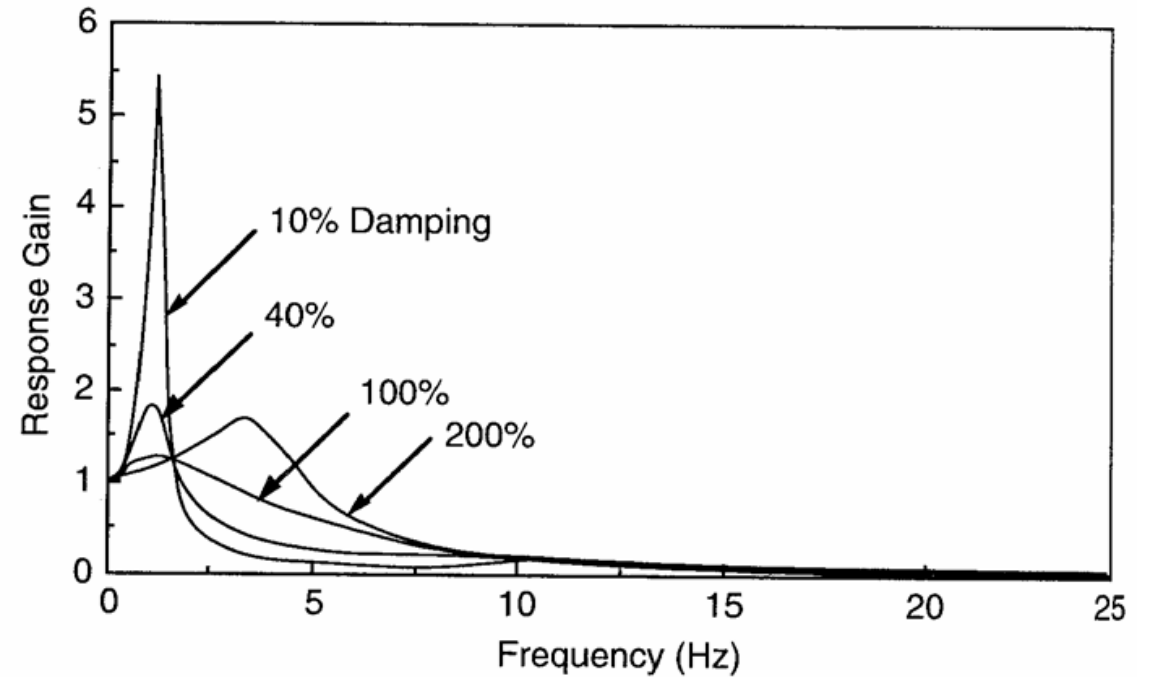Input: from road

Output: suspension response

Ride Response

- ω_n of the sprung mass can be changed by changing stiffness, K_{bb}.

- K_s and K_t act in series. K_t is significantly stiffer and therefore the response is dominated by K_s.

- Limited by;
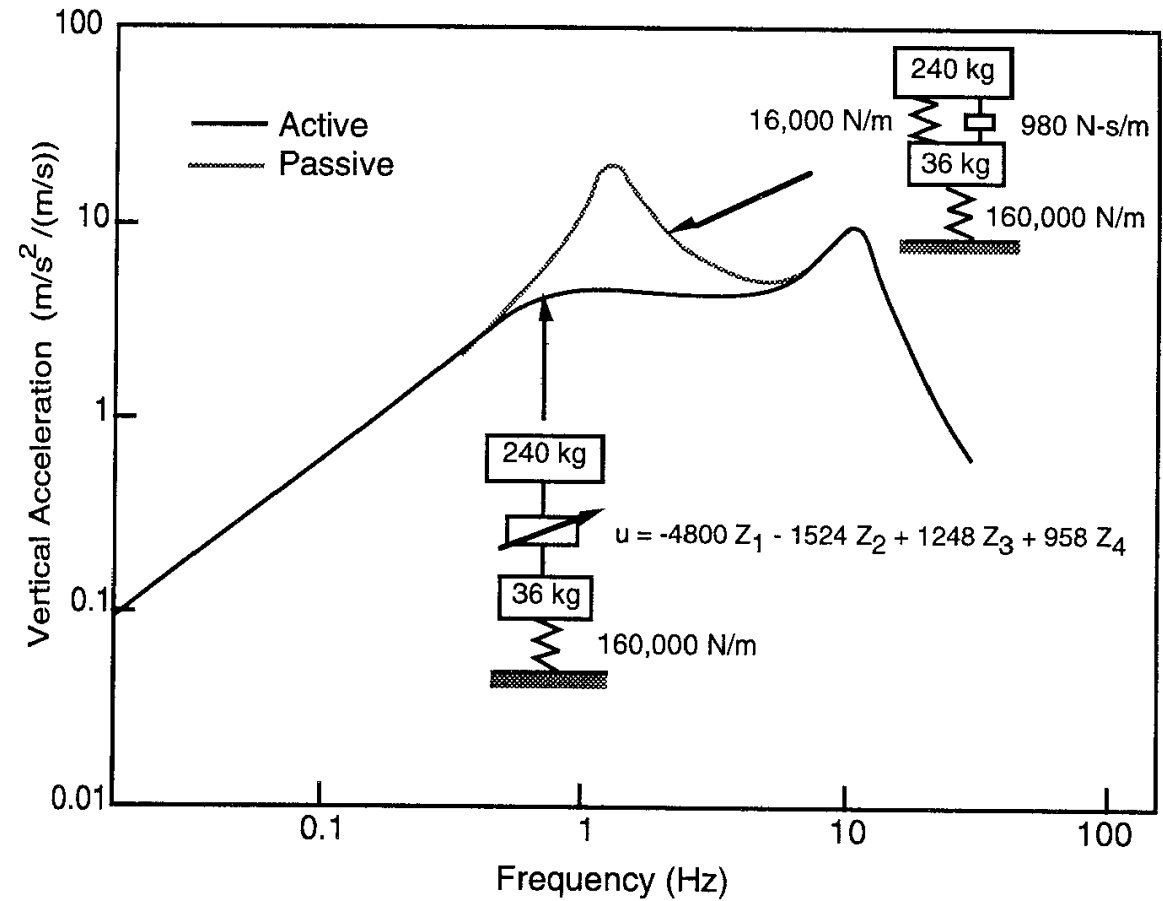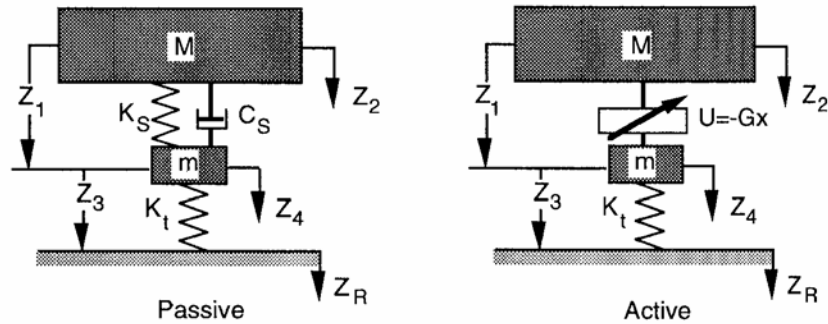 - Suspension travel
  - Handling performance
  - Nausea

Changes to K_s to change ω_n of the sprung mass

Ride Response

- By changing damping also the peak body response can be also reduced.
- There are other consequences though for the lower frequencies whose transmission to the body becomes greater

Active Suspension

Fig. 5.22 *Quarter-car model representations of passive and active suspensions.*

Passive Z_R Active Z_R

Active
Passive

$u = -4800\,Z_1 - 1524\,Z_2 + 1248\,Z_3 + 958\,Z_4$

240 kg
16,000 N/m   980 N-s/m
36 kg
160,000 N/m

240 kg
36 kg
160,000 N/m

Vertical Acceleration (m/s^2/(m/s))

Frequency (Hz)
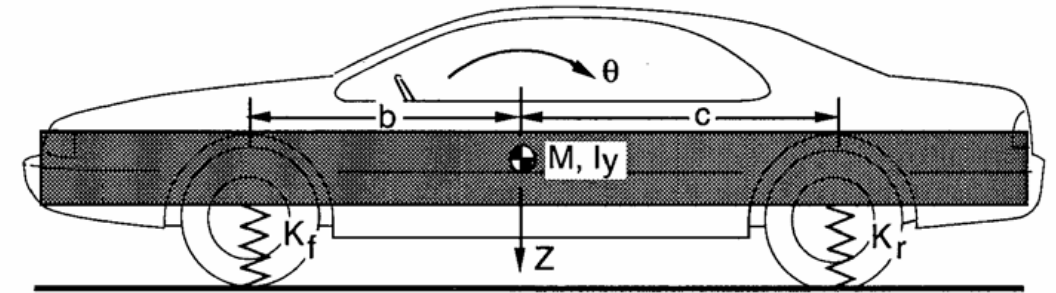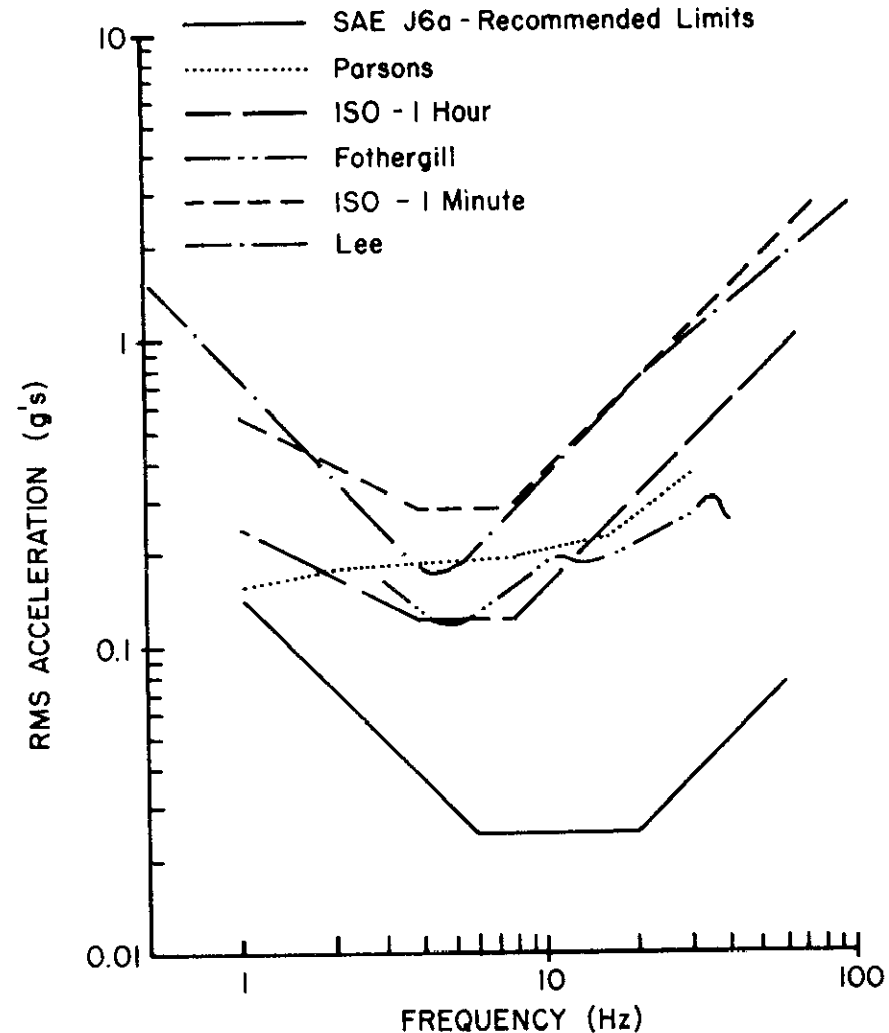
Bounce and Pitch

- Quarter car model – good for body bounce analysis

- Half car model required for pitch and bounce analysis

BOUNCE

PITCH

Human Perception

- We are interested in human perception

- Much like the vehicle the human body responds to different 'excitation' frequencies in different ways.

Legend:
- ——— SAE J6a - Recommended Limits
- ·········· Parsons
- — — ISO – I Hour
- —·— Fothergill
- – – – ISO – I Minute
- —·—· Lee

(Plot: RMS ACCELERATION (g's) vs FREQUENCY (Hz))

Conclusions

- Excitation input

- Quarter car model

- Ride response

    - Active suspension

- Human perception