Vehicle Dynamics and Simulation

Ride Dynamics

Dr B Mason



Lecture overview

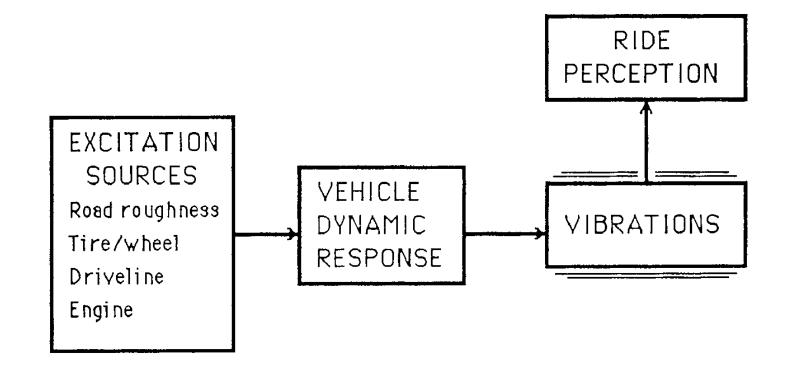
- Excitation input
- Quarter car model
- Ride response
 - Active suspension
- Human perception





The Ride System

- The Ride System
 - Excitation
 - Response
 - Vibration
 - Perception
- Analyses in time or frequency domains





Excitation: Road Roughness

- Road surface is the most significant excitation source.
- Described using;

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

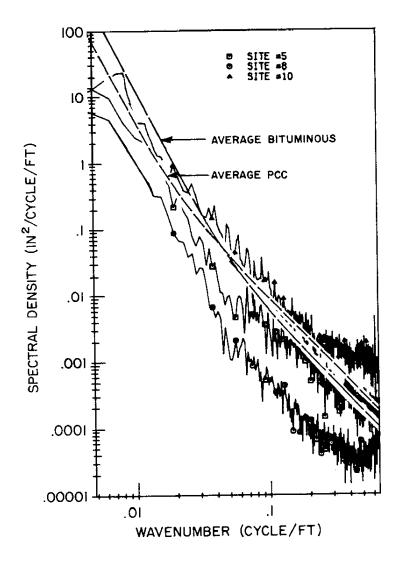
where

 $G_Z(v)$ = PSD amplitude (feet²/cycle/foot)

 ν = Wavenumber (cycles/foot)

 G_O = Roughness magnitude parameter (1.25x10⁵ for rough roads, 1.25x10⁶ for smooth)

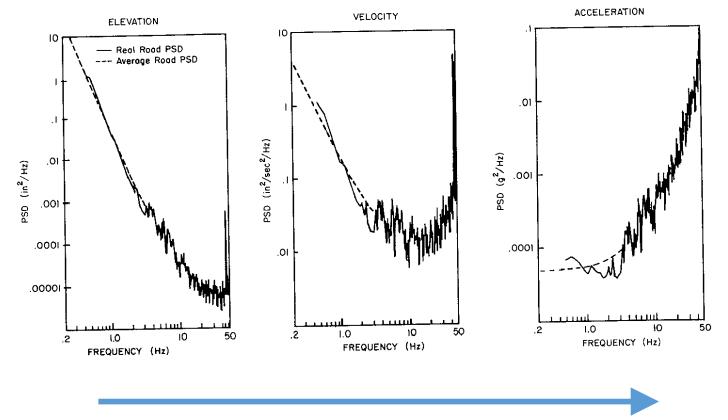
 v_0 = Cutoff wavenumber (0.02 cycles/foot for rough roads, 0.05 cycles/foot for smooth)

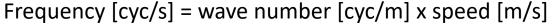




Excitation: Road Roughness

- 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.

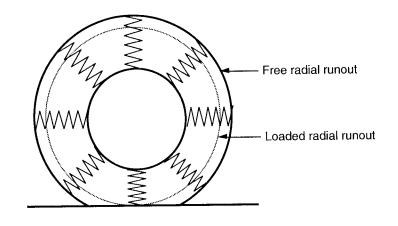




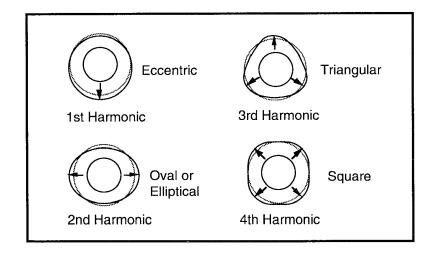


Excitation: Secondary Effects

- 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



'Runout' due to tyre deformation



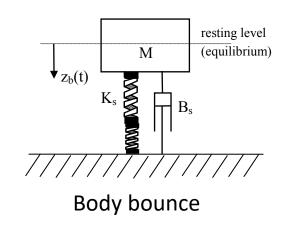


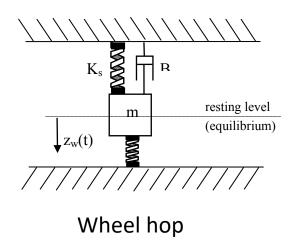
The Quarter Car Model

• The simplest 'useful' representation of vertical ride dynamics



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







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)

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



The Quarter Car Model: Wheel hop

For wheel hop;

$$K_{wh} = K_S + K_t$$

ullet So that the natural frequency, ω_n

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

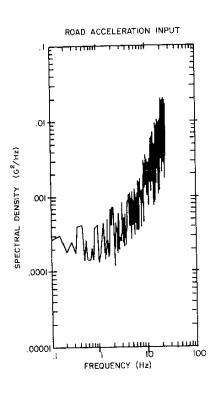
Calculate the wheel hop frequency;

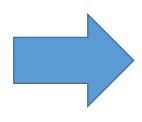




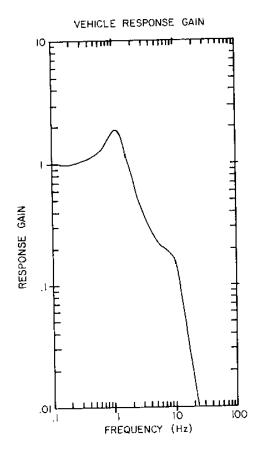
Ride Response

Input: from road

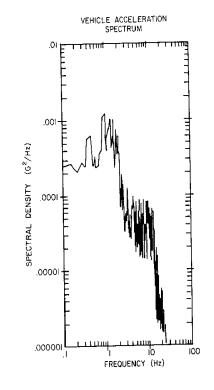




Modelled system



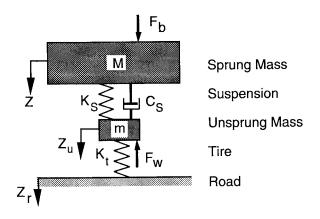
Output: suspension response

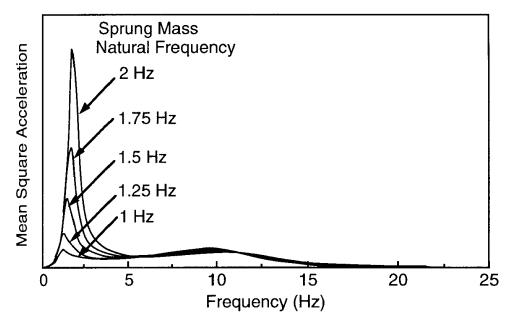




Ride Response

- 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



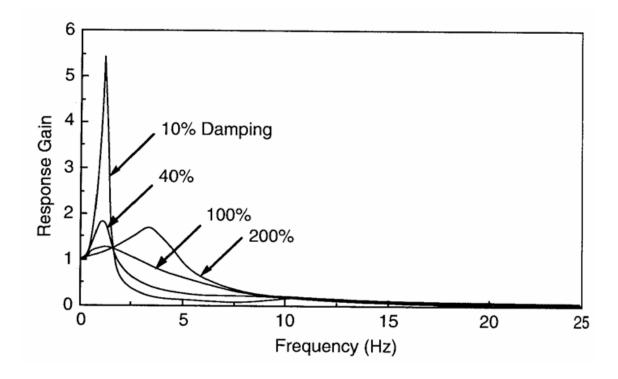


Changes to K_s to change ω_n of the sprung mass.



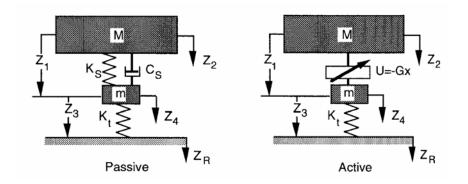
Ride Response

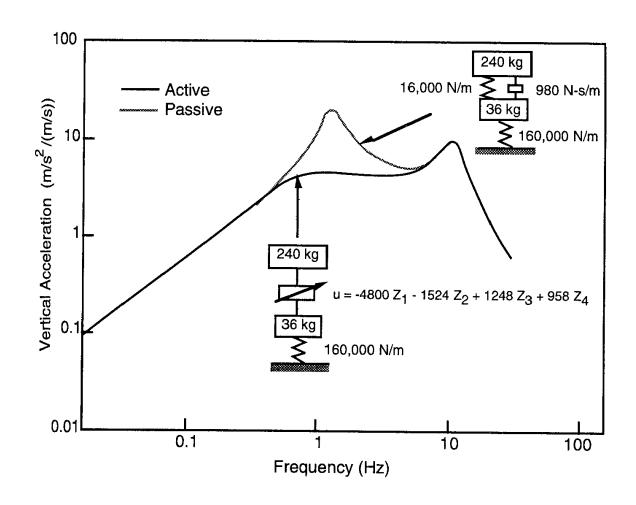
- By changing damping also the peak body response can be also reduced.
- There are other consequences though for the lower frequencies whose transmission to the body becomes greater





Active Suspension

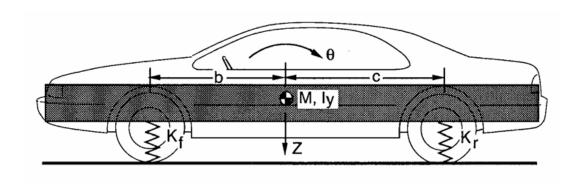






Bounce and Pitch

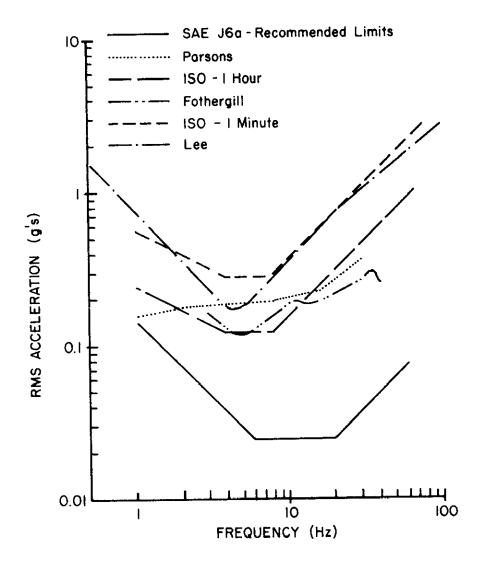
- Quarter car model good for body bounce analysis
- Half car model required for pitch and bounce analysis





Human Perception

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





Conclusions

- Excitation input
- Quarter car model
- Ride response
 - Active suspension
- Human perception

