Vehicle and Driver Vibration

Johan Granlund, MSc
Chief Technology Officer
Vectura Consulting AB, Sweden

Forestry Civil Engineering Scotland & ROADEX
Seminar on Low Impact Vehicles and Tyre Pressure Control
Perth Racecourse, 23 June 2010

Photo: M Risberg
Outline

Ride characteristics in timber logging trucks.
Health and safety aspects on whole-body vibration (WBV).
EU & UK limits on vibration exposure at work.
Performance of heavy truck suspension systems.
TPC system found to reduce average ride vibration by 8 %.
What TPCS can and can´t do to vibration:
  ➢ Long wave bouncing can´t be isolated.
  ➢ Road megatexture (potholes, corrugations) isolated by much more than the 8 %!
Roadex IV will map WBV isolation by TPCS as function of frequency.
Ride characteristics in timber logging trucks

Dominating vibration patterns:
• Vertical bouncing (z-axis).
• Pitch-related fore-aft (pitch => x).
• Roll-related lateral (roll => y).

Frequency content: Mainly 1 - 10 Hz.

Amplitude peaks over 2 m/s²; ”Extremely uncomfortable”.

Intensities typically 0.5 - 1.4 m/s², depending on road condition, speed etc.

Roadex III result on the Beaver Road 331: A(8) = 0.76 m/s².
Health and safety aspects

- **Ride Excitation**
  - Low Level, Distributed
  - Roughness
  - Severe, Localized

- **Ride Environment**
  - Multi-Modal Vibration
  - Dominant Frequencies 1 to 10 Hz
  - Dominant Amplitudes up to 2 m/s²
  - Rattling Control Instruments and Mirrors

- **Driver Response**
  - Physical (Biodynamic) Response – Vibration of Body Parts and Organs
  - Visual Cardiovascular
  - Psychological Effects eg. Discomfort Stress
  - Pathological Effects eg. Back Pain

- **Vehicle Performance**
  - Road Holding
  - Component Wear
  - Component Failure

- **Accidents**
  - Potentially Influenced by
    - Prefatigue Vigilance
    - Fatigue-decreased Vigilance
    - Drivers’ Modulation of Steering and Brake Controls
    - Driver Affected by Ailments
    - Image Clarity in Mirrors
    - “Unseated” Driver by Severe Jolt
    - Vehicle Road-Holding Performance

- **Driver/Vehicle**
  - Driver
    - Visual Acuity
    - Reaction Times
    - Tracking and other Motor Tasks
  - Vehicle
    - Road Holding
    - Component Wear
    - Component Failure

[Highway Safety Research Institute, USA, 1982]
Health and safety aspects (2)

Truck ride in the humans sensitivity range of 0.5 - 80 Hz.
=> Resonance in eye globes, spine and stomach.
Seat vibration intensity often in the ISO 2631-1 ”Health caution zone”
NP professional drivers have 3 times more stress related heart disease => Dies at lower age.
Musculoskeletal pain in neck, shoulders and back.

[von Gierke et al]
Health and safety aspects (3)

Crash rate strongly correlated to increased road roughness. Bumps - stressing effect. Long wave road undulations - create hazardous drowsiness. Road grip and vehicle stability reduced by dynamic phenomenas, such as weight transfer and bump steer. Icy roads: Roll-related lateral buffeting may trig skid crashes.

Photo: Niklas Thunborg.
EU limits on vibration exposure at work are set by Directive 2002/44/EC.

Professional drivers must be under the EU limits.
The UK regulations include the EU limits:
- Action Value of $A(8) = 0.5 \text{ m/s}^2$.
- Exposure Limit of $A(8) = 1.15 \text{ m/s}^2$.

The forestry sector is under a transitional provision until 2014. However:
- The provision applies only to the Exposure Limit.
- Exceeding the Action Value $0.5 \text{ m/s}^2$ still calls for action!

Visit [www.hse.gov.uk/vibration](http://www.hse.gov.uk/vibration) for more info.
Truck suspension systems

[EU Guide to good practice on WBV]

[H Lindh, Volvo 3P]
The tyre acts as a spring

< 10 Hz: Road profile input = Tyre output
@ 10 Hz: Tyre wall resonance makes output up to 3 x input
> 10 Hz: Input is isolated down to less than 25%

In TPCS low pressure mode, both stiffness and eigenfrequency are lower => reduced ride vibration.
The tyre enveloping effect

In TPCS low pressure mode, the increased footprint length improves the tyre’s smearing effect on the road profile.

=> Reduced ride vibration.
Net performance of the suspension systems

Roadex III findings:
(Note: Graph is in log/log-scale)
> 10 Hz: Up to 99.9% isolation
< 3 Hz: Amplification.
Study by Granlund (2004):

Vibration was measured on 5 road stretches. When the TPCS cut in, the seat vibration intensity was reduced by 8% on average.

Greatest improvement was obtained with unladen truck on a potholed dirt road, still allowing relatively high speed.

Very low improvement in paved highway sections without potholes but much long wave uneveness.

However, the study did not quantify the transfer of vibration as function of vibration frequency (roughness wavelength x speed).
Roadex IV demo on vehicle-driver vibration

Demo`s in Highland, northern Finland, Norway & Sweden.
Reproducing the case study in 2007 from the Beaver Road 331:
1. Measuring truck drivers daily vibration exposure, \( A(8) \), and comparing to the Action Value \( 0.5 \, \text{m/s}^2 \).
2. Measuring spine compression, \( S_{ed} \), caused by jolts at severe bumps, and comparing to the \( 0.5 \, \text{MPa} \) stress limit in the ISO 2631-5 standard.
3. Relating truck roll & lateral buffeting to non-uniform road edge deformation (undesired Rut Bottom Cross Slope Variance).
Roadex IV vibration studies in the Highland

The test vehicle will be a “wagon & drag” timber haulage truck from Ferguson Transport fitted with tyre pressure control system (TPCS).

The vehicle also used as a standard vehicle when the TPC is switched off. Test route from forest to the Kilmallie Sawmill at Corpach, Fort William. The national organisation “Transport Scotland” will collaborate for the part of the haulage route on the A82 national road.
Objective:
To further evaluate the benefits of tyre pressure control systems on the transfer of vibrations from the tyre footprint to the driving seat.

The study will quantify the transfer of vibration as function of vibration frequency (roughness wavelength x speed).

Effect of winter time megatexture to be investigated with a TPCS truck on the Beaver Road 331 in Sweden.