Vibrations on Earth-Moving Machines

Dan Roley

Caterpillar

December 2005

Presentation Outline

- Types of Earthmoving Machines (EMM)
- Vibration Reduction Systems on EMM
- Vibration Characteristics of EMM
- New ISO Vibration Standard
- Challenges with Vibration Reduction
- Future Machine Improvements

Earth Moving Machines

- Hauling: Trucks, Articulated Trucks, Scrapers
- Cyclic: Wheel Loaders, Dozers
- Stationary: Excavators, Backhoe Loaders






Earth-Moving Machines

- 12 types of machines with a large size range
- Large machines that weigh over 500 tons
- Small machines that can drive through doors or gates (minimize manual handling)

Vibration reduction systems to improve operator comfort/machine performance

Motor Graders

1940's:Tandem rear axles were introduced on motor graders to reduce bump input by 50 %.

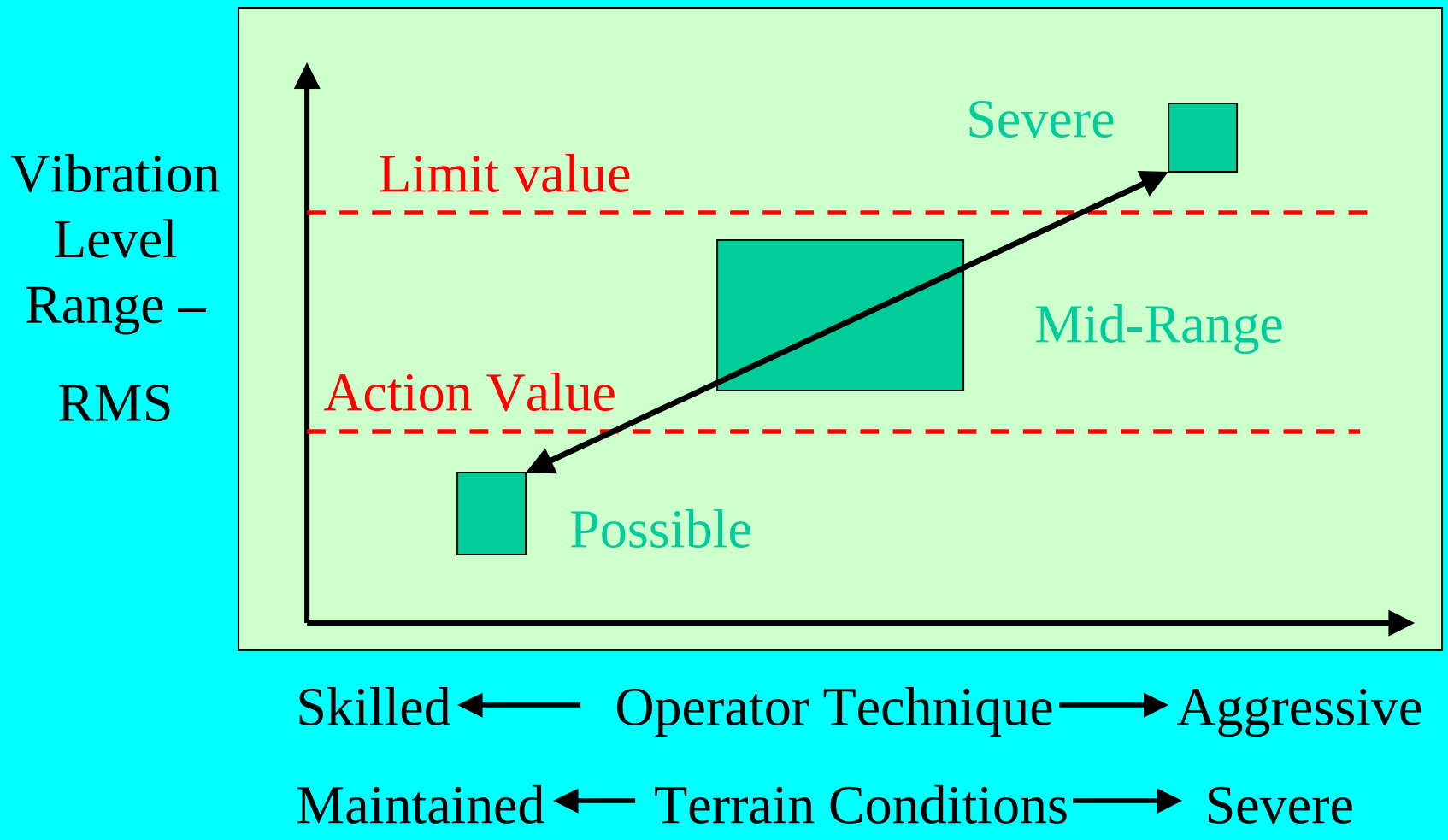
Trucks – Tire/Axle Suspensions

1963: An Air/Oil Strut Suspensions were Introduced on Trucks

Vibration Absorbers – Ride Control

- **Loader linkage and bucket were used as dynamic absorbers starting in 1976**
- **Currently available on:**
  - **Wheel Loaders**
  - **Backhoe Loaders**

Vibration Characteristics of EMM



ISO Vibration Standard

- Response to EU Physical Agents Directive
- Define expected ranges of vibration levels
  - Different types of machines
  - Different types of applications
  - Vertical, fore-aft and lateral vibrations
- Provide guidelines for minimizing vibrations
- Provide guidelines for defining vibration reductions with machine improvements

Expected Vibration Levels

machine kind	typical operating condition	average frequency weighted			standard deviation (s)		
		$1{,}4*a_{w,eqx}$ [m/s²]	$1{,}4*a_{w,eqy}$ [m/s²]	$a_{w,eqz}$ [m/s²]	$1{,}4*s_x$ [m/s²]	$1{,}4*s_y$ [m/s²]	$1{,}4*s_z$ [m/s²]
wheel loader	load & carry motion	0,82	0,79	0,52	0,23	0,21	0,14
wheel loader	mining application	1,19	0,91	0,81	0,49	0,32	0,47
wheel loader	transfer movement	0,76	0,91	0,49	0,33	0,35	0,17
wheel loader	V-shape motion	0,93	0,78	0,54	0,28	0,26	0,14
crawler excavator	excavating	0,38	0,23	0,30	0,19	0,12	0,17
crawler excavator	hydraulic breaker app.	0,48	0,28	0,55	0,25	0,14	0,28
crawler excavator	mining application	0,65	0,42	0,61	0,21	0,15	0,32
crawler excavator	transfer movement	0,47	0,31	0,79	0,19	0,20	0,23

Vibration Challenges

- Dependent upon operator and terrain
- Low Frequency/Large Displacements
- Machine constraints
  - Slopes
  - Ground Contact
- Horizontal Directions
  - Frequency content below 2.0Hz
  - Difficult to isolate
- Appropriate limit values
  - Lab versus with modern seats
  - Additional 1.4 uncertainty factor
- Other causes of back injuries

Back Injury Factors/Causes

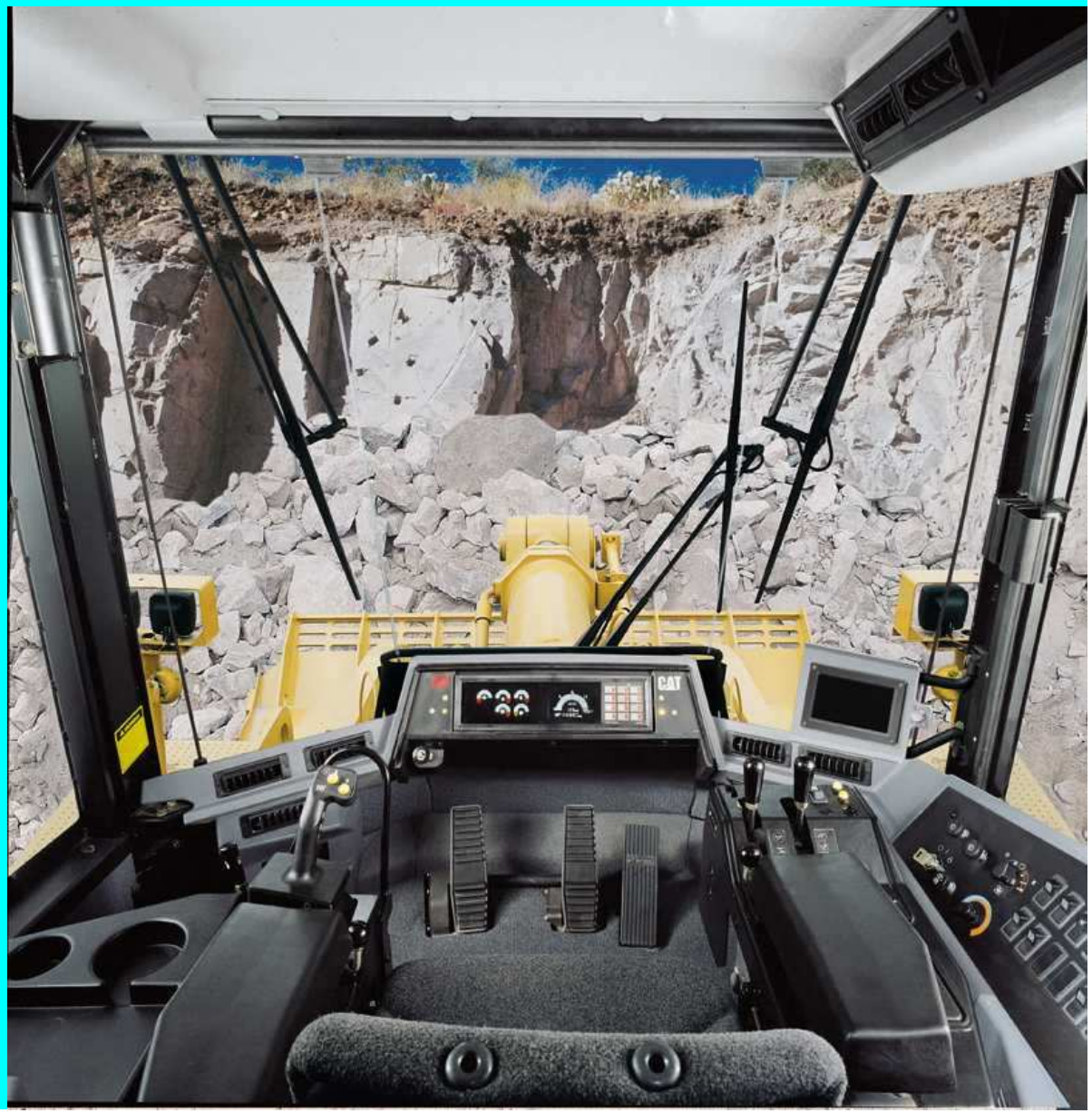
- Lifting
- Long periods of sitting
- Twisted posture
- Shock loads
  - Jumping
  - Impacts
- Sports activities
- Back pain aggravated by vibrations

Caterpillar Vibration Efforts

- Develop Comfortable Cabs
- Reduce Vibration Excitations
- Provide Information to Reduce Vibrations

Comfortable Operator Station

- Seat
  - Suspension
  - Full backrest
  - Adjustable
- Controls
  - Comfortable
  - Low effort
  - Seat mounted
- Visibility
  - Open to front
  - Mirrors for rear



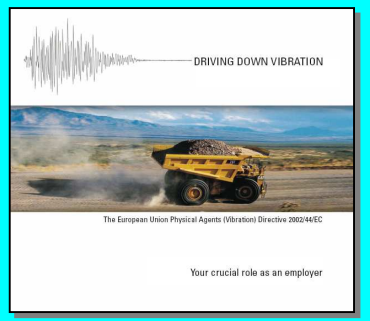
Future Machine Improvements

- Electronic Controls for Implements
- Electronic Power Train Controls
- Automated Work Cycles
- More Remote Control Operations
- Driverless Machines

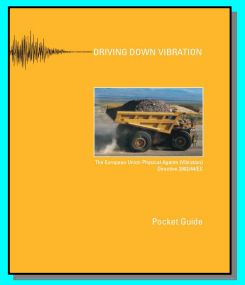
Caterpillar's Vibration Information

Caterpillar has produced the following material to help reduce vibration levels.

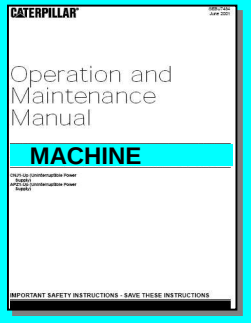
- ***'Driving Down Vibration'*** **Brochure**
  - **Media Number HEGQ3338**



- ***'Driving Down Vibration'*** **Pocket Guidelines**
  - **Media Number HEGQ3339**



- **Operation & Maintenance Manual Updates**



Summary

1. Many types of vibration reduction systems have been developed for earth-moving machines to reduce ride vibration levels and improve operator comfort.

2. There is an opportunity to significantly reduce ride vibration levels with better training on how to operate machines and maintain the terrain conditions in the work area.

3. The biggest challenge now is the horizontal directions, but the current criteria may not be realistic for seated operators on cyclic machines

4. Vibration reductions will be with many small machine improvements