Reference

Colwell, J.L., L. Gannon, T. Gunston, *et al,* "Shock Mitigation Seat Test and Evaluation", Human Factors in Ship Design and Operation Conference, Royal Institution of Naval Architects, London, 2011

J.L. Colwell, DRDC - Atlantic, Canada

L. Gannon, DRDC - Atlantic, Canada

T. Gunston, VJ Technology, UK

R.G. Langlois, Carleton University, Canada

M.R. Riley, The Columbia Group, USA.

T.W. Coats, NSWC CD CCD, USA.

Small High Speed Craft (HSC)

Small High Speed Craft (HSC)

Extreme motions

High-G slam impacts

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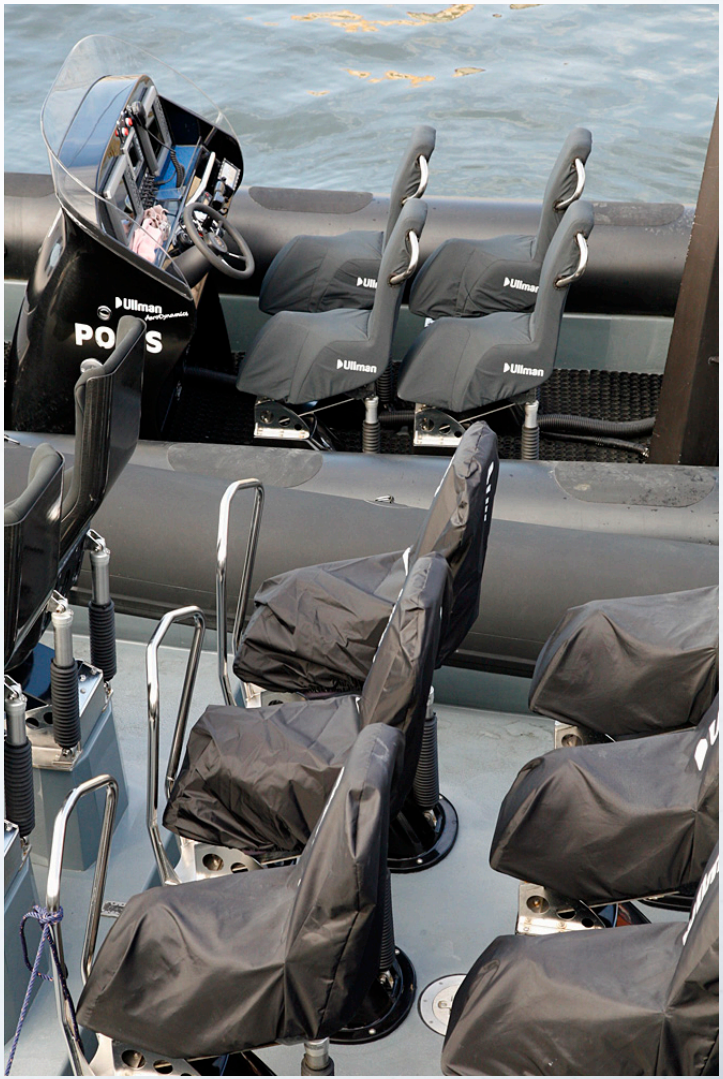
HSC Shock Mitigation

Protect people from high-g slam impacts

HSC Shock Mitigation

Seats



Decks

Shock Mitigation Seats

- Vertical protection, generally adequate

Shock Mitigation Seats

- No lateral protection
- Require novel solutions

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No mitigation for lateral acceleration

(person supported at hips and shoulders)

Shock Mitigation Seat T&E Programme

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Goals

- reduce the risk of acute and chronic injuries to CF personnel

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- improve state of the art for shock mitigation seats

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- develop concise requirements for CF acquisition projects
  - performance specifications
  - evaluation criteria

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  - evaluation criteria
- establish new methodologies for
  - modeling & simulation
  - test & evaluation

Shock Mitigation Seat T&E Programme

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- reduce the risk of acute and chronic injuries to CF personnel
- improve state of the art for shock mitigation seats
- develop concise requirements for CF acquisition projects
  - performance specifications
  - evaluation criteria
- establish new methodologies for
  - modeling & simulation
  - test & evaluation
- not product comparisons for pre-selection

Shock Mitigation Seat T&E Programme

Phase 1 - benchmark contemporary technologies

Phase 2 - develop test capabilities and test protocols

Phase 3 - develop mathematical models and simulation codes

Phase 4 - validate Phase 3 models using Phase 2 methods

Phase 5 - document achievements, make recommendations

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Vessel Class and Exposure Severity

Vessel Class

Class	Description
1	Low speed commercial / leisure
2	High speed commercial / leisure
3	Search and Rescue
4	Military

Vessel Class

Class	Description	Speed
1	Low speed commercial / leisure	< 20 kt
2	High speed commercial / leisure	≥ 20 kt
3	Search and Rescue	≥ 30 kt
4	Military	≥ 40 kt

Racing boats not classified

Exposure Severity

Severity	Description
1	Mild
2	Moderate
3	Severe
4	Extreme

Vessel Class and Exposure Severity

Class	Description
1	Low speed commercial / leisure
2	High speed commercial / leisure
3	Search and Rescue
4	Military

Severity	Description
1	Mild
2	Moderate
3	Severe
4	Extreme

Taken together, vessel class and expected exposure severity provide the basis for risk assessment and for specification of shock mitigation seat requirements

Vessel Class and Exposure Severity

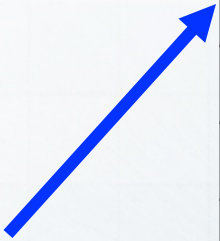
Class	Description
1	Low speed commercial / leisure
2	High speed commercial / leisure
3	Search and Rescue
4	Military

Severity	Description
1	Mild
2	Moderate
3	Severe
4	Extreme

Problem: encountering exposure severity greater than expected for class might result in injury, as shock mitigation equipment is not up to the task (risk mitigation)

Vessel Class and Exposure Severity

Class	Description
1	Low speed commercial / leisure
2	High speed commercial / leisure
3	Search and Rescue
4	Military



Severity	Description
1	Mild
2	Moderate
3	Severe
4	Extreme

Problem: shock mitigation equipment selected for extreme environment might not work so well in much less demanding environment (specify adaptability/control)

Vessel Class and Exposure Severity

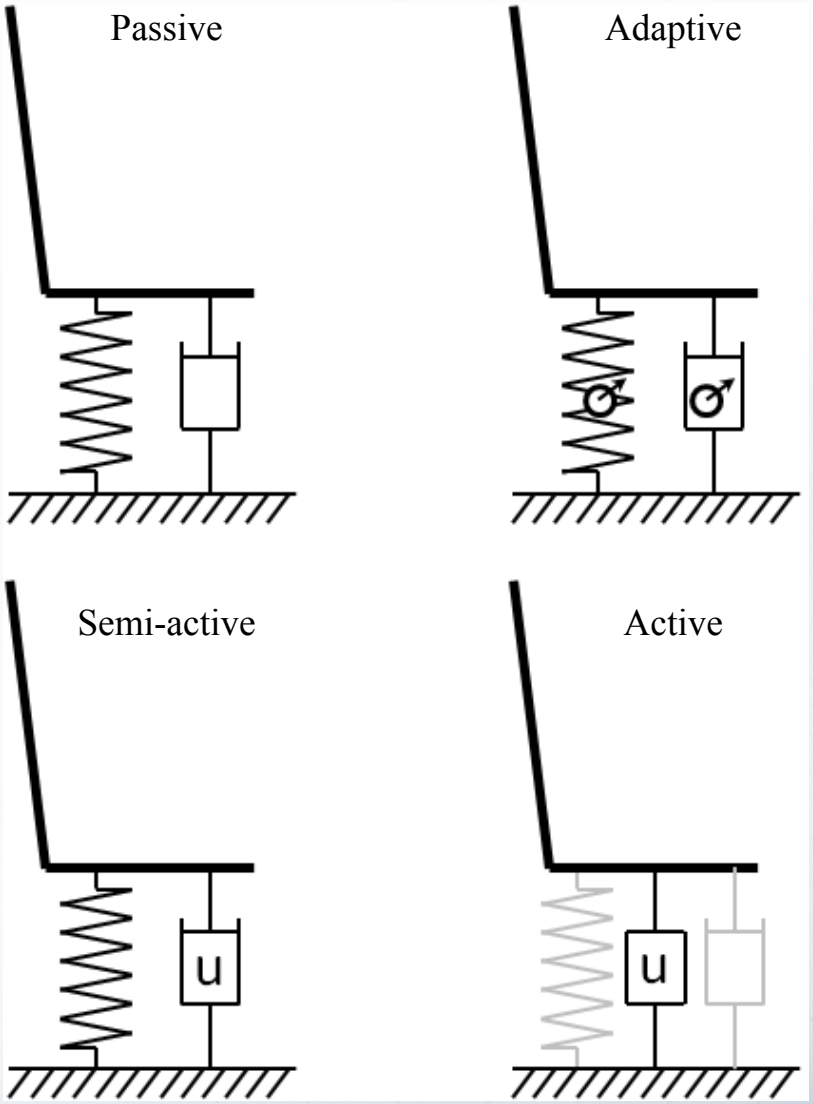
Class	Description
1	Low speed commercial / leisure
2	High speed commercial / leisure
3	Search and Rescue
4	Military

Severity	Description
1	Mild
2	Moderate
3	Severe
4	Extreme

European Physical Agents (Vibration) Directive 2002 may be appropriate for Classes 1 and 2, associated with "mild" and "moderate" exposure severity (what about "severe" & "extreme"?)

Seat Suspension Configurations

1. Passive
2. Adaptive
3. Semi-active
4. Active

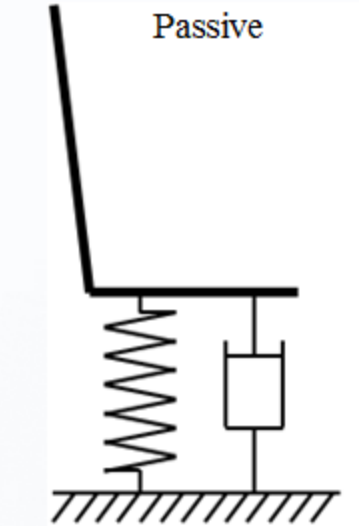


adjustable

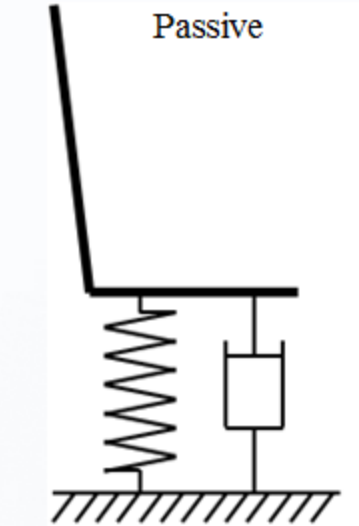
u continuous control signal

Passive Suspension

- Pre-tuned for expected environment
- Simple and robust
  - no electronics, no external power
- Challenges:

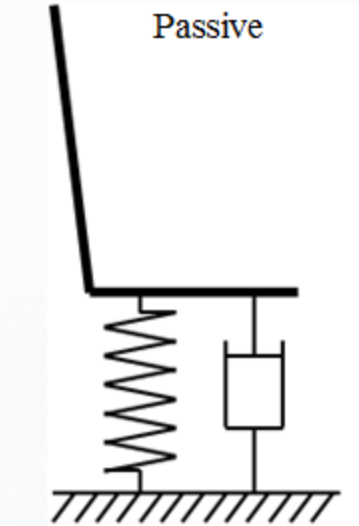


Passive Suspension



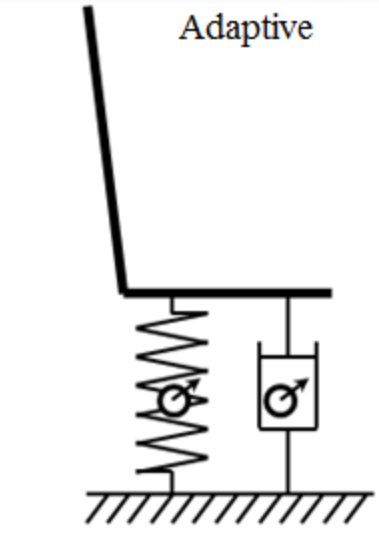
- Pre-tuned for expected environment
- Simple and robust
  - no electronics, no external power
- Challenges:
  - ‘heavy’ occupant or loads > ‘*bottom-out*’

Passive Suspension



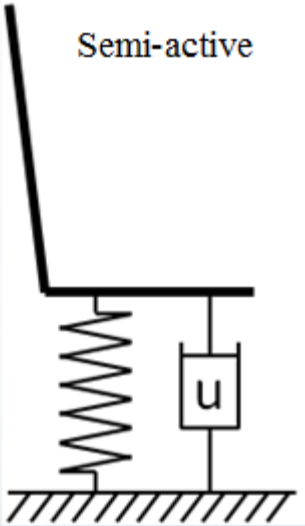
- Pre-tuned for expected environment
- Simple and robust
  - no electronics, no external power
- Challenges:
  - ‘heavy’ occupant or loads > ‘*bottom-out*’
  - ‘light’ occupant or loads > ‘*doing-doing*’

Adaptive Suspension



- Same or similar components as ‘passive’
- Easy to adjust/tune suspension characteristics
  - manual
  - automatic
- Adjustments not continuous, not ‘controlled’ in real time
- Challenges similar to ‘passive’, but less restrictive

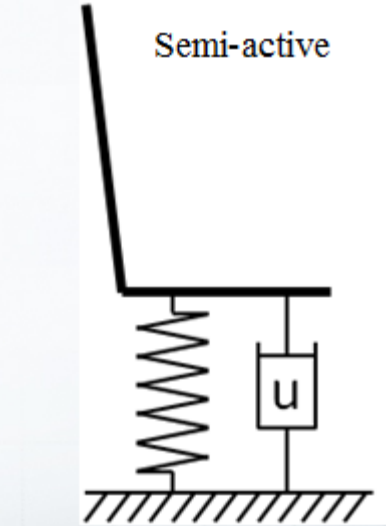
Semi-active Suspension



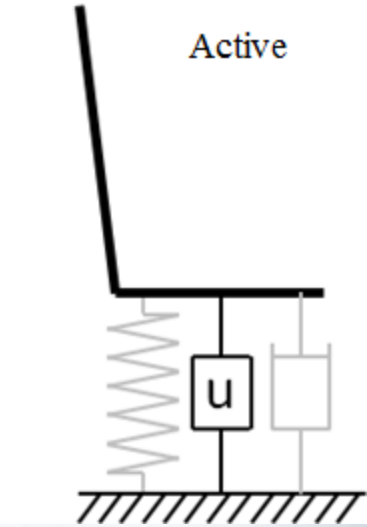
- Dynamic control
  - control suspension characteristics in real time
  - control by removing energy from system (only)
  - includes motion sensor, processor & control actuator
  - possible control strategies:
    - time-averaged characteristics
    - real time, within motion cycle (e.g. rise time)
    - potential for use with real time ‘look ahead’ sensors

Semi-active Suspension

- Challenges:
  - modest external power requirement
  - higher complexity
  - performance in failure modes



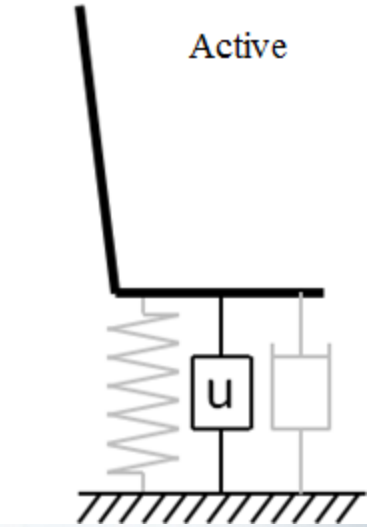
Active Suspension



- Dynamic control
  - control suspension characteristics in real time
  - control by adding energy to system
  - can also remove energy from system
  - includes motion sensor, processor & control actuator
  - possible control strategies:
    - time-averaged characteristics
    - real time, within motion cycle (i.e. rise time)
    - potential for use with real time ‘look ahead’ sensors
  - decouples transmitted force from compression of suspension

Active Suspension

- Challenges:
  - higher external power requirement
  - higher complexity
  - performance in failure modes



Test and Evaluation Programme

Phase 1 - benchmark contemporary technologies

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Shock Mitigation Seat Acquisition

Driver Seat

Pod with storage

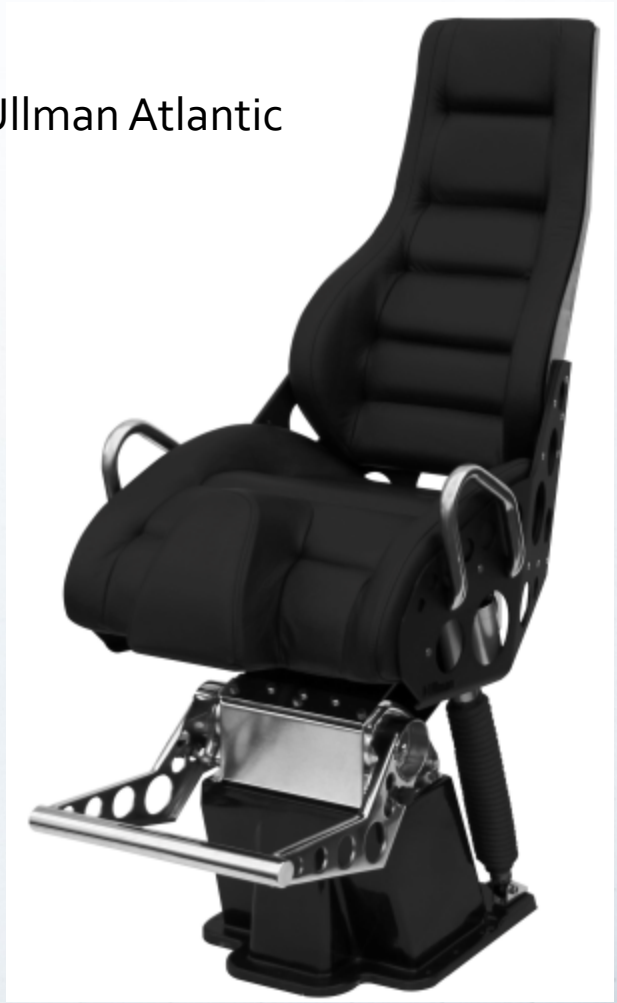
Back + Front mounted

Shock Mitigation Seat Acquisition

Shock Mitigation Seat Acquisition

- **Ullman Dynamics (SE)**

Ullman Atlantic

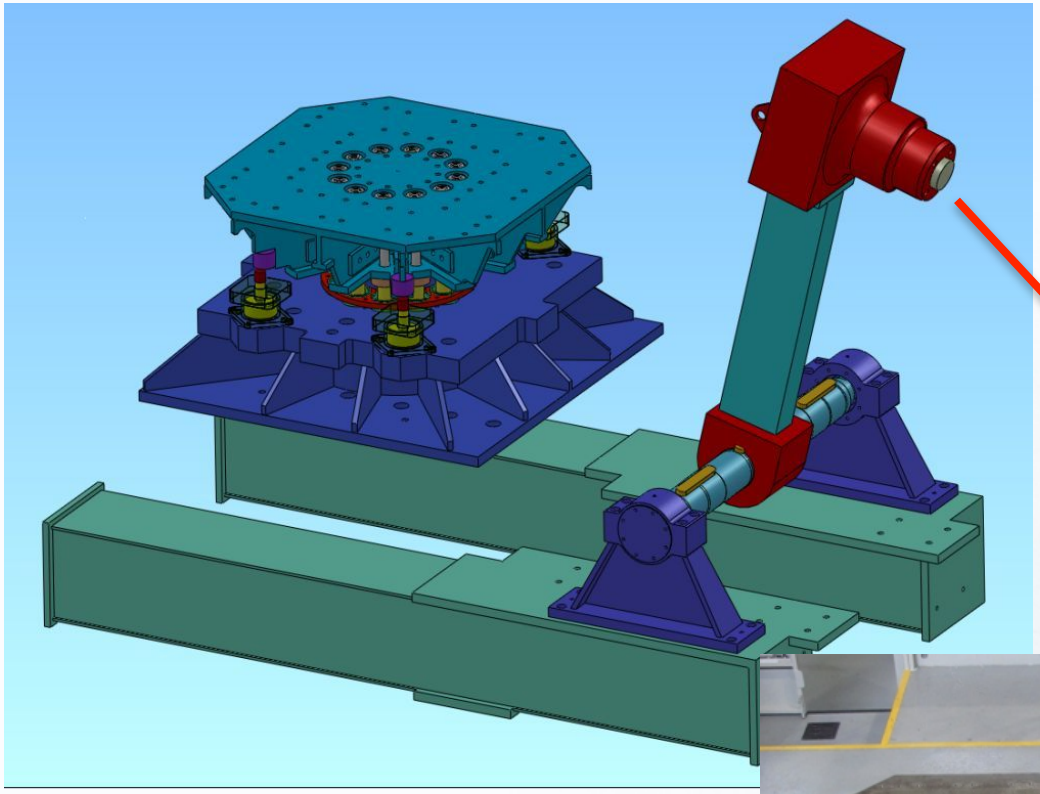


Ullman Jockey

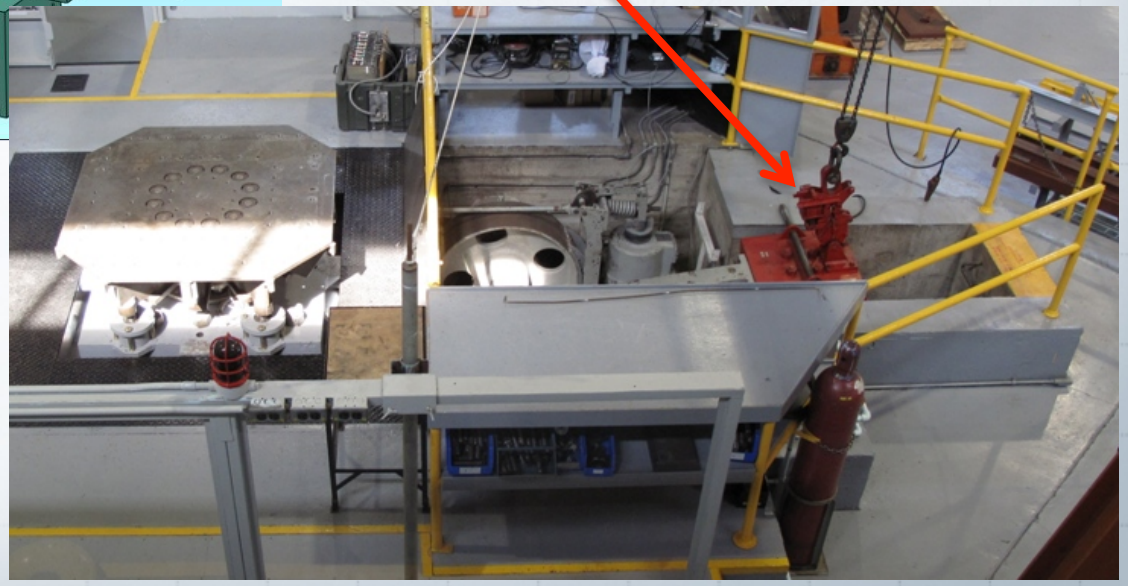
Test and Evaluation Programme

- Testing by Naval Engineering Test Establishment (NETE)
- Single impact test
- 22 seats to test in total
- 11 seat types – 2 of each for repeatability
- 3 impacts for each of 3 g levels = 9 impacts per seat
- Seats hard mounted + 2 resiliently mounted set ups:
  - 9 impacts per seat x 3 mounting configurations = 27 impacts per seat

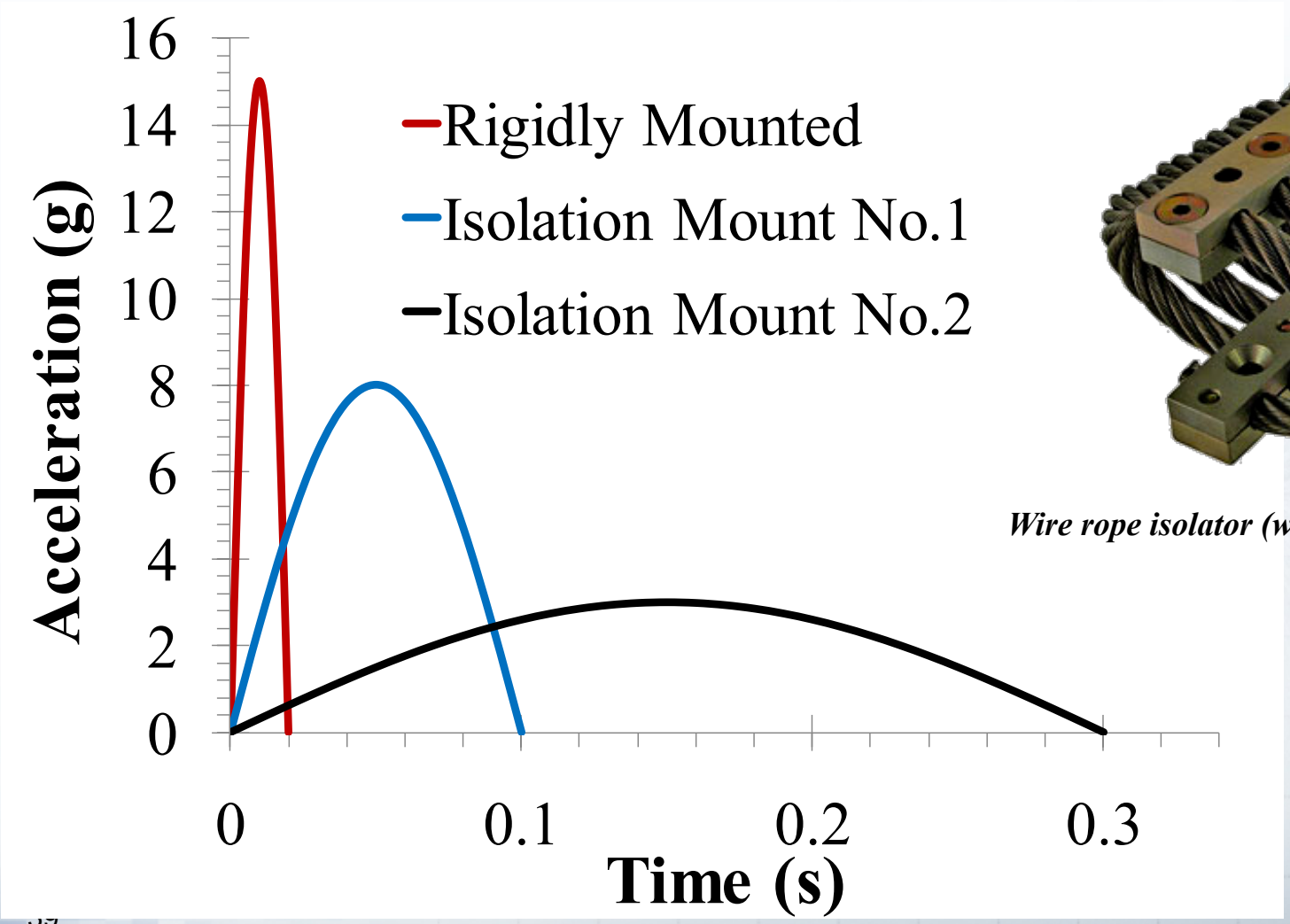
Test and Evaluation Programme



3000 lb hammer



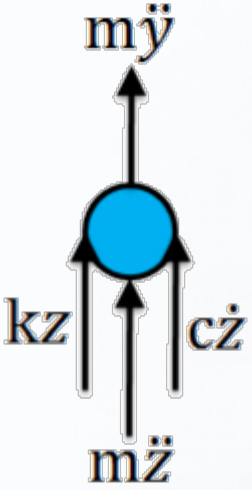
Test and Evaluation Programme



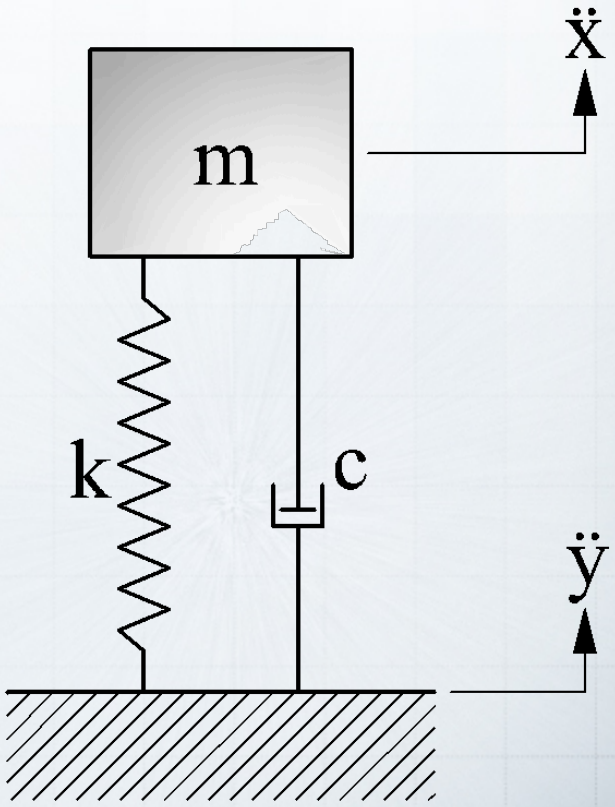
Wire rope isolator (www.vibrationmounts.com)

Numerical Modelling

- MATLAB & Simulink

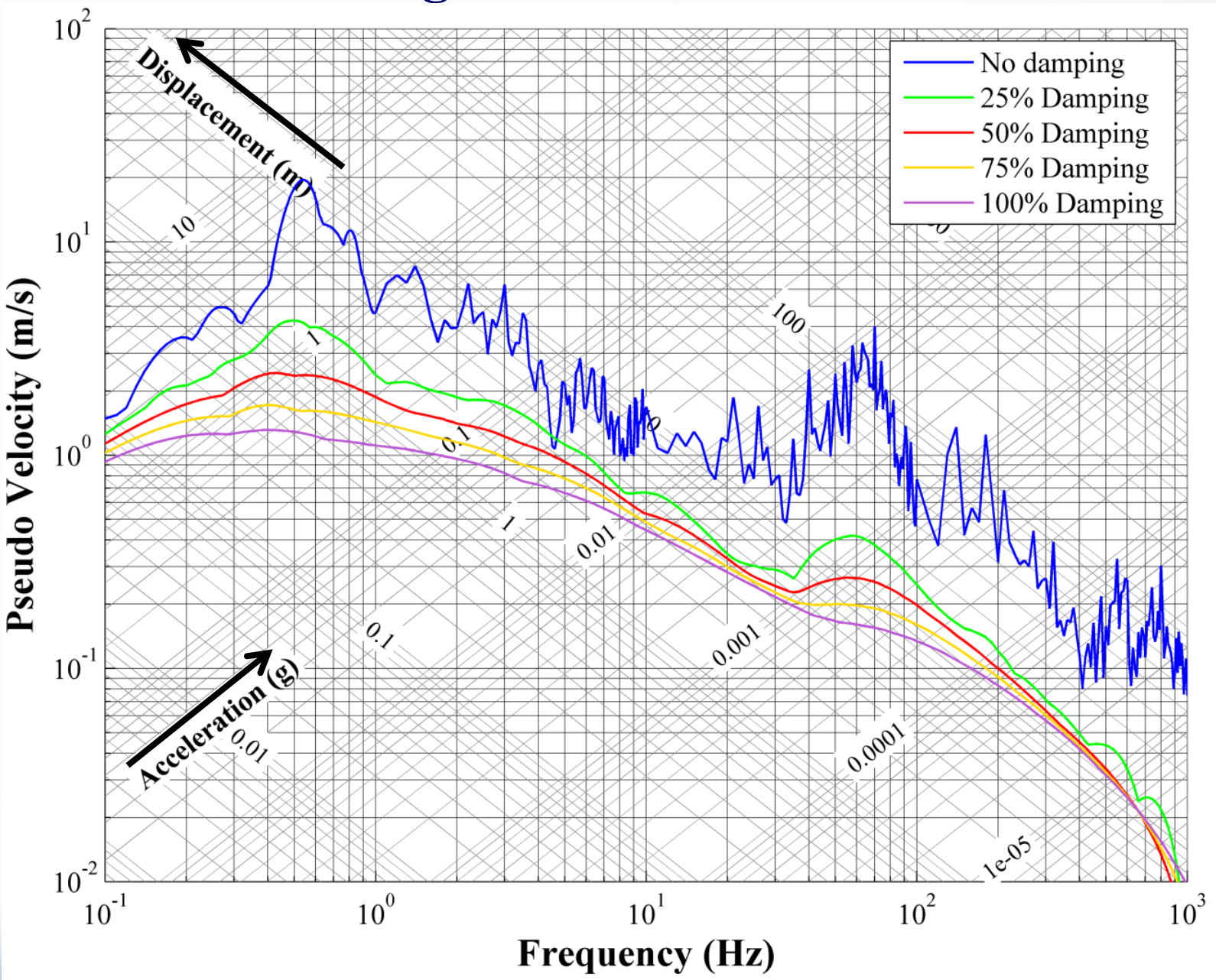


$$m\ddot{z} + c\dot{z} + kz = -m\ddot{y}$$



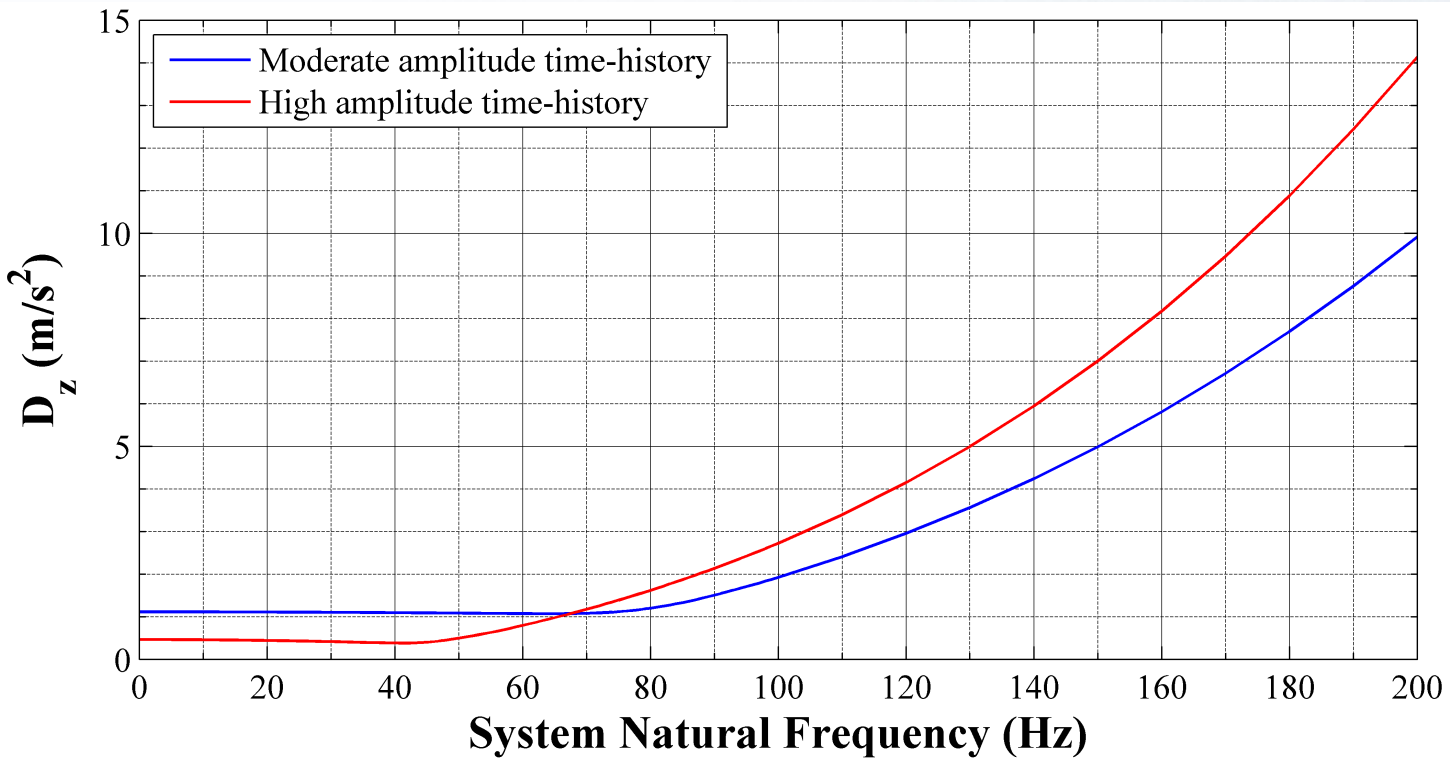
$$z = x - y$$

Numerical Modelling



Numerical Modelling

- Vibration dose: $$D_z = \left[\sum_i A_{iz}^6 \right]^{1/6}$$
- Accelerations are frequency-weighted
- Neural network limited to accelerations < 4 g



Way Ahead

- Test individual suspension components
- Validate numerical models
- Method for testing semi-active and active seats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