Employing the Shovel of an Excavator as a Vibration Absorber

Optimisation potential by considering the whole system

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Freudenberg Group - Facts and Figures

Freudenberg Group

- approx. 32,000 employees worldwide (12,500 in Germany)
- 4,000 Mio. Euro in 2003
- 1,157 employees in Research & Development
- Familiar company with a tradition of 150 years of Innovation
- Moody’s Rating 2004 A3 (20th. Industrial)

Technical Development Center

- Part of Freudenberg Dichtungs- und Schwingungstechnik
- 82 Employees
- 9,3 Mio. Euro in 2003
Engineering Services and their link to FDS-products

**Customer**

- Problem
  - Analysis
  - Optimization
  - Prototypes
  - Verification

**Simrit, Lead Center**

- Manufacturing of Prototypes
- Parts
  - Elastomer-Mounts
  - Hydrobushes
  - Hydropneumatic Systems
- Mass Production

**Customer**

- NVH System and Module Engineering
  - NVH-System-Analysis
    - Holistic View on Vehicle
  - Problem-Analysis
  - Solutions Design
  - Concept Studies
  - Concept Ratings
  - Implementation

**Testing**

- Experimental Analysis
  - Dynamometer
  - Aechoic Chamber
  - Road Simulator
- Comfort-Benchmarking
- Dynamic Measurements
  - Electromagnetic Shakers
  - Structure Borne Noise Analysis

**Customer**

- Mass Production
  - Verification
  - Prototypes

**Customer**

- Solutions Design
  - Concept Studies
  - Concept Ratings
  - Implementation

**Customer**

- Customer
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1. EU Regulations and ISO Norms

- **2002/44/EG: Vibrations**
  - Hand/Arm-Vibrations: Release-Value 2.5 m/sec², Limit 5.0 m/sec²
  - Body-Vibrations: Release-Value 0.5 m/sec², Limit 1.15 m/sec²

- **2003/10/EG: Acoustics:**
  - Release-Value 80 dB(A), 85 dB(A), Limit 87 dB(A)
2. The reason for vibration absorption

The movement of the shovel is used to dissipate energy which, otherwise would contribute to the cabin movement.

In order to achieve this energy dissipation effect, the eigenfrequency of the Shovel must be determined according to the cabin characteristics.
Load and Angle

Influenced Movement

Evaluation Criteria
The movement of the shovel is used to disipate energy in the cabin movement around the Y-Axis.

In order to analyse the results, we observe the rotation of the cabin around the Y-Axis.
3. SIMPACK Model

Motorpower: 44 kW / 60 PS
Shovel capacity: 0.80-1.20 m³
Weight: 4.9 t
Max. load: 2 t

11 Bodies
Masses:

Chassis: 4200 kg
Cabin: 515 kg
Shovel: 125 kg (empty)

23 DOF (total)
7 DOF (restricted)
Cabin rotation about the Y-axis (Pitch)

Energy Distribution
Eigenfrequency Cabin [Hz]

<table>
<thead>
<tr>
<th>Cabin</th>
<th>Frequency [Hz]</th>
</tr>
</thead>
<tbody>
<tr>
<td>X</td>
<td>Longitudinal</td>
</tr>
<tr>
<td>Y</td>
<td>Transversal</td>
</tr>
<tr>
<td>Z</td>
<td>Bounce</td>
</tr>
<tr>
<td>PhiX</td>
<td>Roll</td>
</tr>
<tr>
<td>PhiY</td>
<td>Pitch</td>
</tr>
<tr>
<td>PhiZ</td>
<td>Yaw</td>
</tr>
</tbody>
</table>
Cabin Eigenfrequencies without Tuned Mass Absorber

Frequency [Hz]

0 0.5 1 1.5 2 2.5 3 3.5 4 4.5 5 5.5 6 6.5 7 7.5 8 8.5 9 9.5 10

Pitch
Transversal
Bounce
Longitudinal
Yaw
Roll

Shovel
4. Vibration absorption in the Pitch Eigenmode

Parameter Variation - Rotation around Y-Axis

Amplitude

Frequency [Hz]

- Basis
- K = 60000
- K = 82222
- K = 84444
- K = 86666
- K = 89999
- K = 91111
- K = 93333
- K = 95555
- K = 97777
- K = 100000
Rotation around Y-Axis

Reduction of 50%

<table>
<thead>
<tr>
<th></th>
<th>Without TMA</th>
<th>With TMA</th>
</tr>
</thead>
<tbody>
<tr>
<td>X Longitudinal</td>
<td>4.72</td>
<td>5.06</td>
</tr>
<tr>
<td>Y Transversal</td>
<td>2.09</td>
<td>2.00</td>
</tr>
<tr>
<td>Z Bounce</td>
<td>2.44</td>
<td>2.53</td>
</tr>
<tr>
<td>PhiX Roll</td>
<td>0.55</td>
<td>0.86</td>
</tr>
<tr>
<td>PhiY Pitch</td>
<td>1.44</td>
<td>1.66</td>
</tr>
<tr>
<td>PhiZ Yaw</td>
<td>4.92</td>
<td>4.87</td>
</tr>
<tr>
<td>Shovel PhiY Pitch</td>
<td>-</td>
<td>1.39</td>
</tr>
</tbody>
</table>

**Without Tuned Mass Absorber**

**With Tuned Mass Absorber**
Cabin Eigenfrequencies without Tuned Mass Absorber

Cabin Eigenfrequencies with Tuned Mass Absorber

Eigenfrequency [Hz] | Without TMA | With TMA
--- | --- | ---
X | Longitudinal | 4.72 | 5.06
Y | Transversal | 2.09 | 2.08
Z | Bounce | 2.44 | 2.53
PhiX | Roll | 8.56 | 8.6
PhiY | Pitch | 1.44 | 1.66
PhiZ | Yaw | 4.92 | 4.87
Shovel PhiY | Pitch | - | 1.39
5. Vibration absorption in the Bounce Eigenmode

Parameter Variation - Rotation around Y-Axis

- Frequency [Hz]
- Amplitude

- $K = 100000$
- $K = 155555$
- $K = 211111$
- $K = 266666$
- $K = 322222$
- $K = 377777$
- $K = 433333$
- $K = 488888$
- $K = 644444$
- $K = 600000$
- Basis
Rotation around Y-Axis

Reduction of 36%

Without Tuned Mass Absorber

With Tuned Mass Absorber

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<tr>
<td>Shovel</td>
<td>PhiY</td>
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Cabin Eigenfrequencies

without Tuned Mass Absorber

Frequency [Hz]

0 0.5 1 1.5 2 2.5 3 3.5 4 4.5 5 5.5 6 6.5 7 7.5 8 8.5 9 9.5 10

Pitch

Transversal

Bounce

Longitudinal

Yaw

Roll

Cabin Eigenfrequencies

with Tuned Mass Absorber

Frequency [Hz]

0 0.5 1 1.5 2 2.5 3 3.5 4 4.5 5 5.5

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<tr>
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</tr>
<tr>
<td>Y (Transversal)</td>
<td>2.09</td>
<td>2.02</td>
</tr>
<tr>
<td>Z (Bounce)</td>
<td>2.44</td>
<td>2.96</td>
</tr>
<tr>
<td>PhiX (Roll)</td>
<td>8.66</td>
<td>8.61</td>
</tr>
<tr>
<td>PhiY (Pitch)</td>
<td>1.44</td>
<td>1.39</td>
</tr>
<tr>
<td>PhiZ (Yaw)</td>
<td>4.92</td>
<td>4.88</td>
</tr>
<tr>
<td>Shovel PhiY (Pitch)</td>
<td>-</td>
<td>2.28</td>
</tr>
</tbody>
</table>
6. Optimization potential

Diagram showing a series of tractor illustrations with arrows indicating potential points of optimization, labeled with percentages: 20%, 0%, 5%, 40%, 16%, 25%, 36%, 50%.
7. Conclusions

feito possible to use the shovel of an excavator as a vibration absorber for the cabin by considering the excavator as a whole system.

The use of the shovel as a vibration absorber can reach up to 50% of reduction in the pitch movement of the cabin.

The stiffness of the shovel hanging system, for this studied case, lies between 90 and 320 [N/mm]. A possible solution is the use of an hydraulic cylinder.

The use of other sub-components of the excavator, like for example the motor, show also essential improvement.
Thank you very much for your attention.

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