DESIGN OF SEMIACTIVE SEAT SUSPENSION FOR AGRICULTURAL MACHINES

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CONTENT

- Motivation
- Model
- Control algorithms
- Measurements
- Simulation results
- Conclusions

DESIGN OF SEMIACTIVE SEAT SUSPENSION FOR AGRICULTURAL MACHINES
MOTIVATION

- The need of seat suspension
  - Health aspects of operators
  - Traffic safety

- Main goal of new semiactive suspension control
  - Reduce of vibration transfer from frame to the operator’s body
MODEL

- **1 DOF Model**
  - non-linear damping
  - Response time of damper implemented

- **Performance criterium**

\[
\sigma(a_1) = \left[\frac{1}{N} \sum_{i=1}^{N} a_1^2(t)\right]^{\frac{1}{2}}
\]

- \( m = 100 \) kg
- \( k = 9000 \) N·m\(^{-1}\)

Simplified seat model and F-v dependency of semiactive damper
(https://www.firehouse.com)
CONTROL ALGORITHMS

- On/off skyhook (SH-2)
  \[ F_c = \begin{cases} 
  F_{c,\text{min}}(v) & \text{if } v_1 \cdot (v_1 - v_0) \leq 0 \\
  F_{c,\text{mid}}(v) & \text{if } v_1 \cdot (v_1 - v_0) > 0 
  \end{cases} \]

- Acceleration driven damper control (ADD)
  \[ F_c = \begin{cases} 
  F_{c,\text{min}}(v) & \text{if } a_1 \cdot (v_1 - v_0) \leq 0 \\
  F_{c,\text{max}}(v) & \text{if } a_1 \cdot (v_1 - v_0) > 0 
  \end{cases} \]

- Skyhook linear approximation (SH-L)
  \[ F_c = \begin{cases} 
  F_{c,\text{min}}(v) & \text{if } v_1 \cdot (v_1 - v_0) \leq 0 \\
  \text{sat} \left( \frac{a \cdot F_{c,\text{max}}(v) \cdot (v_1 - v_0) + (1-a) \cdot F_{c,\text{max}}(v) \cdot v_1}{v_1 - v_0} \right) & \text{if } v_1 \cdot (v_1 - v_0) > 0 
  \end{cases} \]
DESIGN OF SEMIACTIVE MAGNETORHEOLOGICAL DAMPER

- **MR damper**
  - Based on LORD RD-1005-3
  - Fast response time (up to 1.5 ms)
  - Stroke 44 mm
Non linear damping -> results are dependent on the excitation signal

Measured signals by IMU
- Vertical acceleration of frame
- Vertical acceleration of seat

Measured values on John Deere 6110M
- Frame: 3-6 m·s\(^{-2}\)
- Seat 1–2,5 m·s\(^{-2}\)
### RESULTS

<table>
<thead>
<tr>
<th>Response time (ms)</th>
<th>Standard deviation of seat – acceleration (m·s(^{-2}))/position (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>SH-2</td>
</tr>
<tr>
<td>20</td>
<td>0,289/1,94</td>
</tr>
<tr>
<td>10</td>
<td>0,265/1,75</td>
</tr>
<tr>
<td>5</td>
<td>0,254/1,67</td>
</tr>
<tr>
<td>1,5</td>
<td>0,248/1,62</td>
</tr>
<tr>
<td>Passive suspension</td>
<td>0,339/2,81</td>
</tr>
<tr>
<td>Excitation signal</td>
<td>0,982/2,31</td>
</tr>
</tbody>
</table>
RESULTS

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CONCLUSIONS

- Real excitation signals used for simulations
- Model with implemented non linear damping and time response
- Semiactive algorithm improves vibroisolation
  - 26.8 % vibration reduction for on/off skyhook
  - 29.5 % vibration reduction for Skyhook linear approximation
  - 29.2 % vibration reduction for Acceleration driven damping
- Short response time of damper improves the performance
- Future work
  - Experimental stand for measurement of seat vibrations in the laboratory
  - Design of control unit
  - Manufacturing of the damper
THANK YOU FOR YOUR ATTENTION

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