DESIGN OF SEMIACTIVE SEAT SUSPENSION FOR AGRICULTURAL MACHINES

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INSTITUTE OF **MACHINE**
AND **INDUSTRIAL DESIGN**

CONTENT

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

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

Operator's seat
(https://www.firehouse.com)

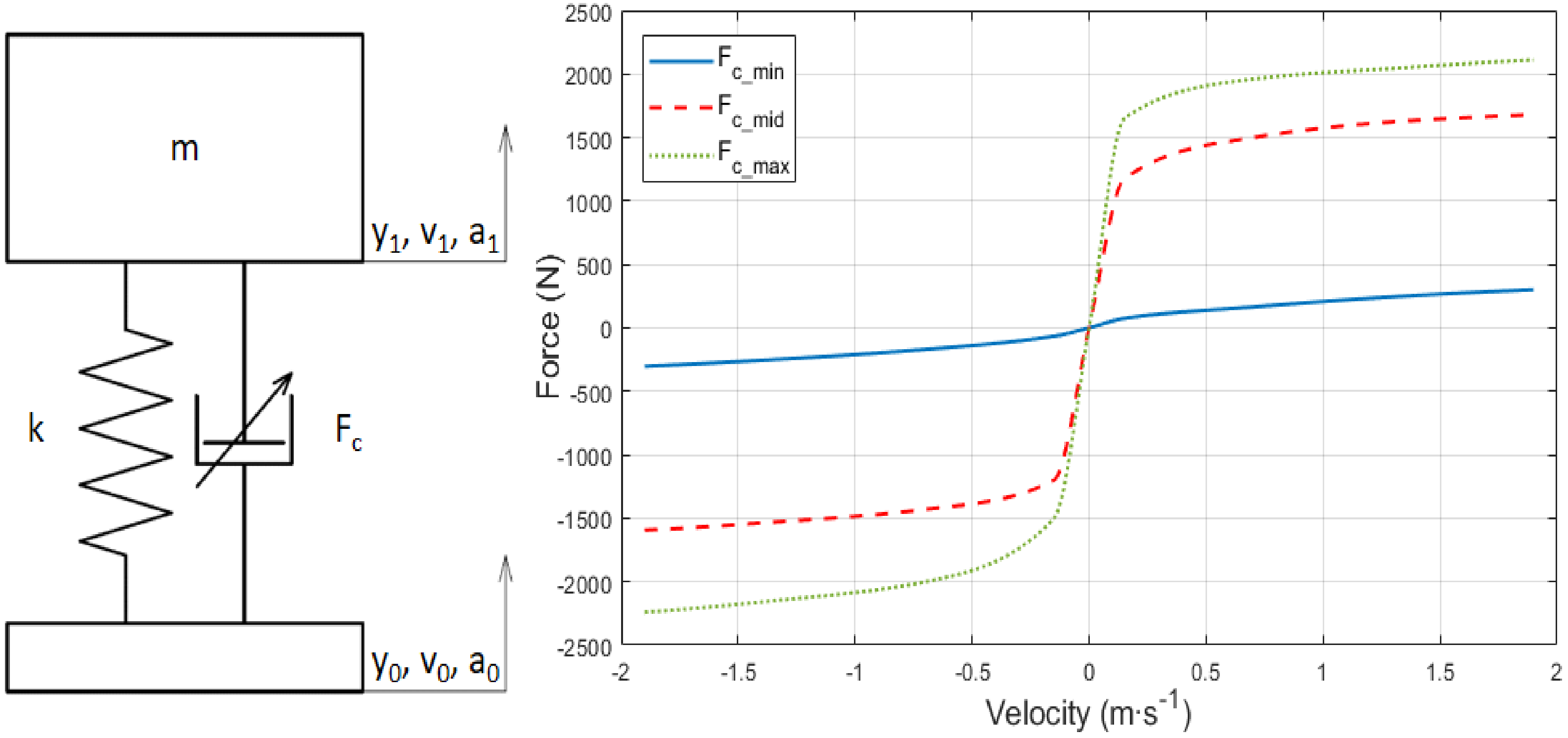
MODEL

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

- **Performance criterium**

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

- 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)**

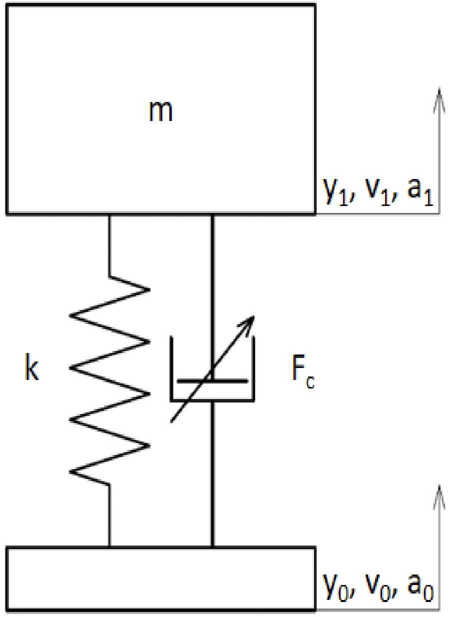
$$F_c = \begin{cases} F_{c\_min}(v) & \text{if } \; v_1 \cdot (v_1 - v_0) \leq 0 \\ F_{c\_mid}(v) & \text{if } \; v_1 \cdot (v_1 - v_0) > 0 \end{cases}$$

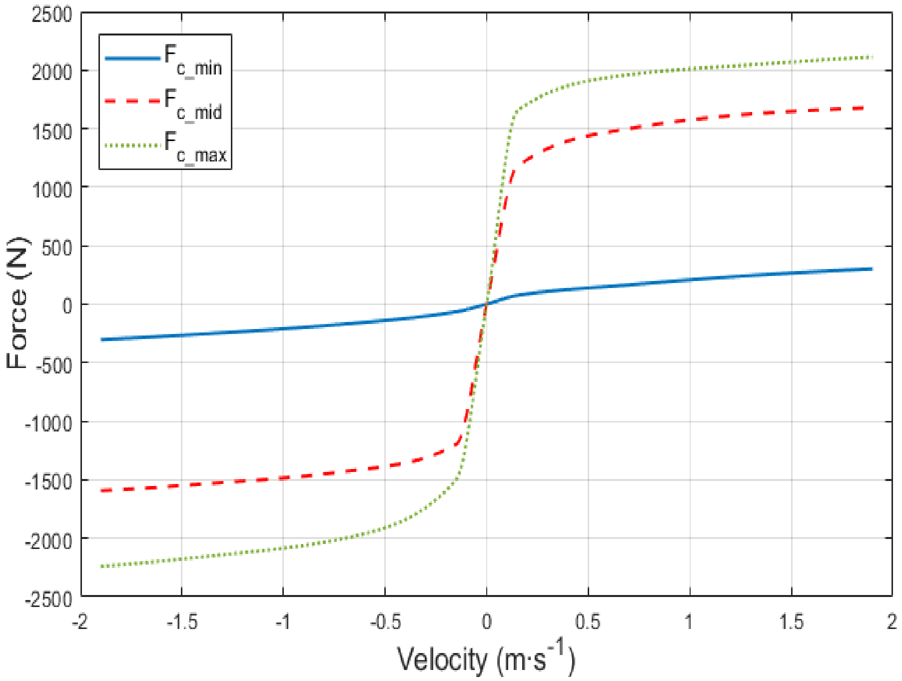
- **Acceleration driven damper control (ADD)**

$$F_c = \begin{cases} F_{c\_min}(v) & \text{if } \; a_1 \cdot (v_1 - v_0) \leq 0 \\ F_{c\_max}(v) & \text{if } \; a_1 \cdot (v_1 - v_0) > 0 \end{cases}$$

- **Skyhook linear approximation (SH-L)**

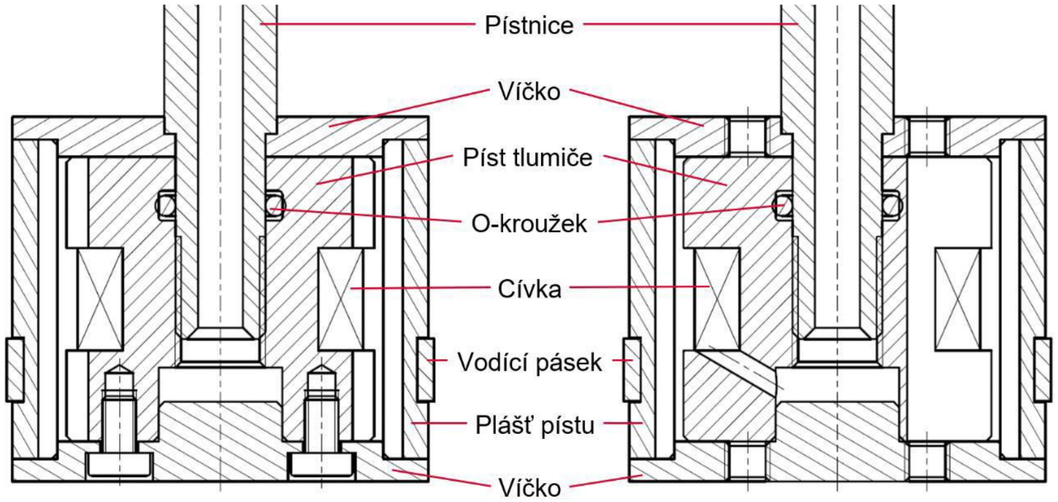
$$F_c = \begin{cases} F_{c\_min}(v) & \text{if } \; v_1 \cdot (v_1 - v_0) \leq 0 \\ sat\left(\frac{\alpha \cdot F_{c\_max}(v) \cdot (v_1 - v_0) + (1-\alpha) \cdot F_{c\_max}(v) \cdot v_1}{(v_1 - v_0)}\right) & \text{if } \; v_1 \cdot (v_1 - v_0) > 0 \end{cases}$$

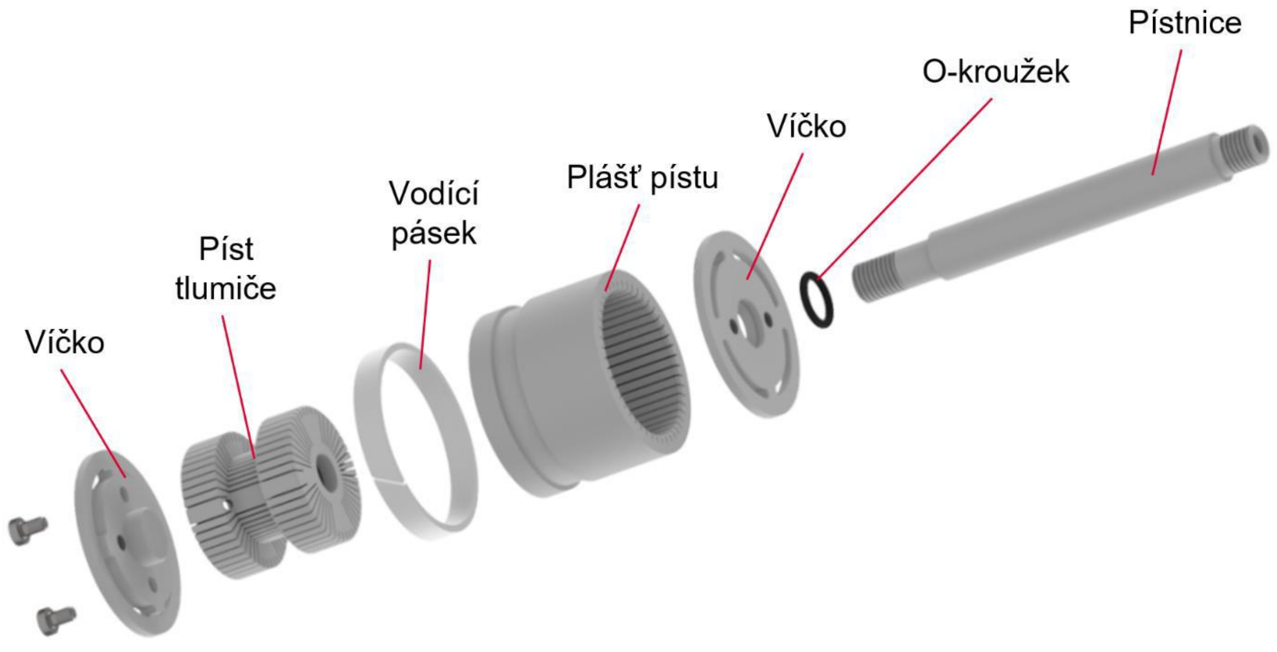




DESIGN OF SEMIACTIVE MAGNETORHEOLOGICAL DAMPER

- **MR damper**
  - Based on LORD RD-1005-3
  - Fast response time (up to 1.5 ms)
  - Stroke 44 mm



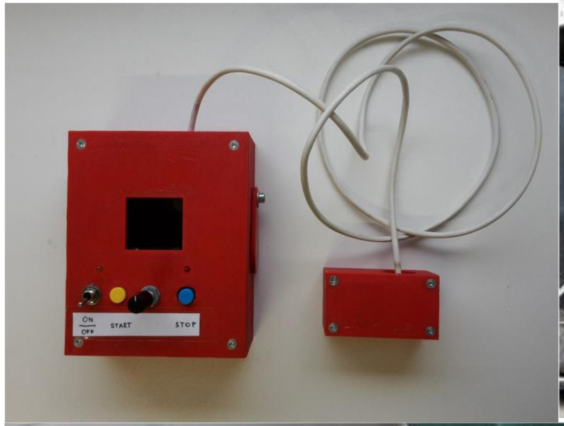


INPUT SIGNAL MEASUREMENT

- **Non linear damping -> results are dependent on the excitation signal**

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

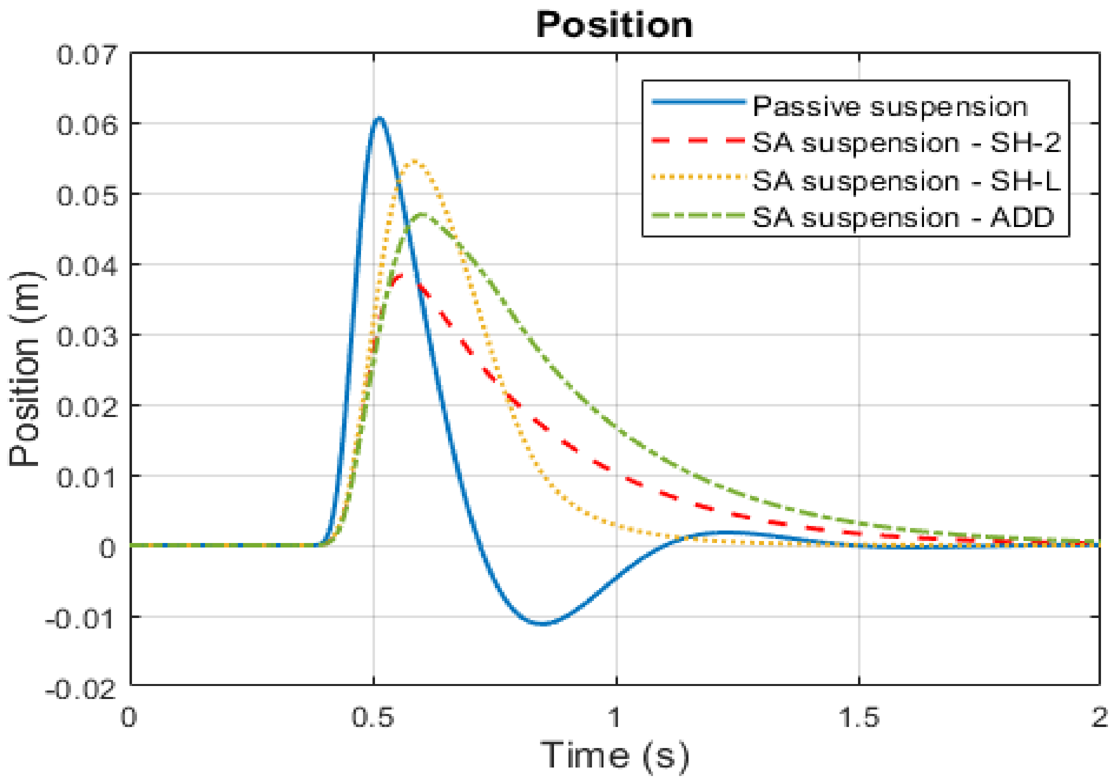
- **Measured values on John Deere 6110M**
  - Frame: 3-6 $m \cdot s^{-2}$
  - Seat 1–2,5 $m \cdot s^{-2}$

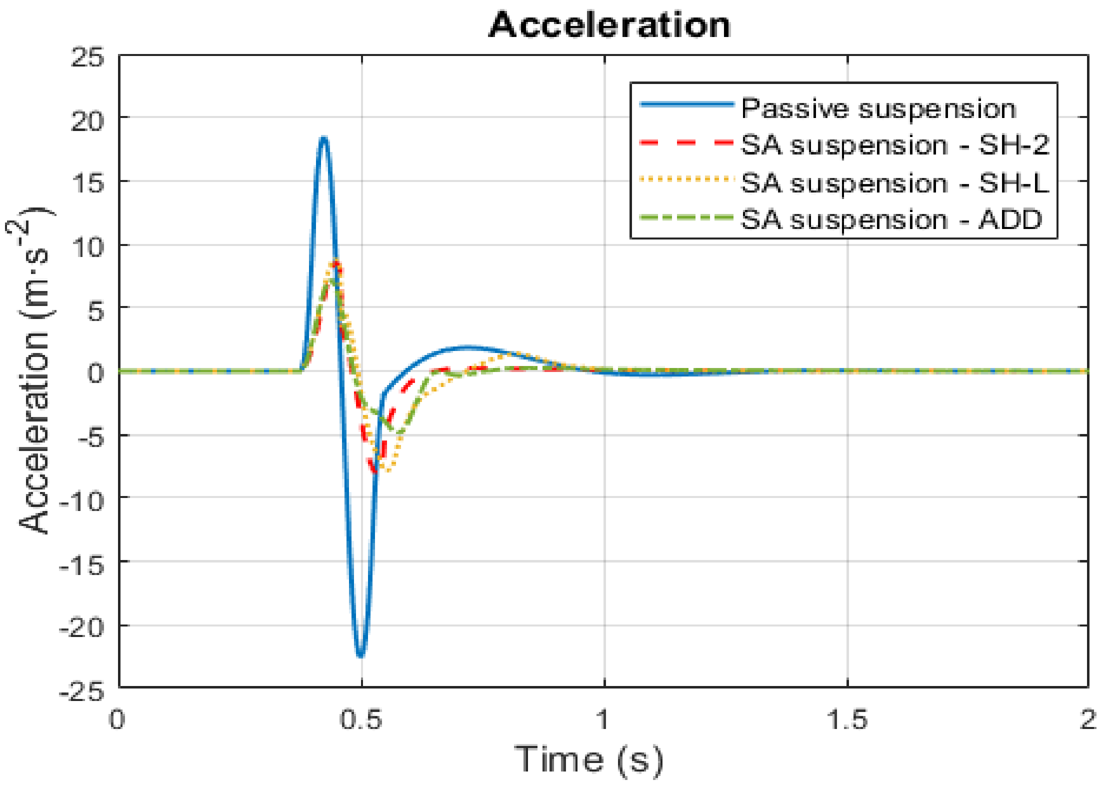


RESULTS

Response time (ms)	Standard deviation of seat – acceleration ($m \cdot s^{-2}$)/position (mm)		
	SH-2	**SH-L ($\alpha = 0$)**	**ADD**
20	0,289/1,94	0,256/2,23	0,255/2,63
10	0,265/1,75	0,247/2,16	0,248/2,56
5	0,254/1,67	0,242/2,12	0,244/2,51
1,5	0,248/1,62	0,239/2,10	0,241/2,47
Passive suspension	0,339/2,81		
Excitation signal	0,982/2,31		

RESULTS


Position
Passive suspension
SA suspension - SH-2
SA suspension - SH-L
SA suspension - ADD
Position (m)
Time (s)
0.07
0.06
0.05
0.04
0.03
0.02
0.01
0
-0.01
-0.02
0
0.5
1
1.5
2


Acceleration
Passive suspension
SA suspension - SH-2
SA suspension - SH-L
SA suspension - ADD
Acceleration (m·s-2)
Time (s)
25
20
15
10
5
0
-5
-10
-15
-20
-25
0
0.5
1
1.5
2

CONCLUSIONS

- **Real excitation signals used for simulations**
- **Model with implemented non linear damping and time response**
- **Semiactive algorithm improves vibroisolation**
  - 26.8 % vibration reducement for on/off skyhook
  - 29.5 % vibration reducement for Skyhook linear approximation
  - 29.2 % vibration reducement 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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