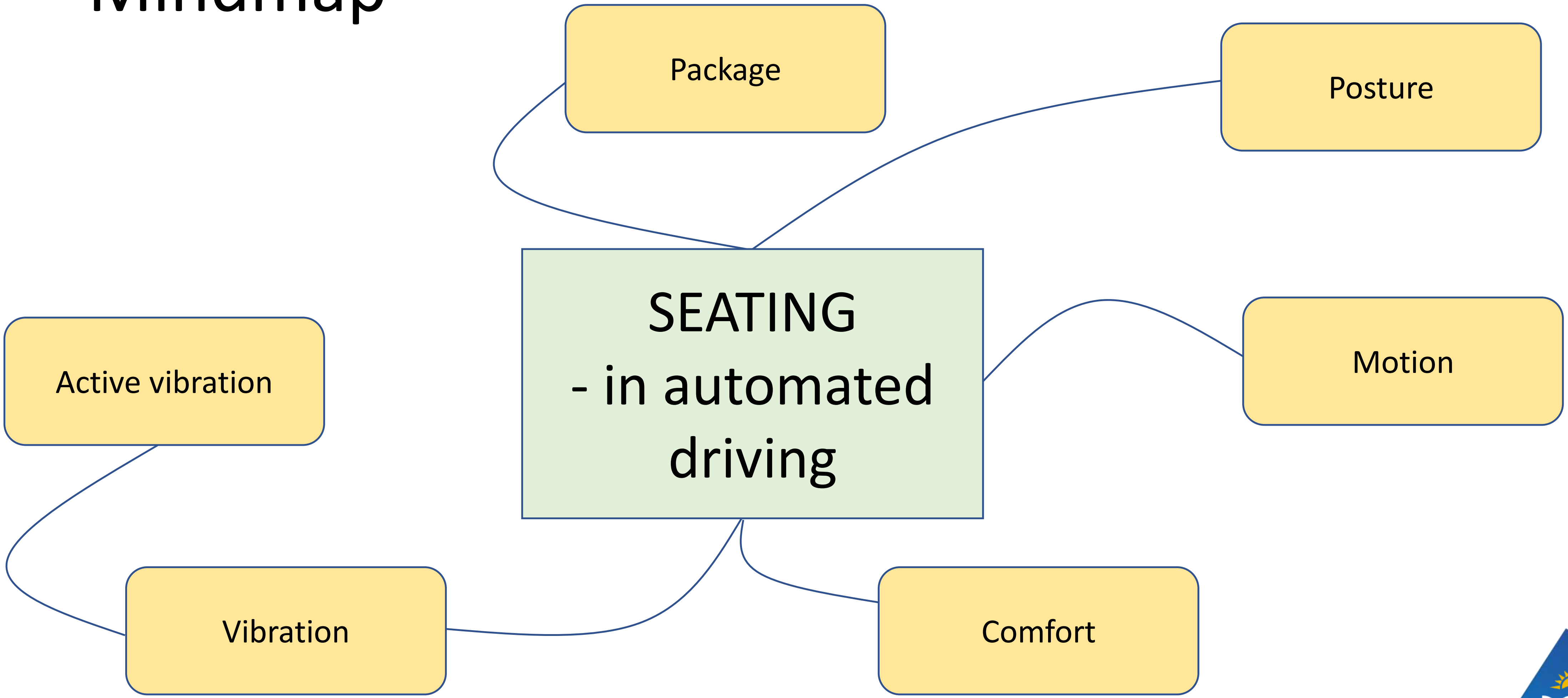
Associate Professor Dr Gunther Paul
jointly w/ Prof Dr Heinz Ulbrich

Active seat suspension enhancing driver comfort

JAMES COOK UNIVERSITY AUSTRALIA

Mindmap



Package

Posture

SEATING
- in automated
driving

Active vibration

Motion

Vibration

Comfort

Pressure discomfort
-Localized points of high or low pressure distribution which cause discomfort
-General areas of pressure which give support and help maintain posture

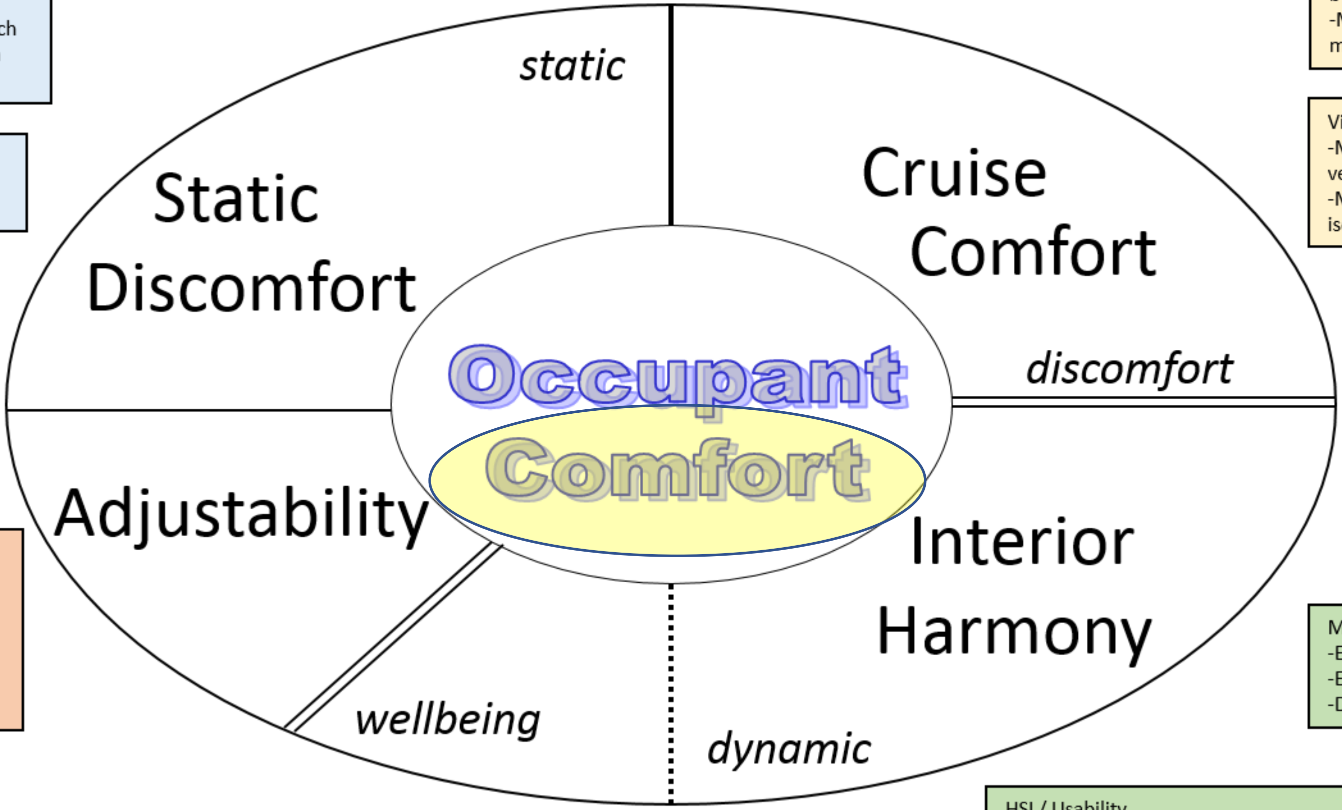
Motion discomfort
-Enable smooth and effortless ingress/egress to/from seat

Posture discomfort
-Adequate sitting posture – optimize
static muscular activity
-Optimize pelvic and trunk orientation
-Optimize joint angles

Seat belt discomfort
-Position of seatbelt and influence on attaining comfortable posture

Thermal discomfort
-Good airflow to optimise heat and moisture transfer from occupant skin

Posture support
-Sufficient support of occupant will allow maintain ideal posture commensurate to driving conditions



Interior Noise
-Optimize engine, road and wind noise influence on customer well being
-Minimize noise from seat mechanisms

Vibration discomfort
-Minimize low frequency lateral, vertical, and longitudinal impact
-Maximise mid and high frequency isolation (localized)

Vision discomfort
-Minimize occlusion, distortion, space anxiety
-Maximise situational awareness

Mobility
-Ease of changing posture
-Ease of reach
-Dynamic accessibility of systems

Visual design
-Interior should look appropriate for vehicle (i.e. sporty in a sports car, comfortable in a luxury car)
-Seat should give impression of safety
-Controls should look accessible

Tactile feel
-Surfaces should feel pleasing to the target customer

HSI / Usability
-Ease of adjustment and ability to adjust systems to comfortable settings
-Ease of communication with systems

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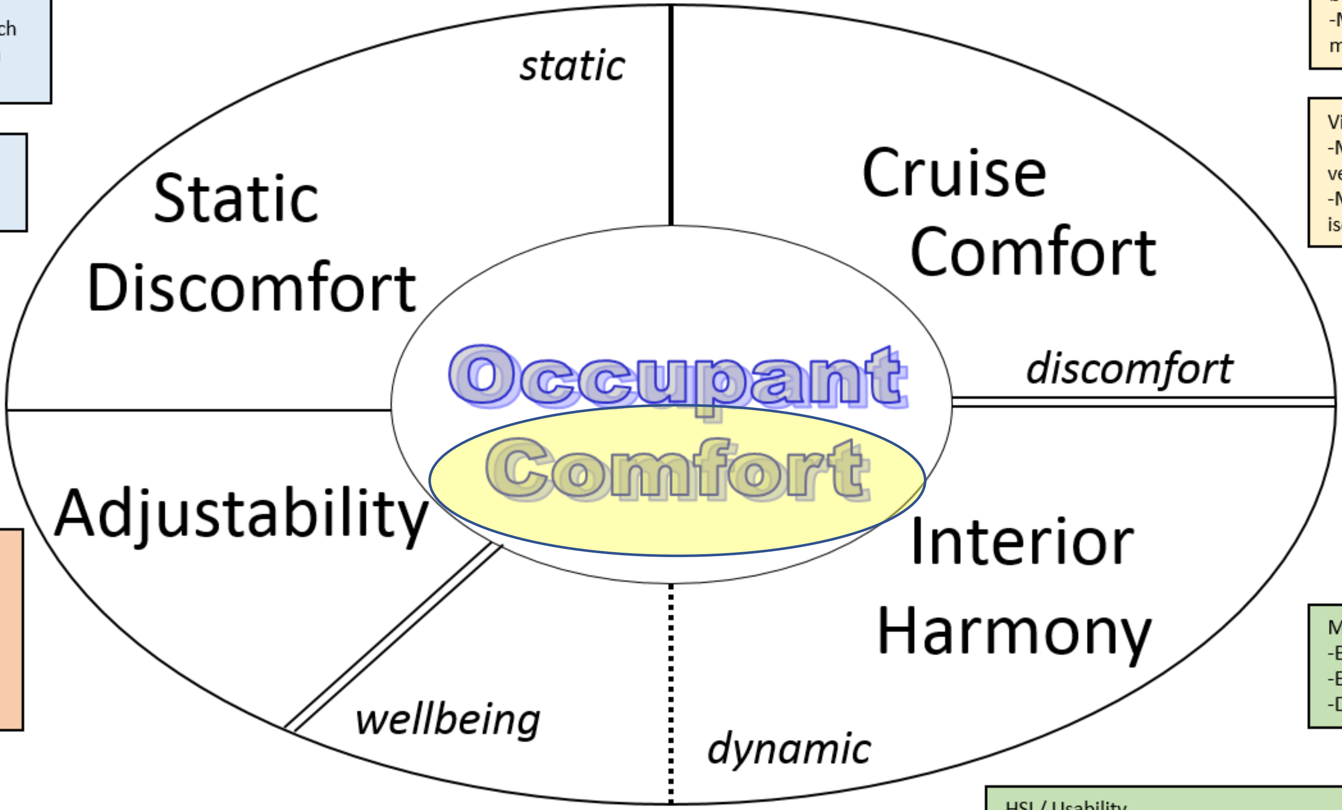

Vibration discomfort
-Minimize low frequency lateral, vertical, and longitudinal impact
-Maximise mid and high frequency isolation (localized)

Vision discomfort
-Minimize occlusion, distortion, space anxiety
-Maximise situational awareness

Motion sickness
- Align vision and acceleration

Posture discomfort
-Adequate sitting posture – optimize
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-Optimize joint angles

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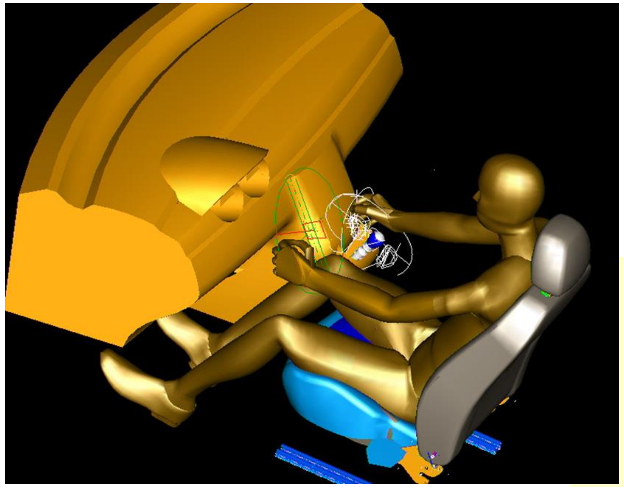
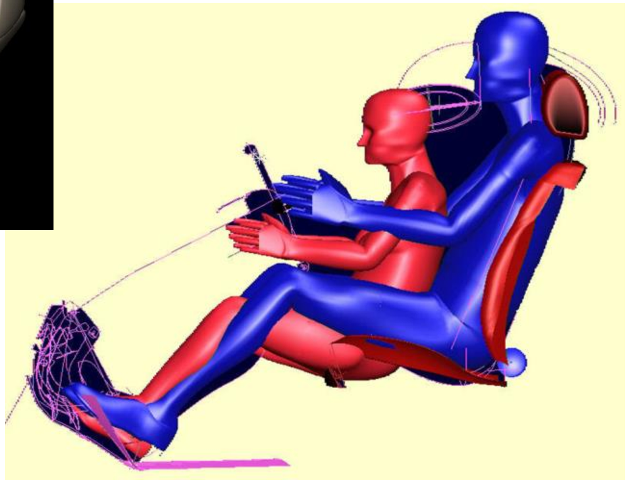
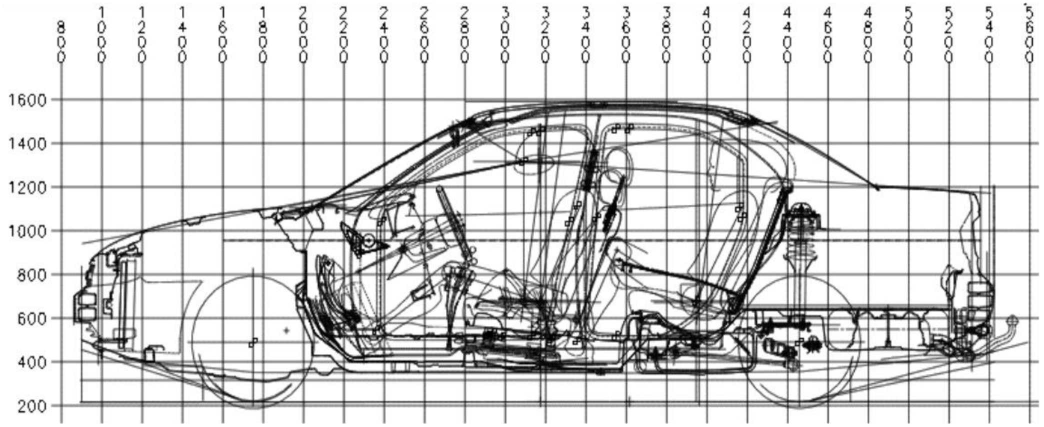
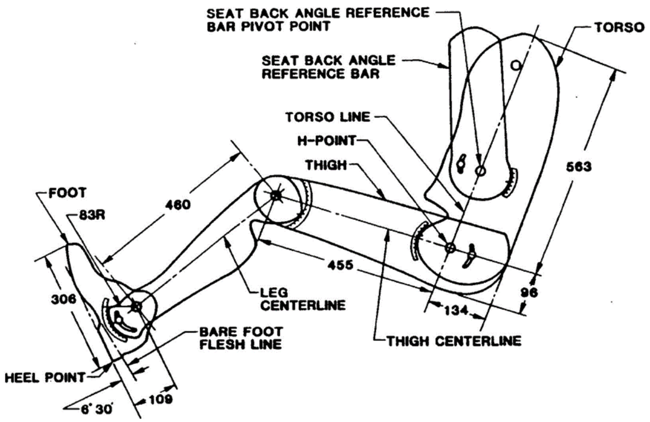
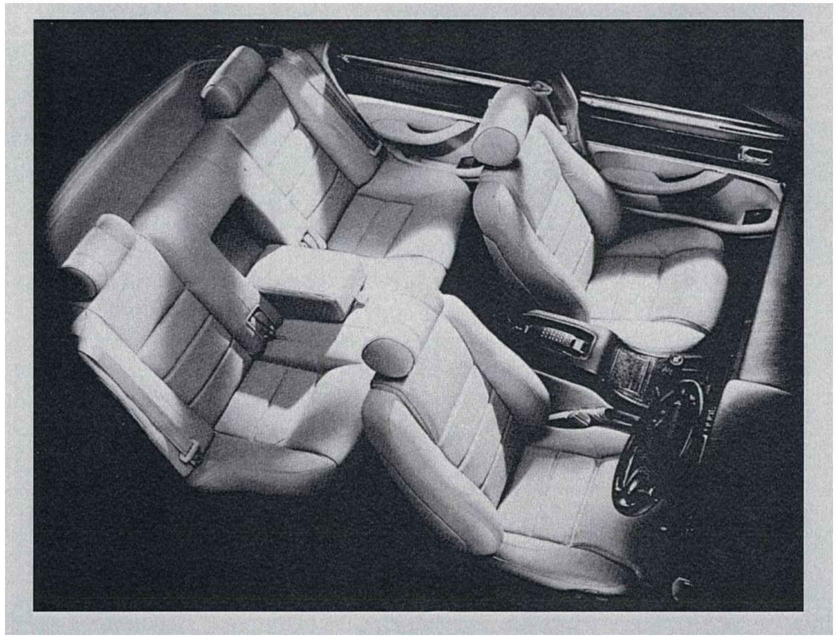
Interior Package Concept

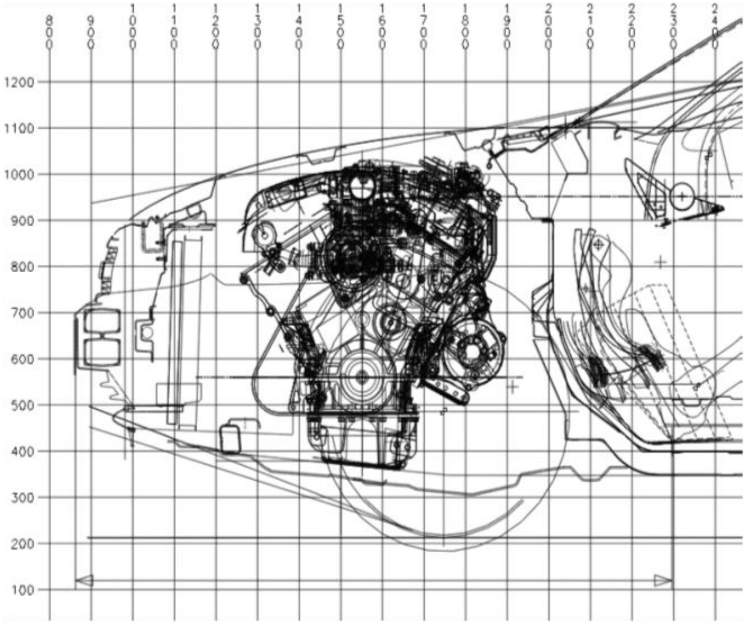








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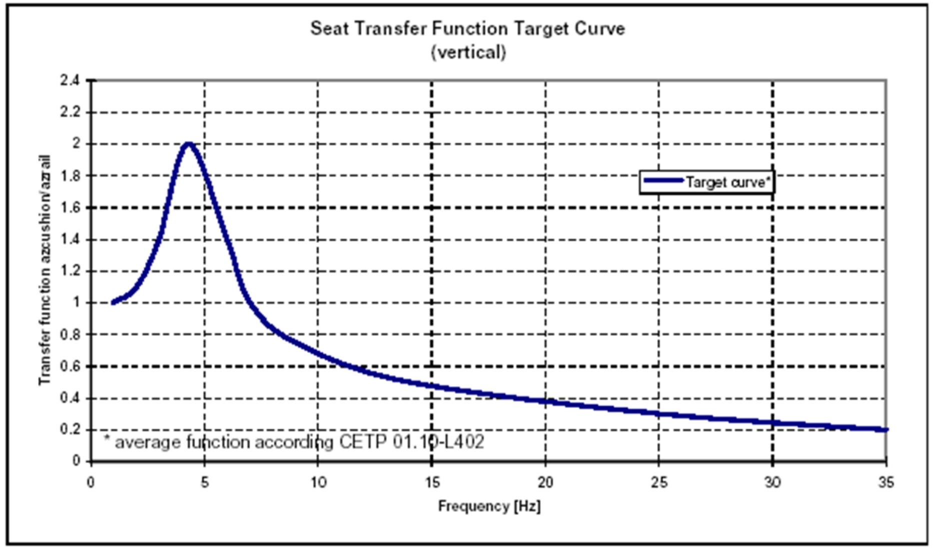
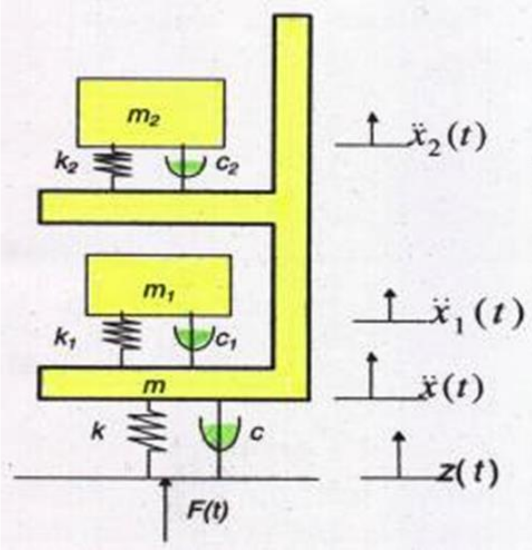
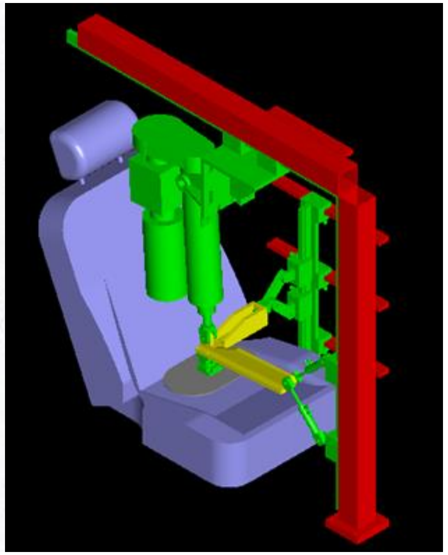
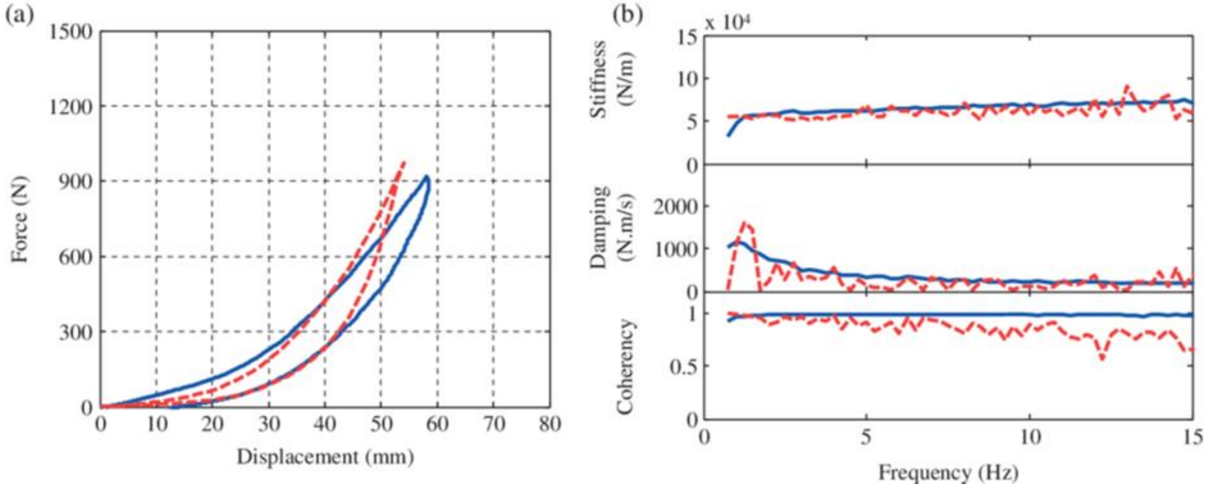
Transmissibility

SEAT

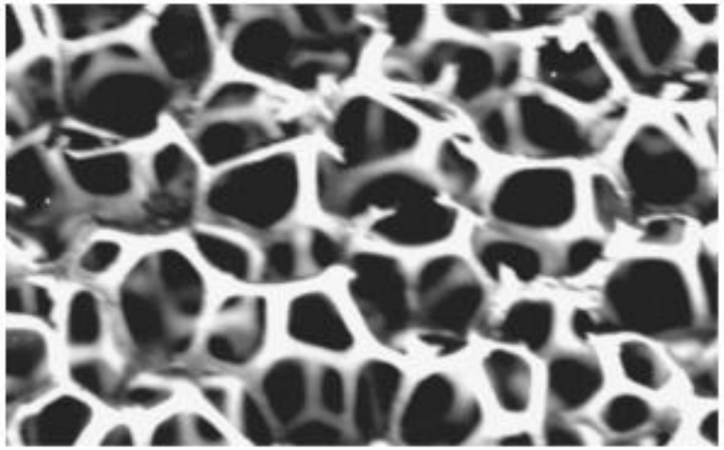




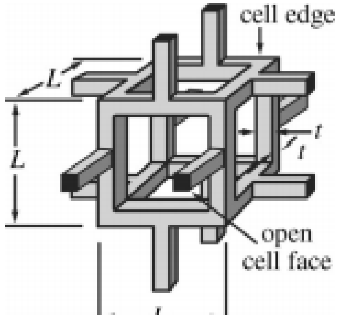


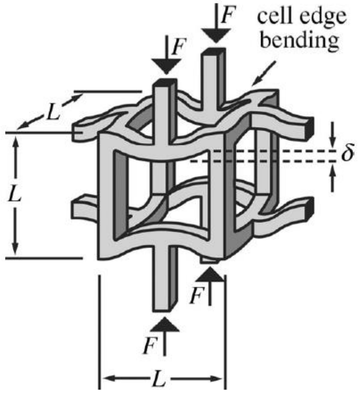


(Zhang et al 2015)



(Ashby 2006)





- stiffness
- strength
- relaxation
- thermal conductivity
- electrical resistivity
- ….

depend on

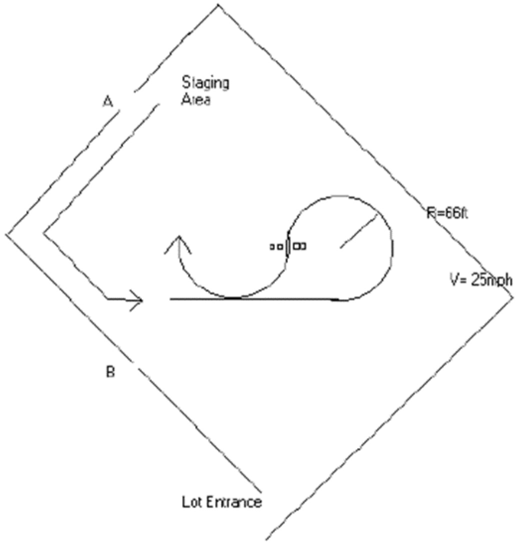
- properties of the (solid) material
- topology and shape of cell lattice
- relative density of foam

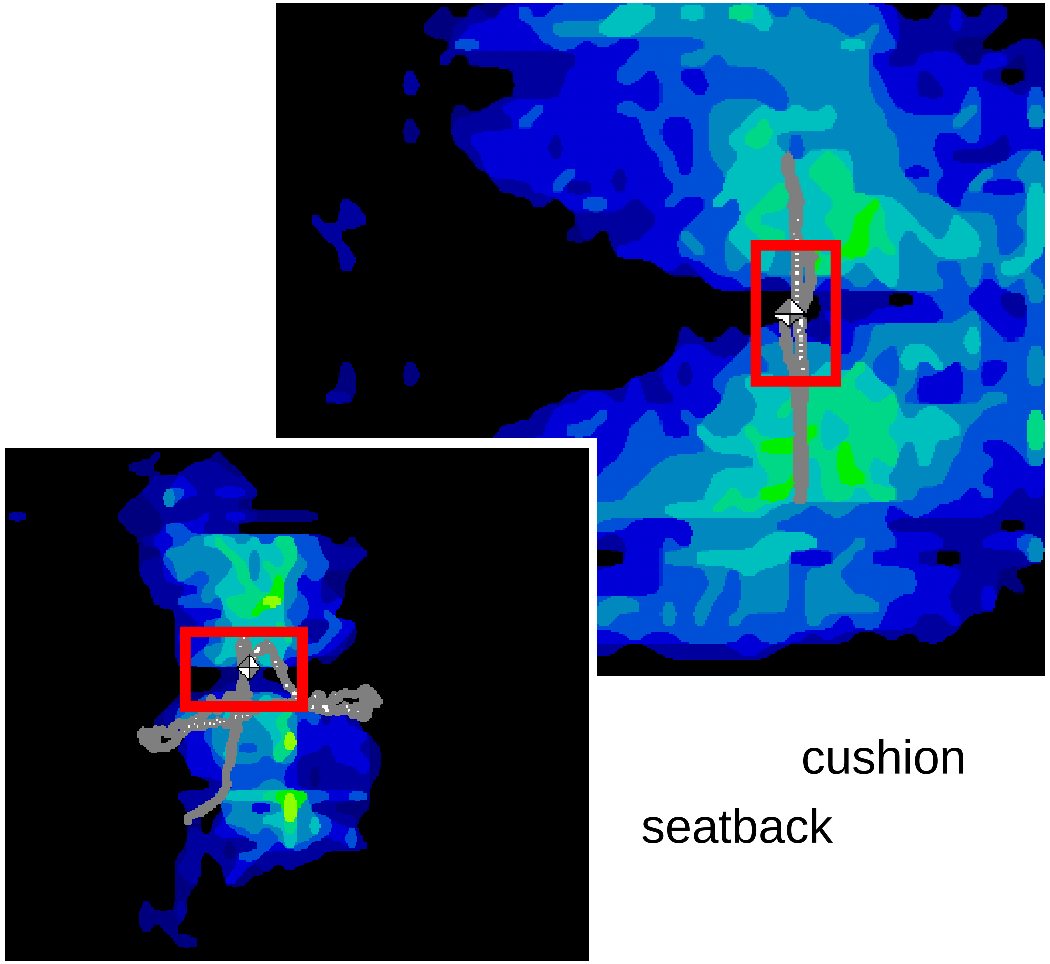
and indentation (i.e. posture)!

Some considerations:

1. Safety?
   - Big issue – requires significant research effort: out of place etc.
   - Supine posture is unrealistic and will not be authorised
2. Comfort?
   - The part we can deal with currently
   - Now requires consideration of rotational DOF
   - New postures
   - X/Z is no more the only biomechanical direction, requiring new paradigm
3. Motion sickness?
   - Motion sickness is not just discomfort, it is an illness
   - Motion sickness heavily depends on visual alignment with motion/inertia, and there is no realistic way to achieve complete alignment (e.g. projections)
   - Mitigation must be aim
4. Package?
   - Can be solved, e.g. speech control, seat mounted controls etc.
   - "Driver package space" will continue to be confined, however larger than in traditional packaging

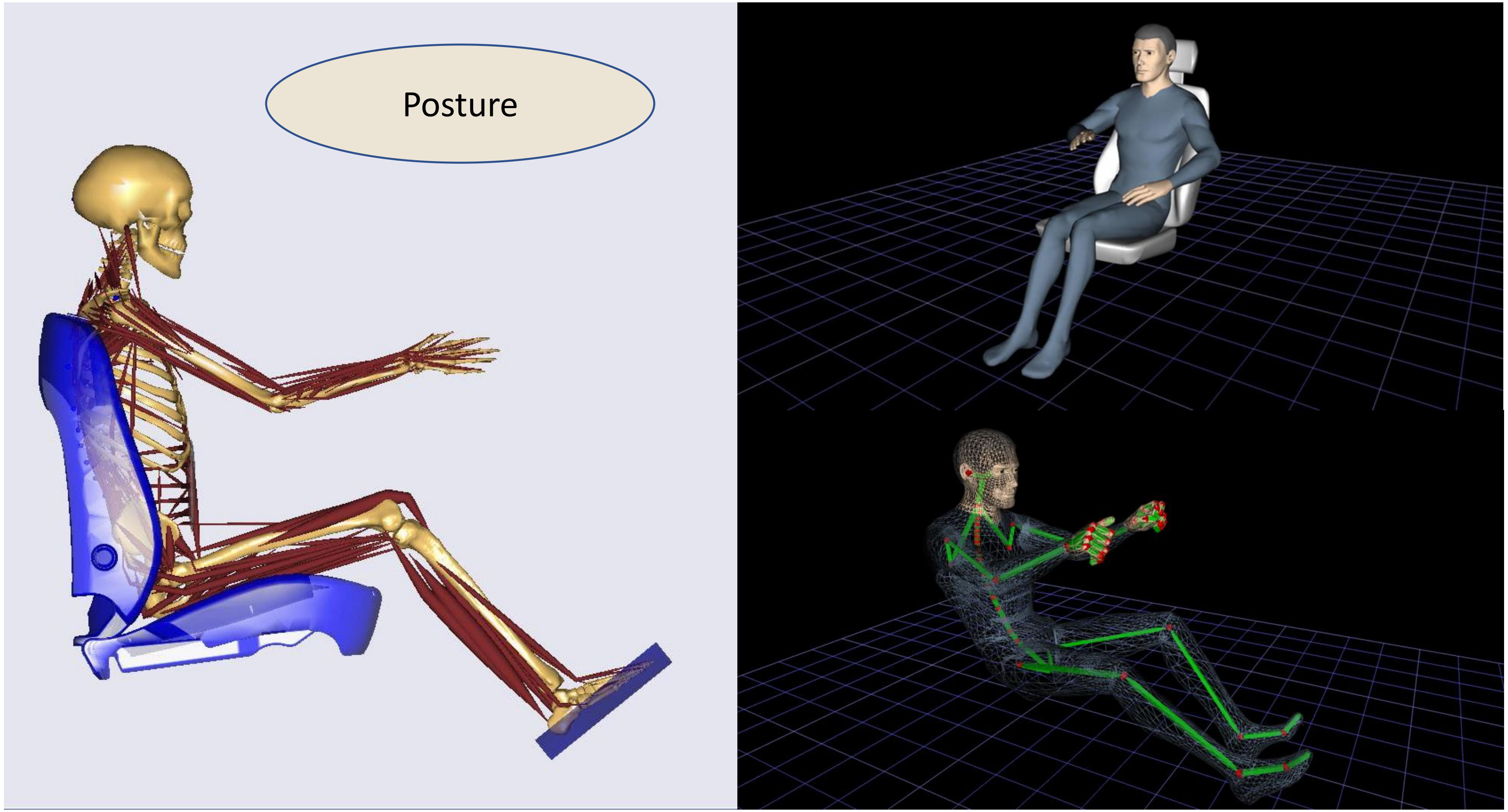
Motion





cushion

seatback



Posture


FE Model 3 36/M
6918 2958.104
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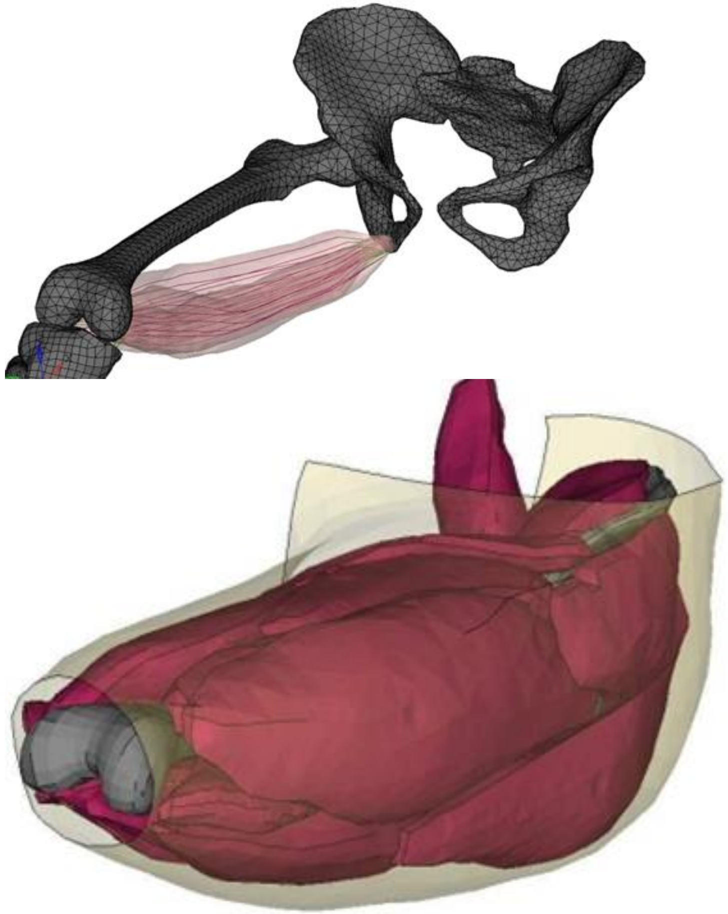
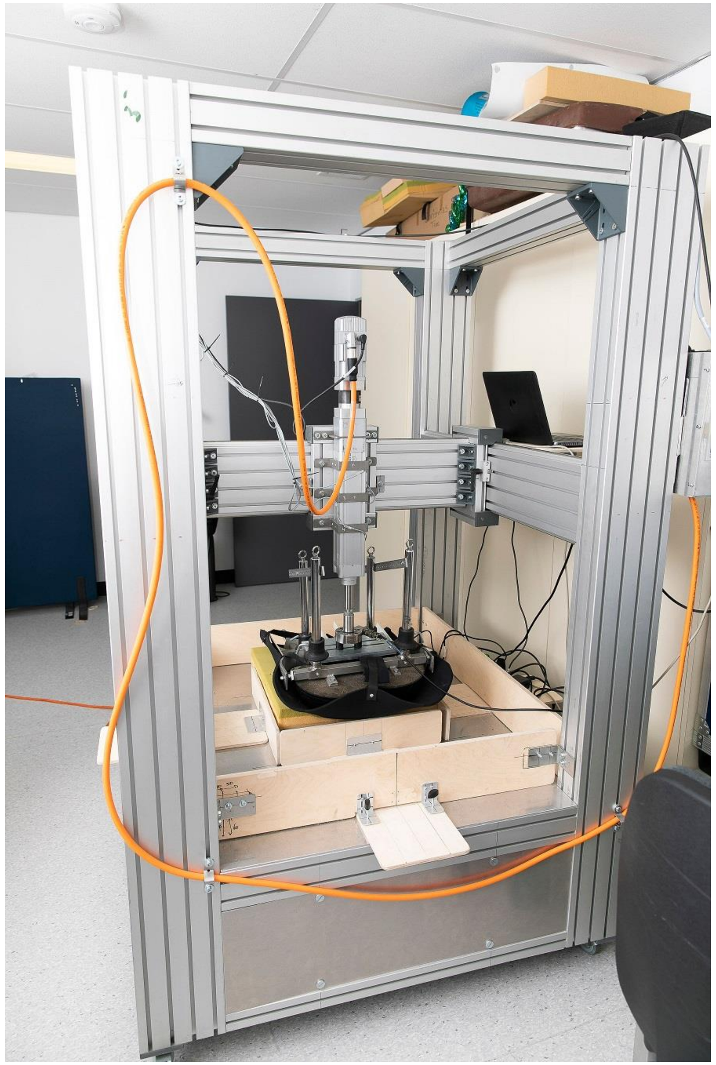
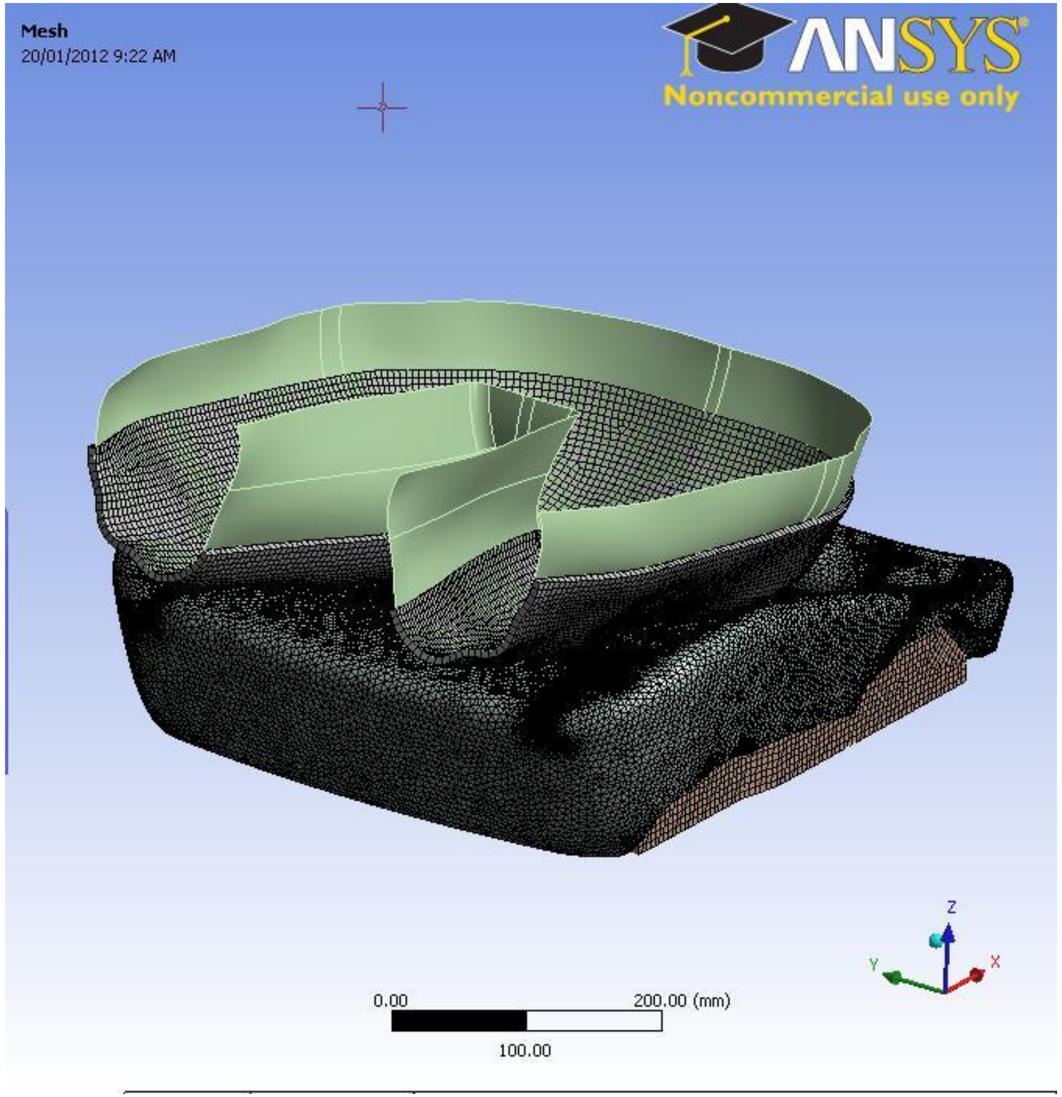
5:03 (10, 1:15)
S
M 1947
W 3554
09:50:45 AM
Jun-22-2011
A
50
mm
N 1
F 40.0
TR 715.0
TE 20.0
M 256 x 180
V 1.56x2.22x10.0=34.72
FONAR 0.6 T
NOT FOR DIAGNOSIS
pMRI=Ver
-81.1 S
109.4 A
-138.2 L
SAG A/P
Site



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20/01/2012 9:22 AM
ANSYS
Noncommercial use only
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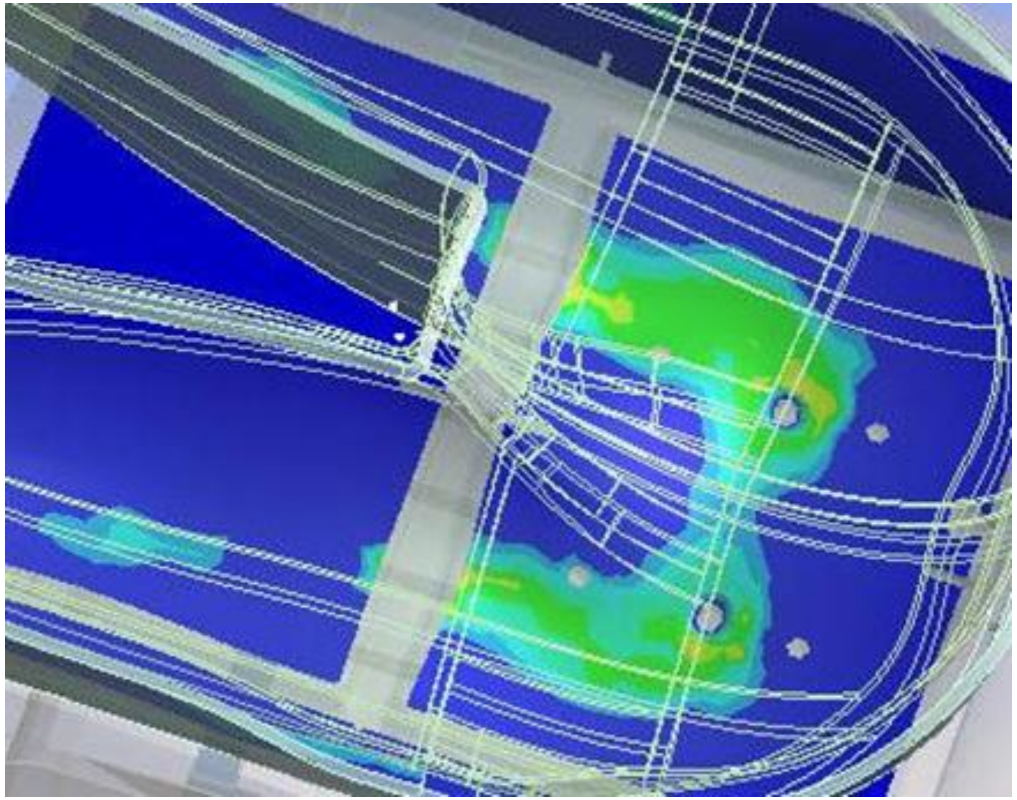

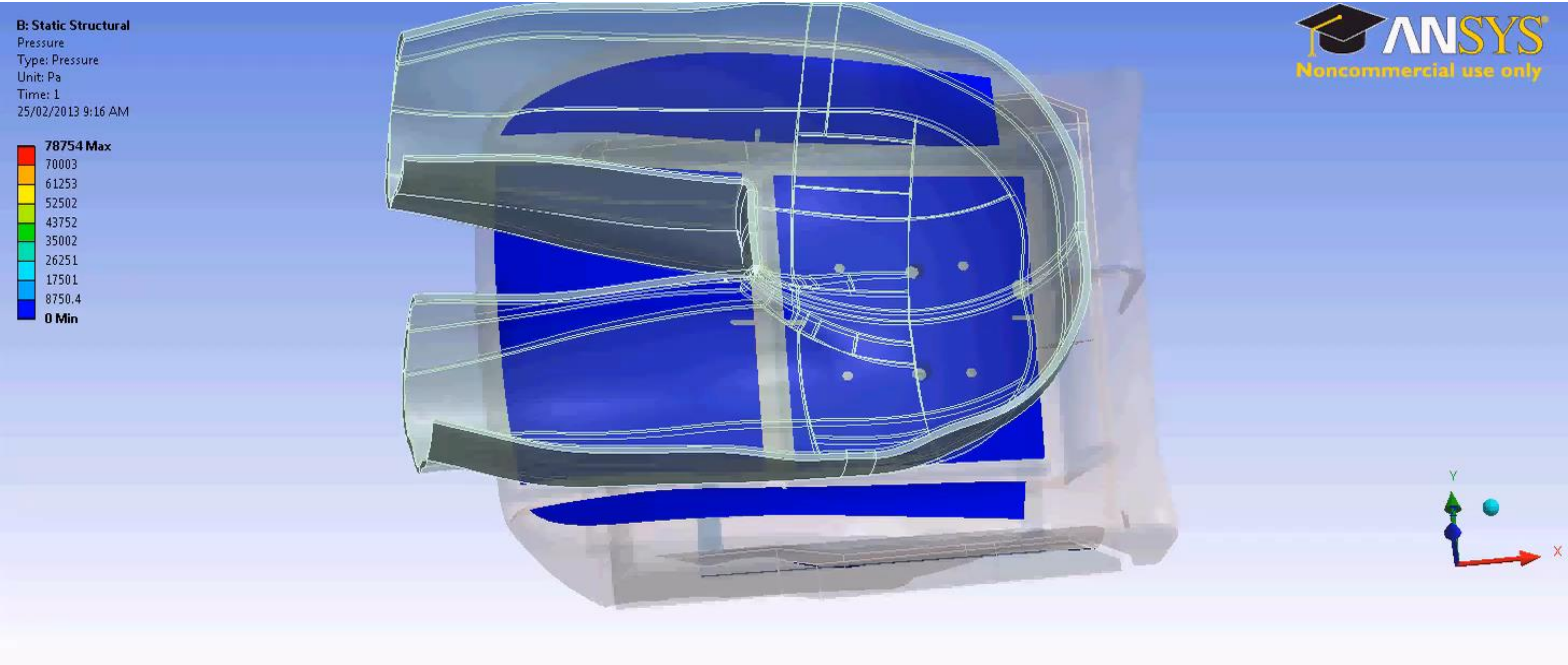

B: Static Structural
Pressure
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Unit: Pa
Time: 1
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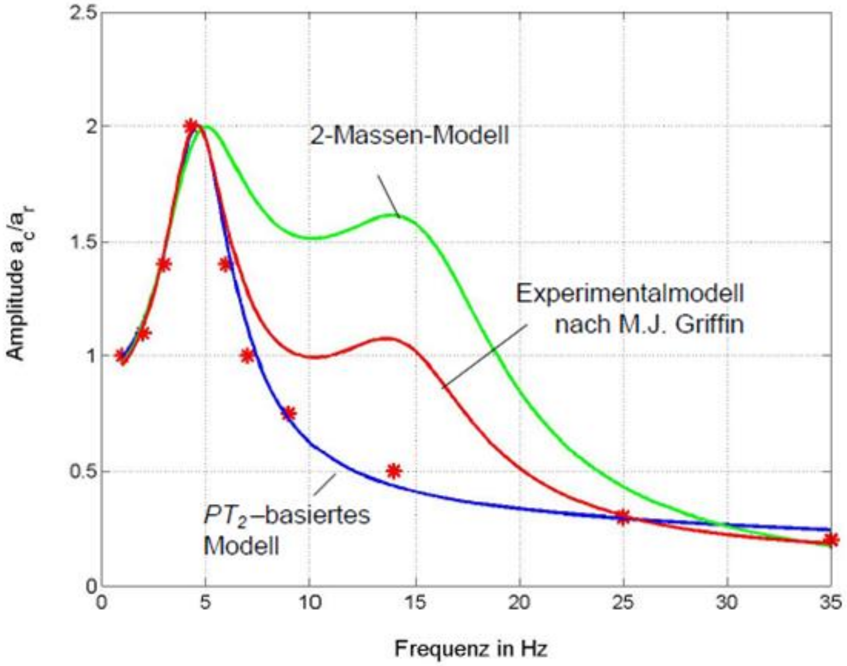


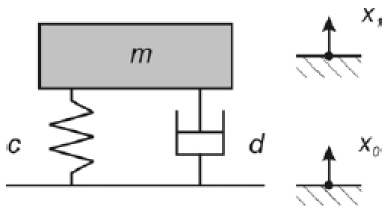


Abbildung 3: 1-Massen-Modell des Pkw-Sitzes

$$G_S(s) = \frac{T_1\, s + 1}{T_2^2\, s^2 + T_1\, s + 1} \cdot \frac{T_{AR,Z}\, s + 1}{T_{AR,N}\, s + a_0}$$

Tabelle 1: Parametersatz des 1-Massen-Modells

T_1	T_2	$T_{AR,Z}$	$T_{AR,N}$	a_0
$20{,}5 \cdot 10^{-3}$ s	$32{,}5 \cdot 10^{-3}$ s	$15{,}9 \cdot 10^{-3}$ s	$4 \cdot 10^{-3}$ s	1,05

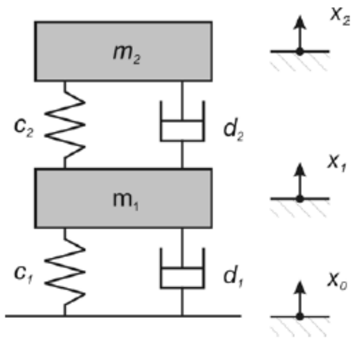


Abbildung 7: 2-Massen-Modell

$$G_S(s) = G_{PT_4}(s) \cdot G_{AR}(s)$$

$$\mathbf{G}_{PT_4}(s) = \frac{Y(s)}{\mathbf{U}(s)} = \mathbf{c}^T (s\,\mathbf{I} - \mathbf{A})^{-1}\, \mathbf{B}$$

$$G_{AR}(s) = \frac{(T_{AR,Z}\, s + 1)(T_d\, s + 1)}{T_{AR,N}\, s + a_0}$$

Tabelle 2: Parametersatz des 2-Massen-Modells

m_1	m_2	c_1	c_2	$T_{AR,Z}$	$T_{AR,N}$	a_0
40 kg	30 kg	$70 \cdot 10^3$ N/m	$170 \cdot 10^3$ N/m	$7{,}5 \cdot 10^{-3}$ s	$50 \cdot 10^{-3}$ s	1,1

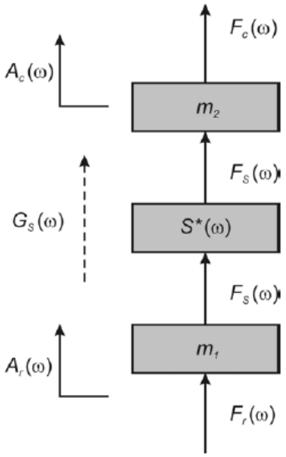


Abbildung 11: Experimentalmodell in Anlehnung an M.J. Griffin (Quelle: M. J. Griffin [3])

$$\begin{aligned} G_S(s) &= \frac{A_c(s)}{A_r(s)} \\ &= \frac{T_{11}\, s + 1}{T_{12}^2\, s^2 + T_{11}\, s + 1} \cdot \frac{T_{21}\, s + 1}{T_{22}^2\, s^2 + T_{21}\, s + 1} \cdot \frac{T_{AR,Z2}^2\, s^2 + T_{AR,Z1}\, s + 1}{T_{AR,N2}^2\, s^2 + T_{AR,N1}\, s + a_0} \cdot (T_d\, s + 1)^2 \\ &= \frac{\sum_{i=0}^{6} b_i\, s^i}{\sum_{i=0}^{6} a_i\, s^i} \end{aligned}$$

Vibration

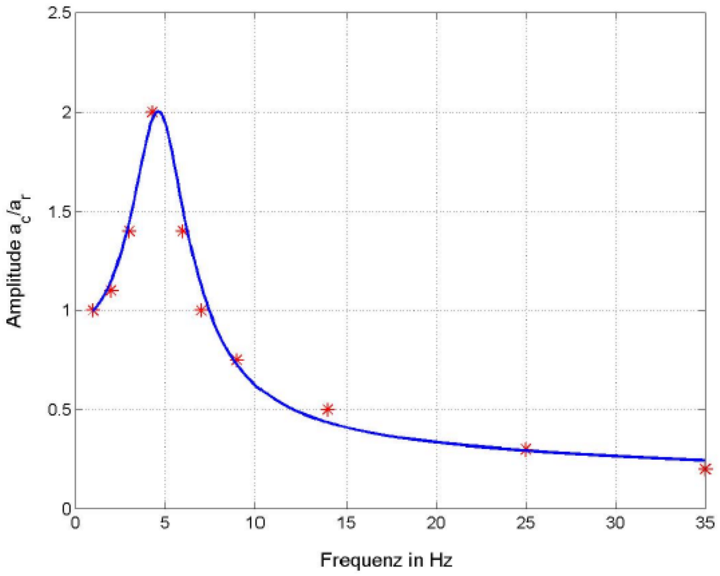
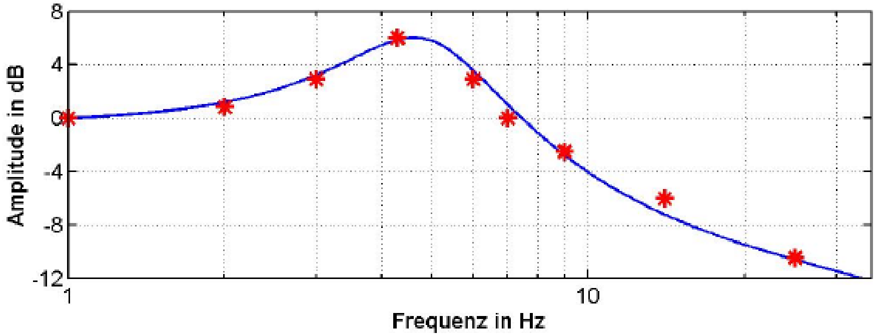


Abbildung 5: Gegenüberstellung des simulierten und experimentell erfassten Amplitudengangs: ▬ PT_2-basiertes Modell; * Experiment



two-mass model

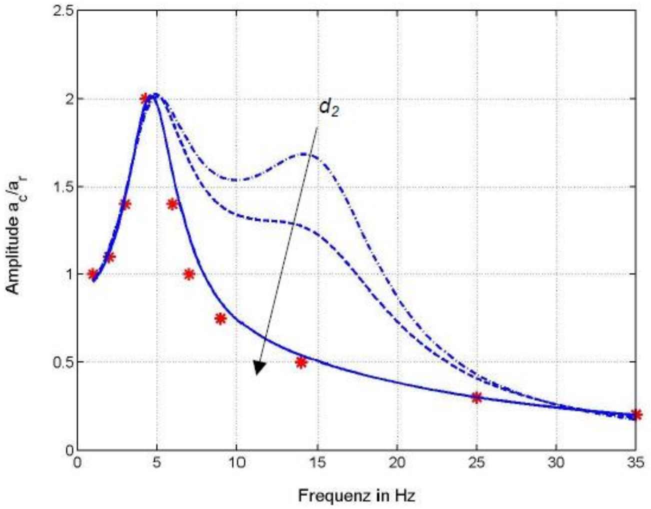
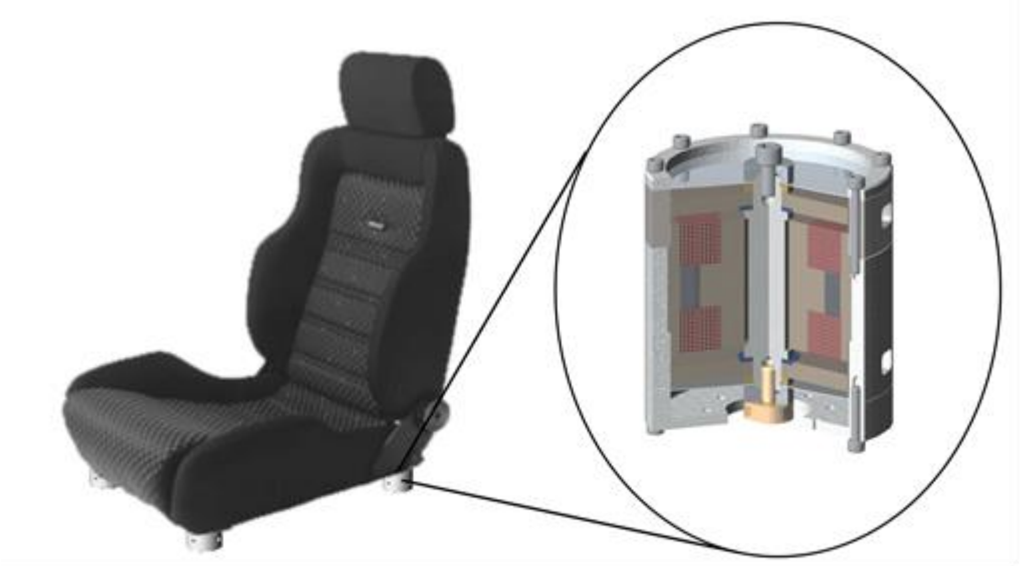


Abbildung 9: Amplitudengang der Sitz-Übertragungsfunktion in Abhängigkeit des Dämpfungskoeffizienten d_2: ▬ Simulation, * Experiment



Active vibration

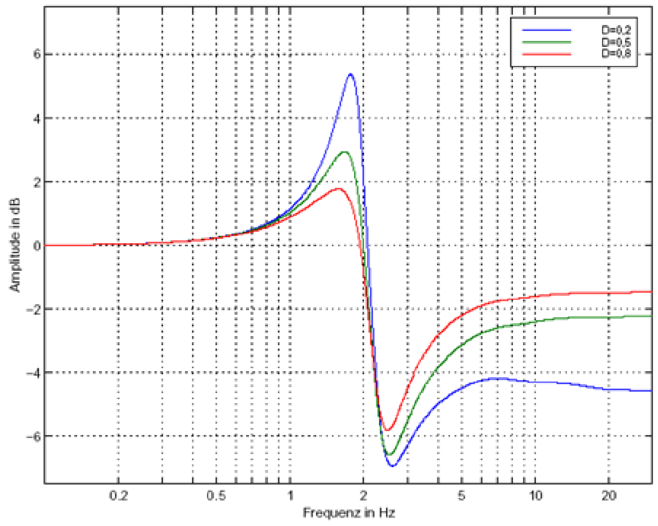


Abbildung 5.10: Isolationsgrad bei konstanter Steifigkeit c_{10}=50000 N/m

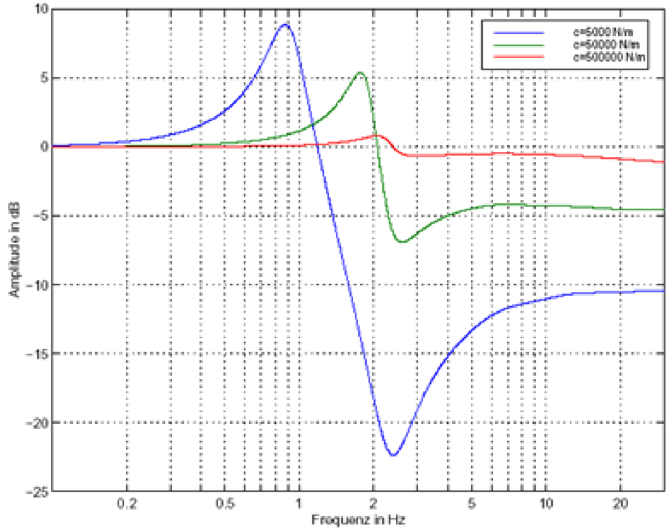


Abbildung 5.6: Isolationsgrad bei konstanter Lehr'scher Dämpfung D=0,2

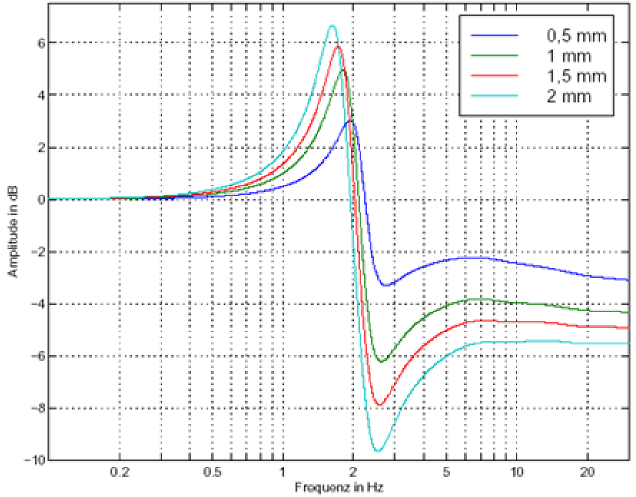
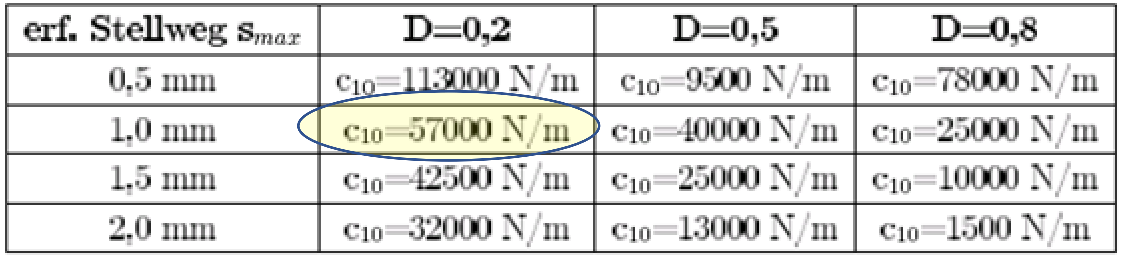


Abbildung 5.15: Isolationsverhalten für verschiedene erforderliche Stellwege s_{max} bei konstanter Lehr'scher Dämpfung D=0,2



erf. Stellweg s_{max}	D=0,2	D=0,5	D=0,8
0,5 mm	c_{10}=113000 N/m	c_{10}=9500 N/m	c_{10}=78000 N/m
1,0 mm	c_{10}=57000 N/m	c_{10}=40000 N/m	c_{10}=25000 N/m
1,5 mm	c_{10}=42500 N/m	c_{10}=25000 N/m	c_{10}=10000 N/m
2,0 mm	c_{10}=32000 N/m	c_{10}=13000 N/m	c_{10}=1500 N/m

- small actor amplitude drives high stiffness
- the higher the stiffness, the smaller the actor amplitude
- the higher the stiffness, the higher the required actor power
- the stiffer the system, the worse the vibration isolation
- the larger the actor amplitude, the smaller the resonance frequency
- the higher the damping, the higher the required actor power
- the higher the damping, the smaller the resonance amplitude
- the smaller the damping and the higher the actor amplitude, the better the vibration isolation above 4 Hz
- no vibration isolation below 1 Hz possible

⇨ Medium actor amplitude
⇨ Medium stiffness
⇨ Small damping
⇨ Modern high power battery systems capable