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Fully trimmed vehicle models with poroelastic finite element method, modelling technics

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Erlebnis
Gesamtfahrzeug

Summary

- Context
- Classical FEM modeling method for trims
- Theoretical background
- Full vehicle model creation process
- Trimmed Body validation
- Model investigations
- Conclusions

Context

- FEM full vehicle acoustic models are widely used all along the product development process to optimize the low frequency acoustics inside the cabin
- Standard method FEM-NSM allows to understand and improve structural issues by real life excitations but has a lot of limitations
- Other methodologies need to be use to help to understand deeper the action of the trims on the vibro-acoustic behavior of the vehicle

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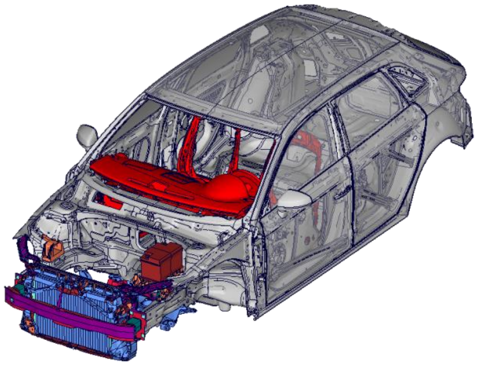
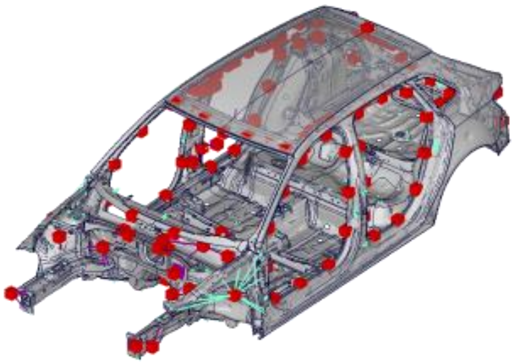
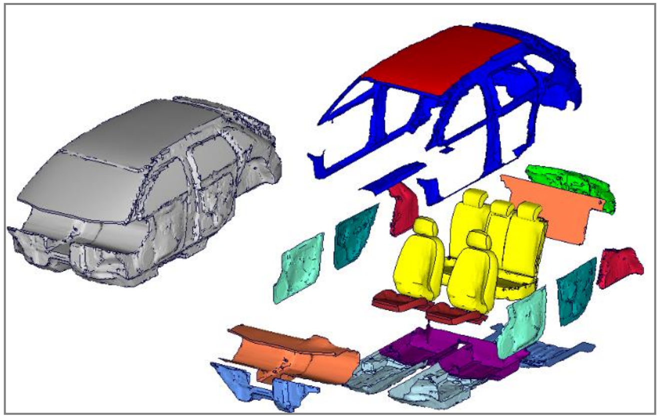
Classical FEM modeling method for trims

- Interior parts represented as concentrated masses or non structural masses
- Surface absorption
- Limitation of the method at 150-200Hz







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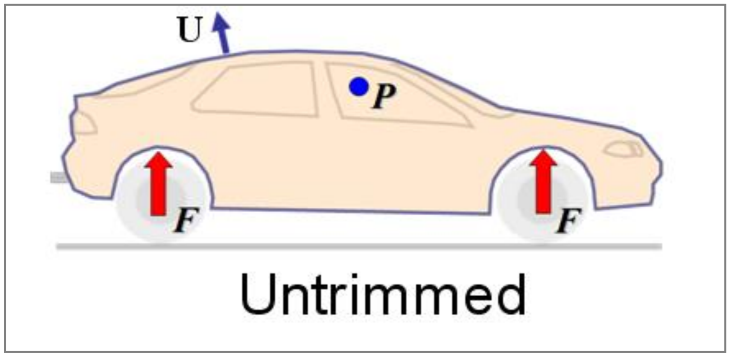
Theoretical background
PEM Numerical Model

- Untrimmed Formulation



C : FEM coupling matrix
on DOF's belonging to S

$$\begin{bmatrix} K-\omega^2 M & -C \\ -C^T & H/\omega^2 - Q \end{bmatrix} \begin{Bmatrix} W \\ P \end{Bmatrix} = \begin{Bmatrix} F \\ 0 \end{Bmatrix}$$

After condensation on structure variables …

$$\Longrightarrow \quad \boxed{\left\lfloor Z_S - \underbrace{C[A]^{-1}C^T}_{Z_a(\omega)} \right\rfloor W = F}$$

The structure is charged by an added impedance matrix $Z_a(\omega)$ which is resonnating vs. frequency

Theoretical background
Biot parameters

- Use of Biot Model:
  - Homogeneization technique to estimate visco elastic coupling between:

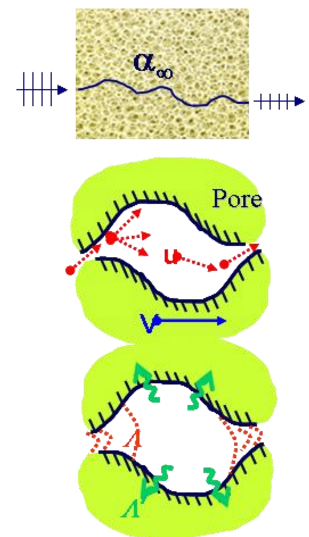
    Solid elastic frame displacement (standard solid equation)

    Pores fluid acoustic pressure (Helmholtz)
  - Set of 9 parameters to describe the porous media

$\{\tilde{K}_f, \tilde{\rho}_f, \tilde{\gamma}, \tilde{\rho}_s, \tilde{\mu}, \tilde{\lambda}\} \mapsto$

ϕ	porosity	Acoustic parameters
σ	static flow resistivity	
α_∞	tortuosity	
Λ	viscous characteristic length	
Λ'	thermal characteristic length	
ρ_1	density of the foam	Acoustic parameters / Structure parameters
$E(\omega)$	Young's modulus	Structure parameters
ν	Poisson ratio	
$\eta(\omega)$	structural loss factor	

9 parameters



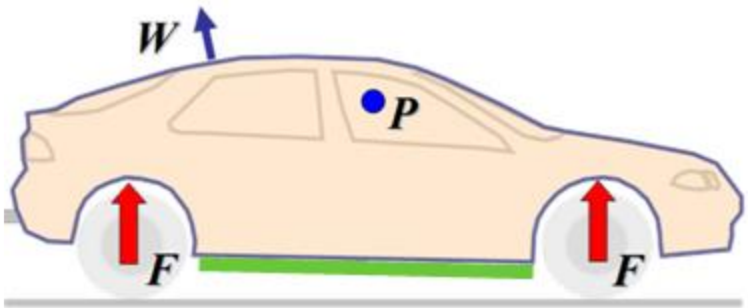
A measure of the complexity of the pore network

A measure of small pores and viscous effects

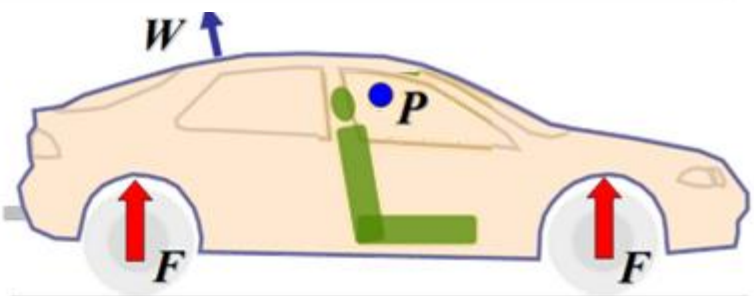
A measure of large pores and thermal effects

Theoretical background
PEM Numerical Model

- Trim Impedance Matrices

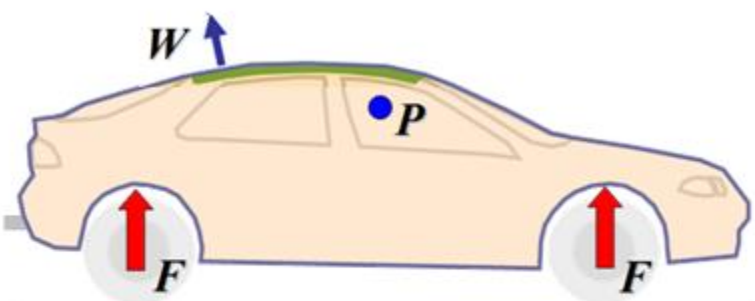


ONLY Y_{SS}



ONLY Y_{CC}

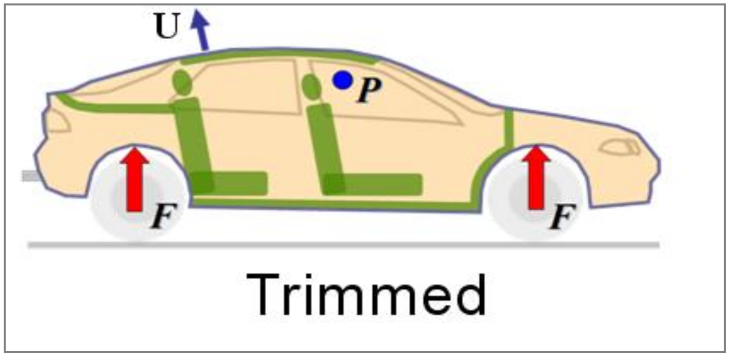
$$\begin{pmatrix} Y_{SS} & Y_{SC} \\ Y_{CS} & Y_{CC} \end{pmatrix}$$



$$Y_{SS}, Y_{CC}, Y_{SC}$$

Theoretical background
PEM Numerical Model

- Trimmed Body Formulations



Y : Impedance Matrix related to DOF's of S_1 and S_2

$$\left[\begin{pmatrix} Z_S & -C \\ -C^T & A \end{pmatrix} - \begin{pmatrix} Y_{SS} & Y_{SC} \\ Y_{CS} & Y_{CC} \end{pmatrix}\right] \begin{Bmatrix} W \\ P \end{Bmatrix} = \begin{Bmatrix} F \\ 0 \end{Bmatrix}$$

The porous Domain (trim) act as a coupler between the DOF's of the structure and the ones of the internal cavity

After modal projection …

$$\left[\begin{pmatrix} \left[\Omega_S^2 - jD - \omega^2 I\right] & -\tilde{C} \\ -\tilde{C}^T & \left[\Omega_F^2 - \omega^2 I\right] \end{pmatrix} - \begin{pmatrix} \tilde{Y}_{SS} & \tilde{Y}_{SC} \\ \tilde{Y}_{CC} & \tilde{Y}_{CC} \end{pmatrix}\right] \begin{Bmatrix} \tilde{W} \\ \tilde{P} \end{Bmatrix} = \begin{Bmatrix} \tilde{F} \\ 0 \end{Bmatrix}$$

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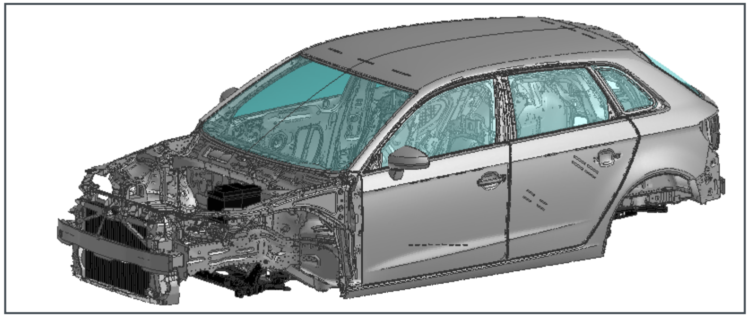
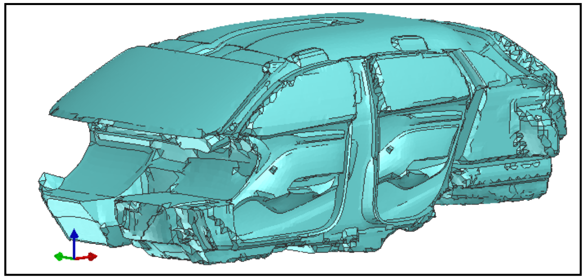
Full vehicle model creation process
Overview

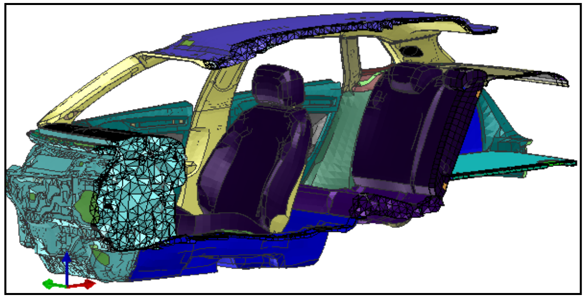
- Structure



- Acoustic cavity



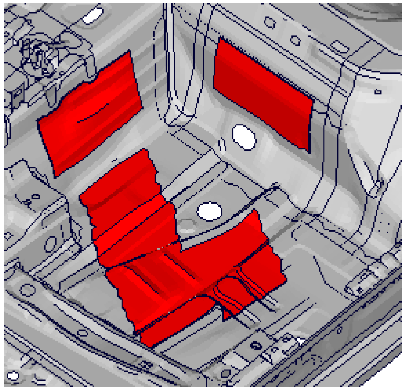
- Trim



Full vehicle model creation process
Structure

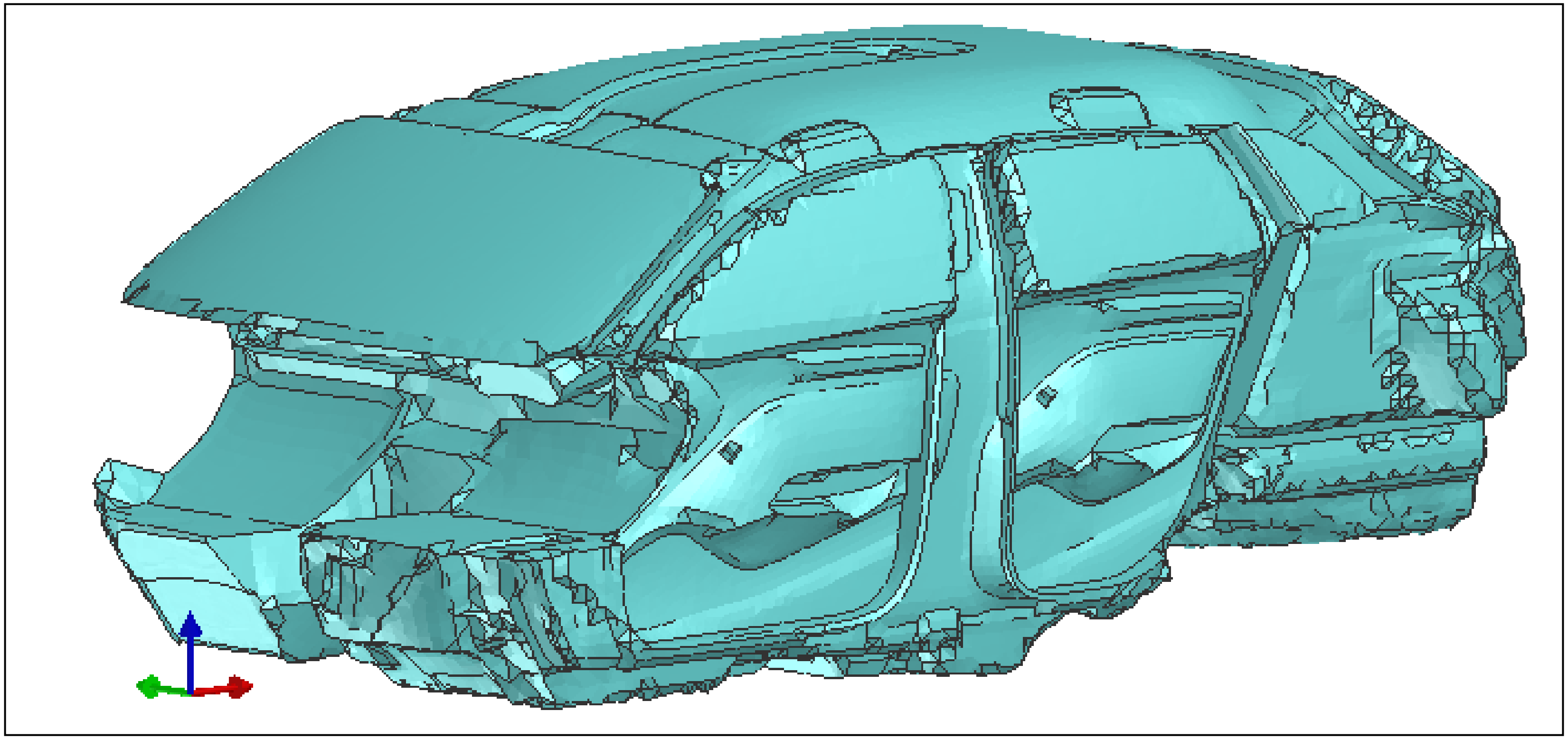
- Classical NVH trimmed FEM model
- Remove concentrated mass and smeared masses representing trims
- Damping pads as solid elements
- Reduce amount of data exported during modal basis computation
- Compute structural damping and export it as input for the coupled computation

	
Complete trimmed body vehicle model	Reduced vehicle trimmed body model for acoustics computations



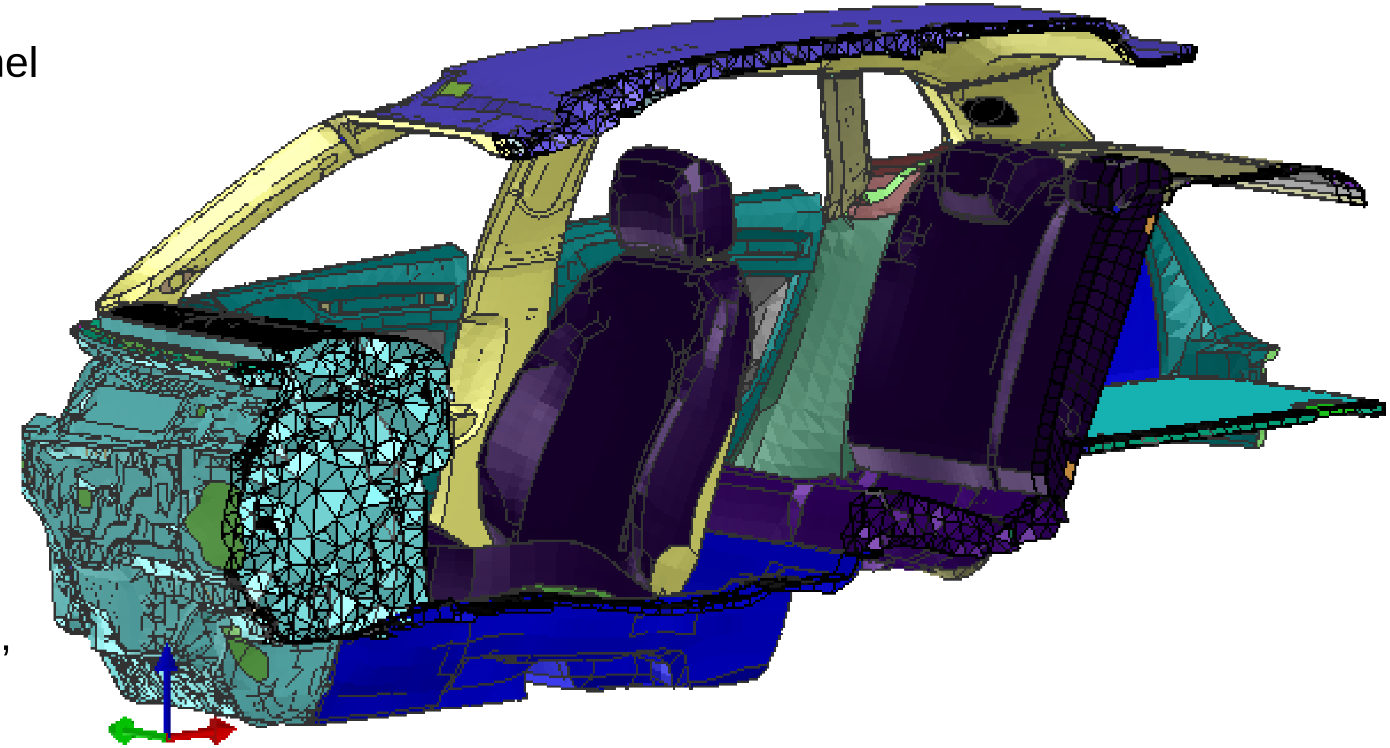
Full vehicle model creation process Acoustic domain

- Morph acoustic domain on geometry of trims and coupled structure



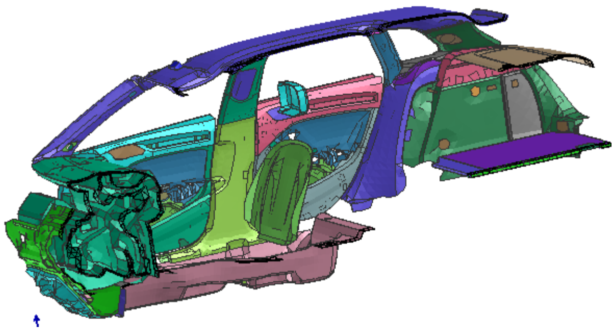
Full vehicle model creation process
Trim meshes

- Trims modeled as PEM
  - Dash-insulator
  - Instrument Panel
  - Doors
  - Carpet
  - Front seats
  - Rear seats
  - Package tray
  - Trunk carpet
  - Trunk trim,
  - A-B-C-D pillars,
  - Headliner

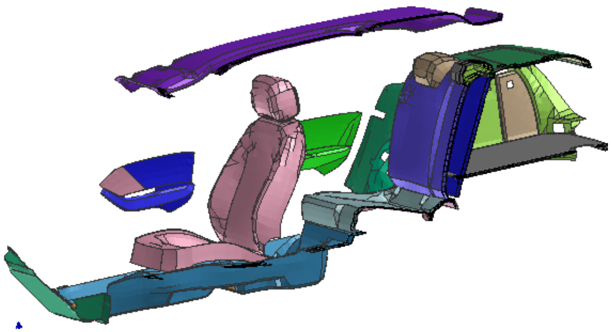


Full vehicle model creation process
Materials

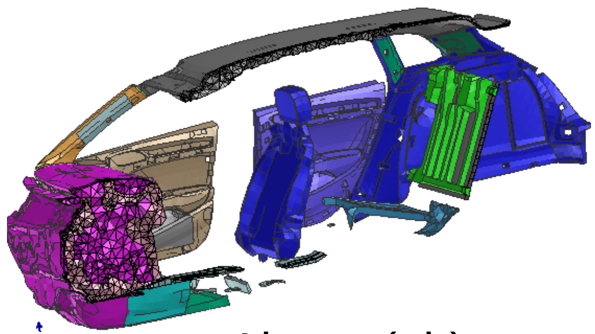
- Biot parameters for the porous materials (15 sample measured for the trim different parts of the car)
- Material property types



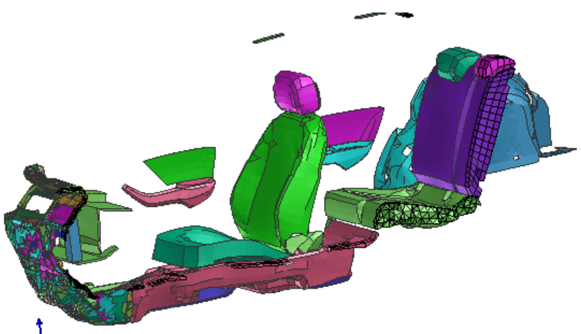
Solid elastic (plastic)



Equivalent fluid (fiber)



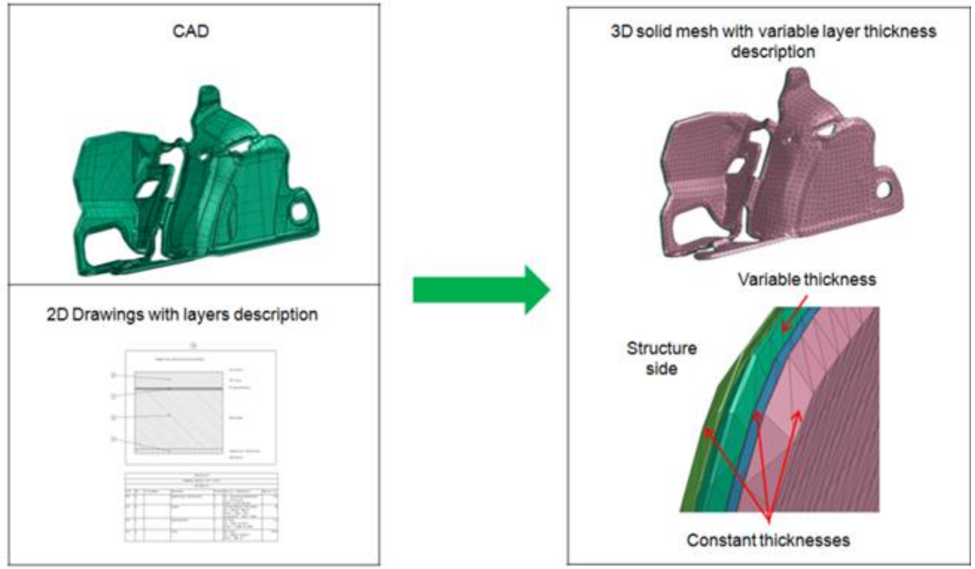
Airgap (air)



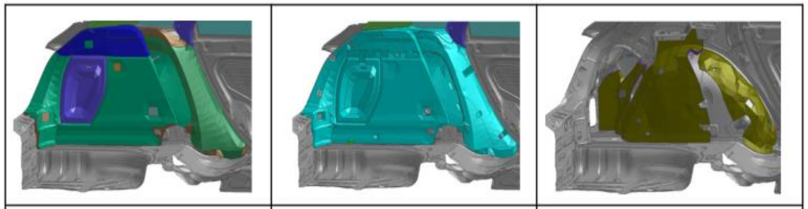
Porous (foam)

Full vehicle model creation process
Trim mesh creation

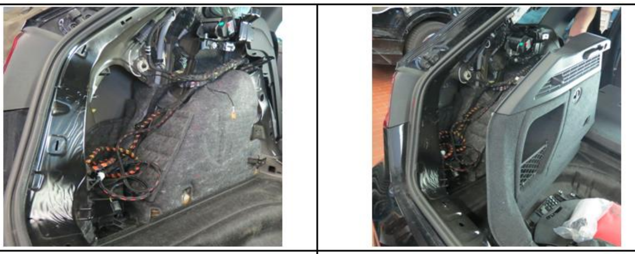
- Input data:
  - 2D drawings
  - CAD
  - Real part observation



- Integration of trims in the vehicle



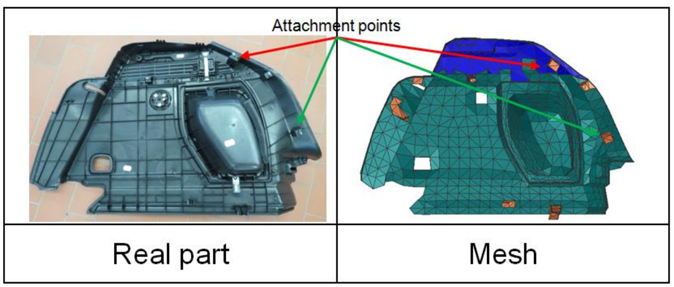
Trunk plastic trim | Trunk airgap | Wheelhouse absorbing trim

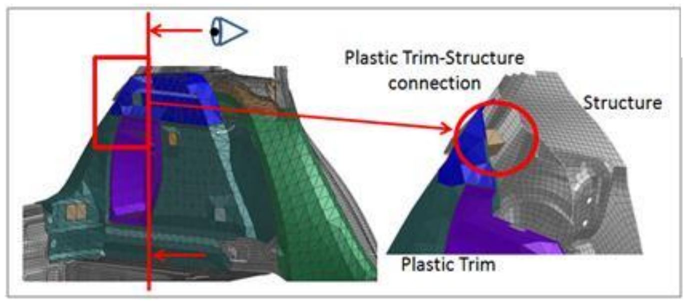


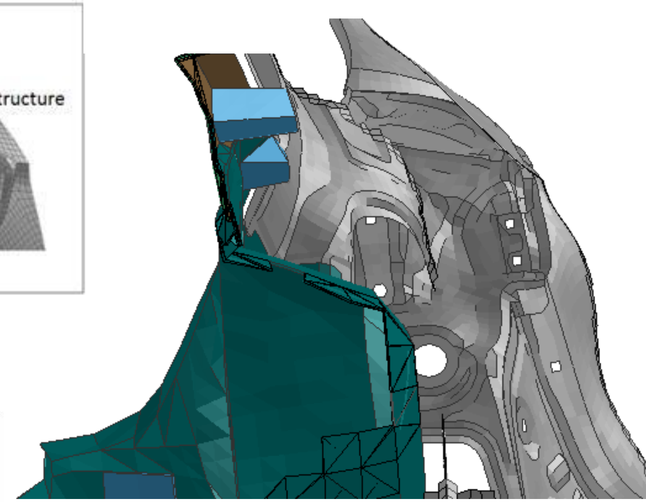
Wheelhouse absorber | Trunk plastic trim

Full vehicle model creation process
Trim coupling

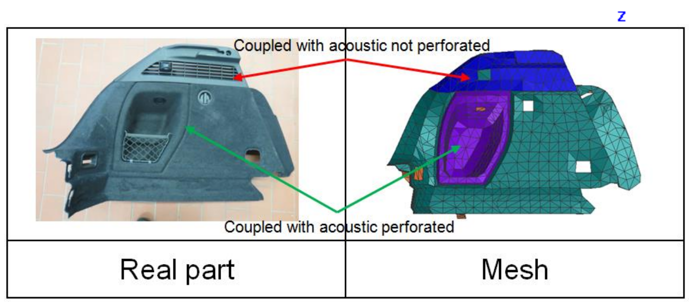
- Coupling with structure:
  - Most of the parts are laying on the structure: Use slider condition
  - Some parts are glued or pinned to the structure: Use fixed condition
    - Represent attachment points explicitly in the model





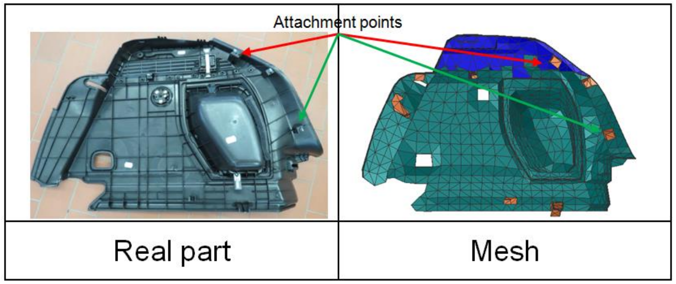


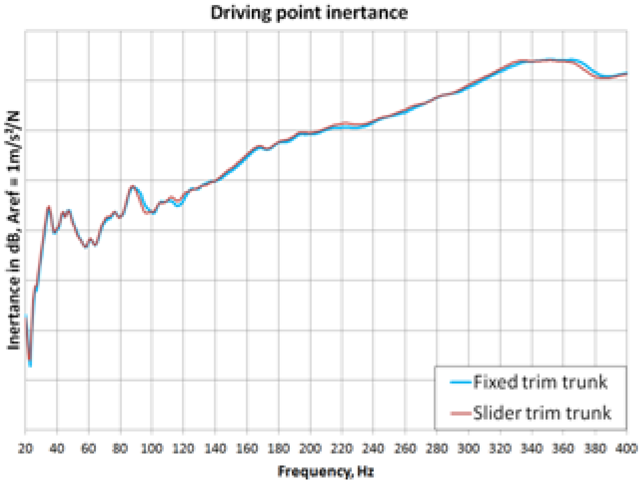
- Coupling with acoustic

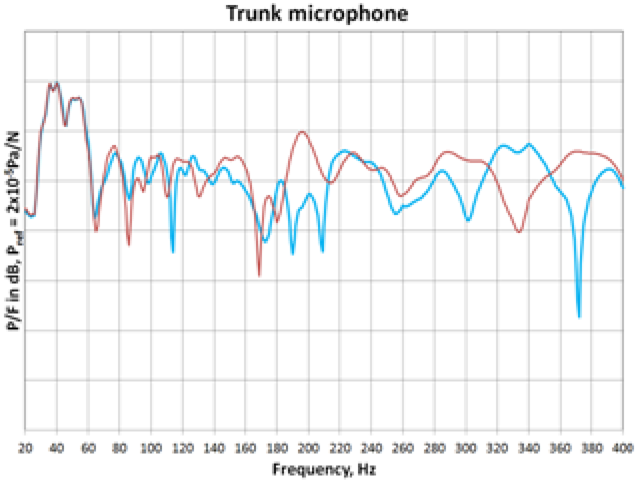


Full vehicle model creation process
Trim coupling: influence of coupling conditions

- Modify the coupling conditions at trunk trim fixation point to the structure
  - From fixed to slider







It is important to set the coupling as in the real car

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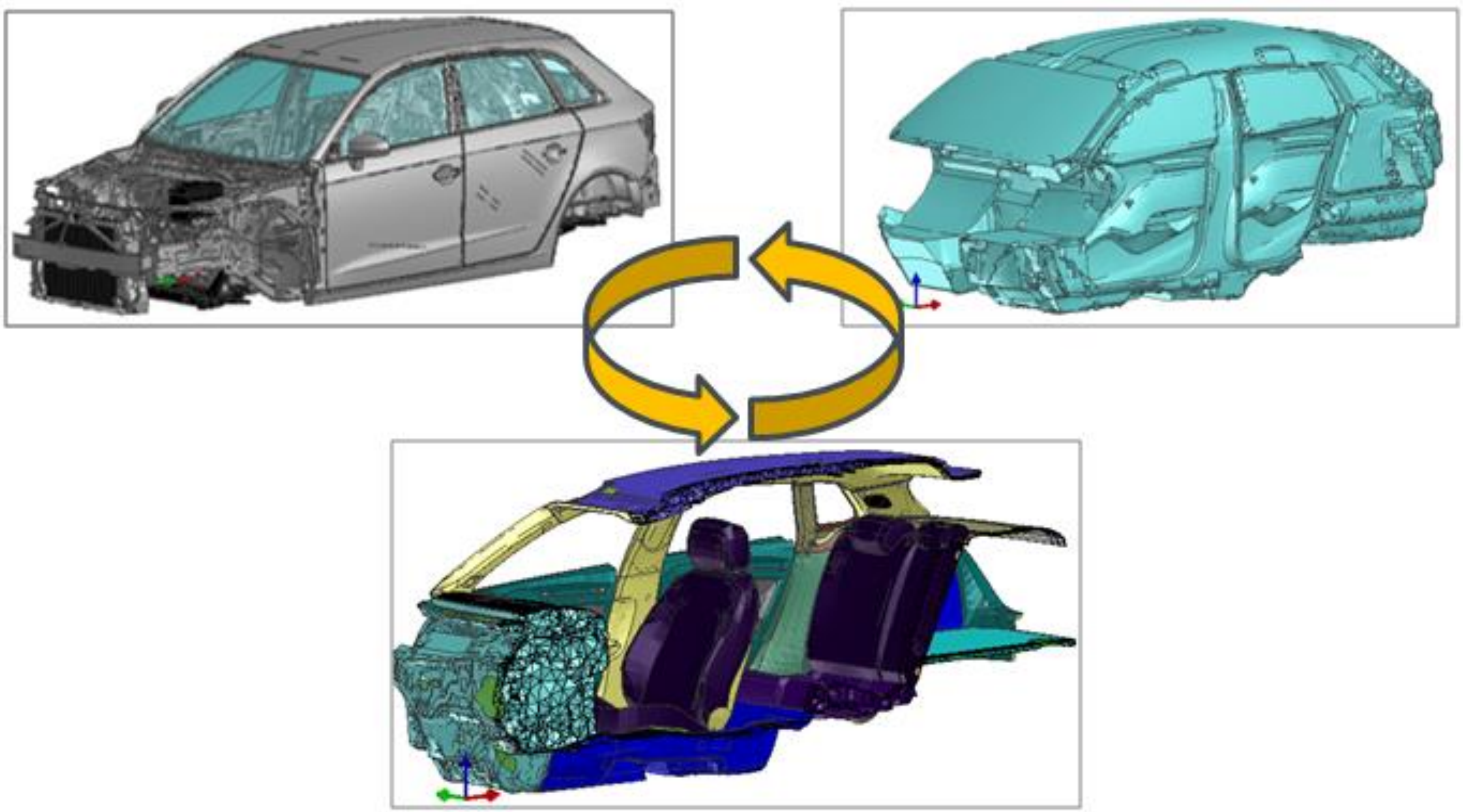
Trimmed body validation Measurements

- 5 structureborne excitation points
- 125 accelerometers
- 21 microphones

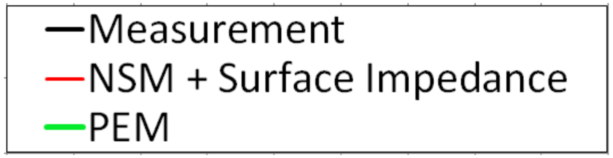
Excitation on rear suspension mount

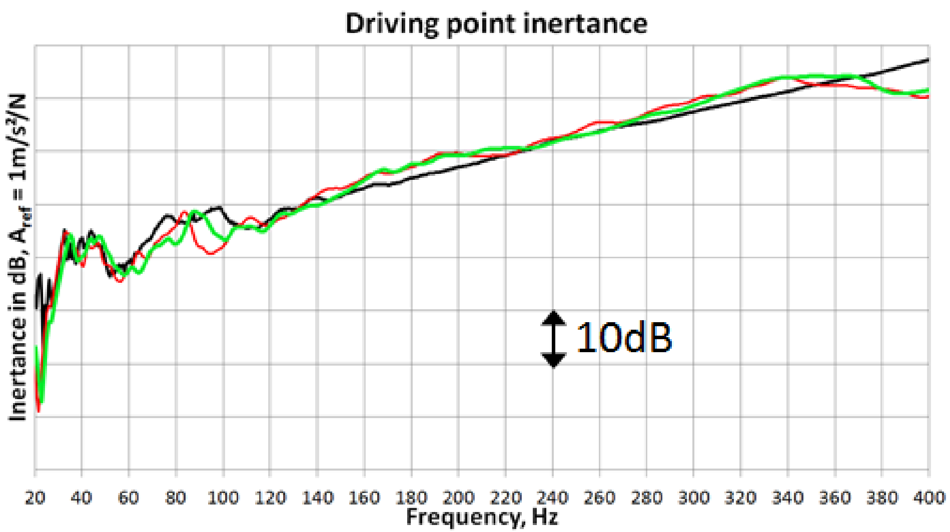
Trimmed body validation
Full vehicle FEM-PEM model

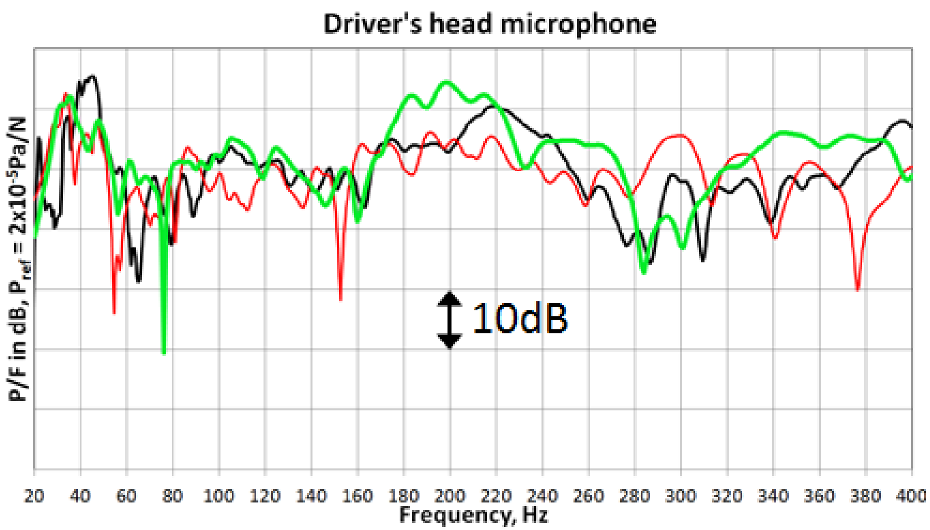


Trimmed body validation
Measurement vs Classical method vs FEM-PEM

- Results compared
  - Measurements
  - Classical FEM method (NSM + surface absorbers)
  - FEM-PEM

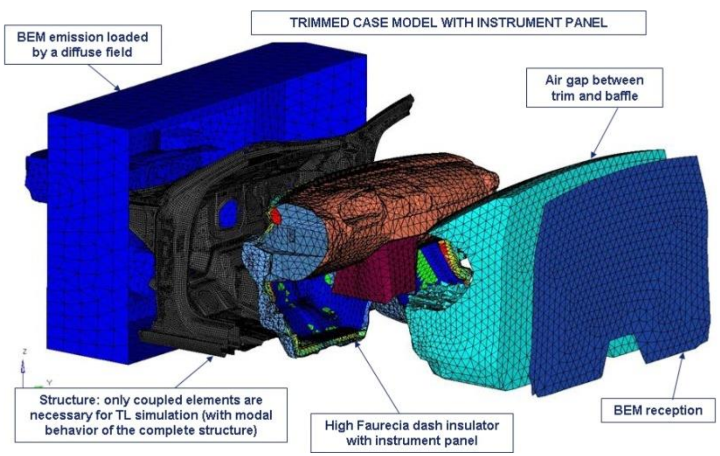


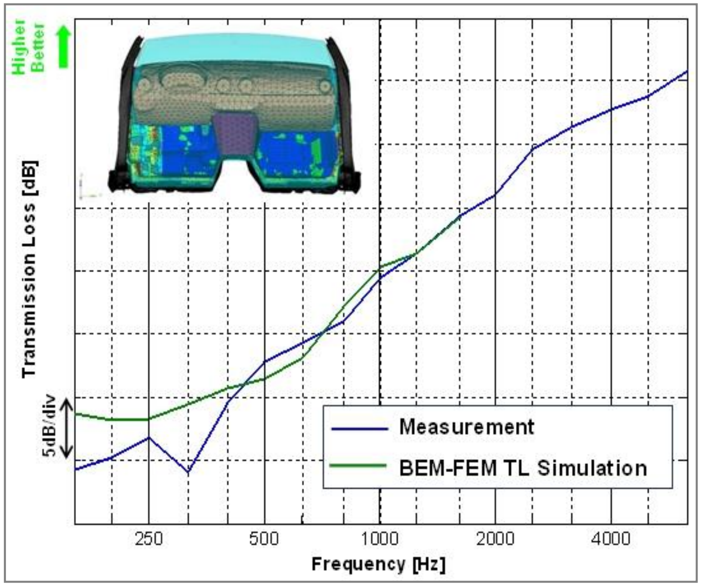




Trimmed body validation
Component validation

- Investigate and validate the individual behavior of trims
  - TL of component (dash insulator + instrument panel)





Cockpit module analysis using poroelastic finite elements, J.F. Rondeau, L. Dejaeger, Faurecia Acoustics And Soft Trim Div.; A. Guellec, AUDI AG; A. Caillet, ESI; L. Bischoff, Faurecia Acoustics And Soft Trim Div., SAE Paper 2014-01-2078

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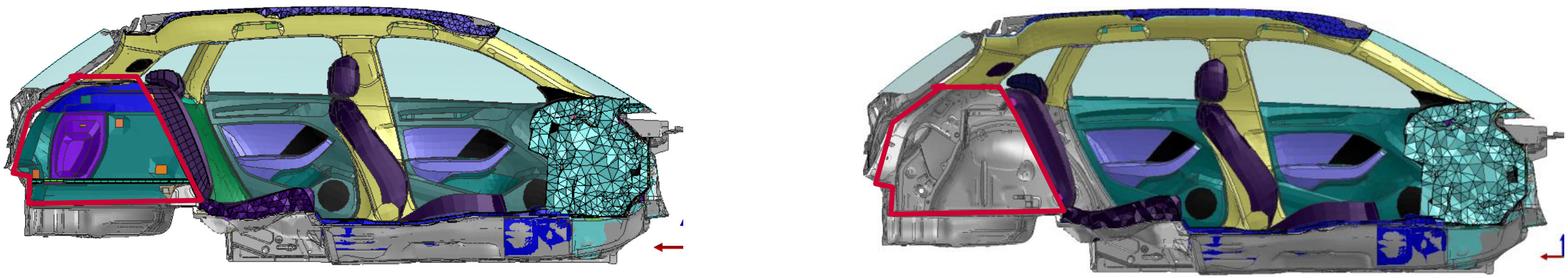
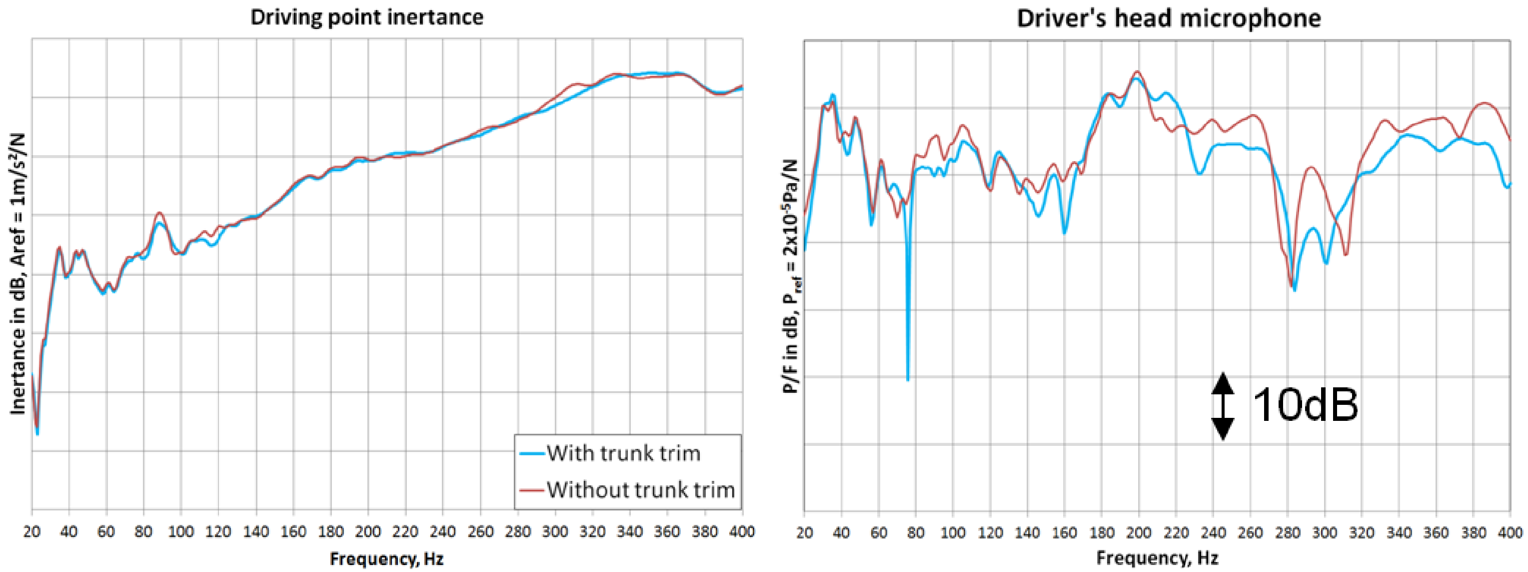
Model investigations
Configuration changes

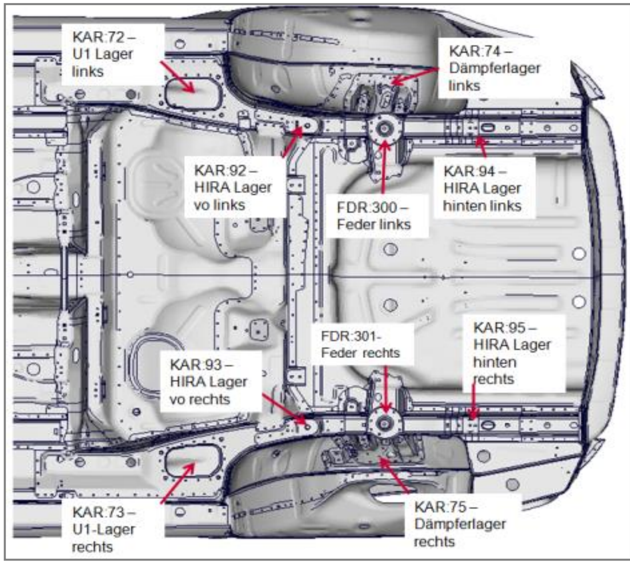
- Influence of removing the trunk trim by ideal excitation

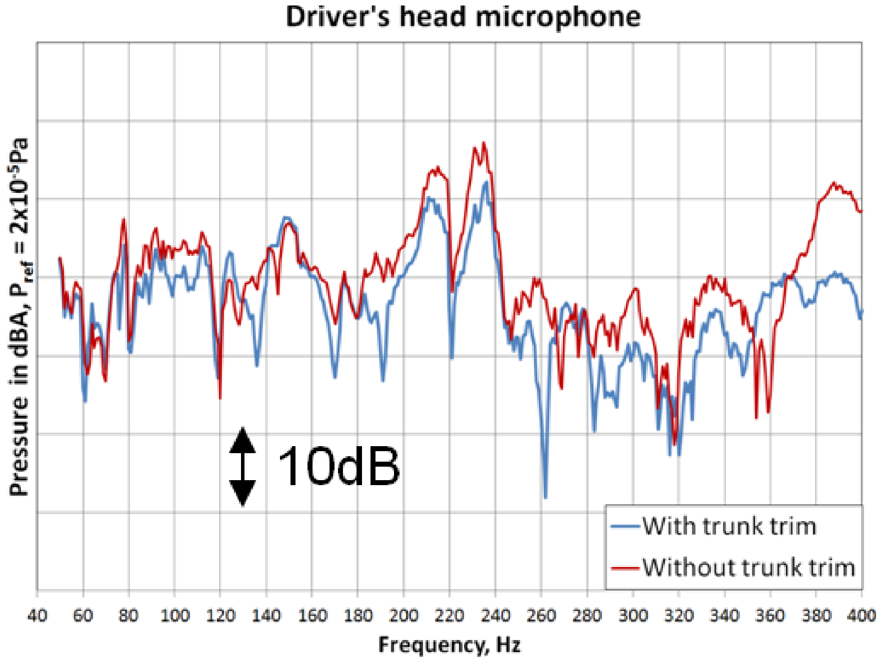


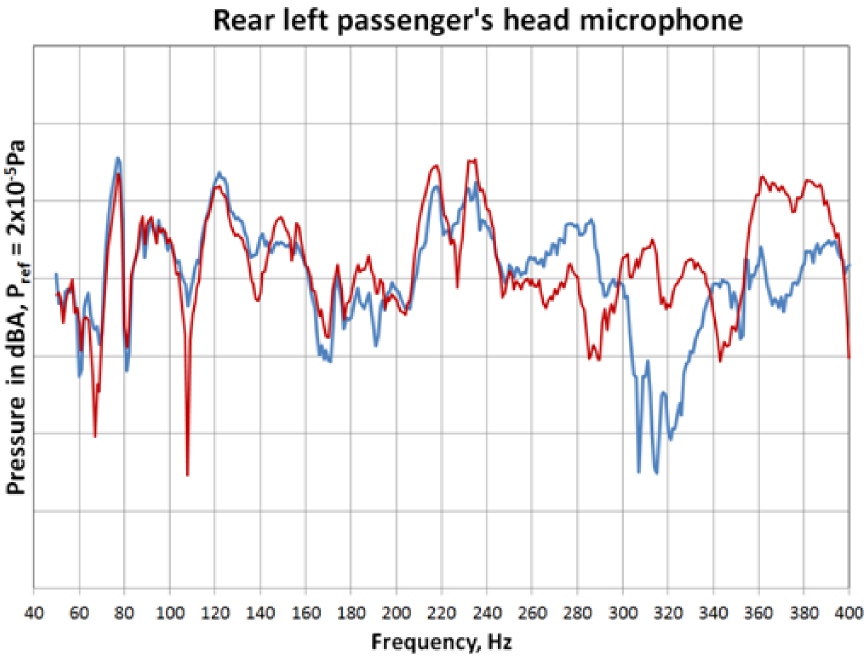


Model investigations
Real life excitation

- Influence of removing the trunk trim by a real life excitation (road noise)







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Conclusions

- FEM-PEM is validated on a component level and can be used in the product development process for TL predictions and optimization of car components

- Next Challenges
  - Perform sensitivity correlation on a full vehicle level
  - Improve analysis process

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Questions?

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