



# Effective FE Methodology for Full Trimmed Vehicle Body NVH Analysis in the Mid Frequency Range Applied to a Genetic Algorithm Optimization Process

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Methodology Description

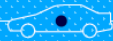
- Validation
- First results

Methodology applied to vehicle NVH optimization

- GOLD: Rieter Optimizer
- FE analysis methodology in GOLD
- Damping & Shape optimisation of trimmed vehicle

Conclusions

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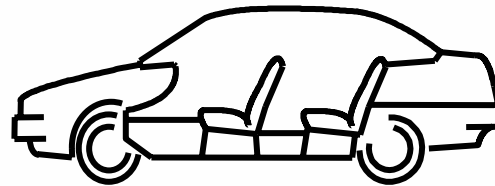
# INTRODUCTION



Why this methodology?

VIBRATION ANALYSIS AT VEHICLE LEVEL

Low Frequency



Mid Frequency

**Hardware requirements and computational time**

**Global modes**

**Low modal density**

**Simplified component FE models**

**Local modes**

**High modal density**

**Detailed component FE models**

**Local damping & stiffening effects**

**Efficient analysis methodology needed**

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## INTRODUCTION



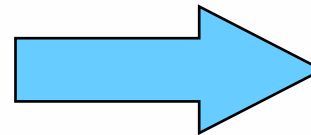
Why this methodology?

### NVH optimization problem

Large optimization problem

Many variables

Many possible solutions  
(billions)

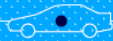


**RIETER GOLD**

(GENETIC ALGORITHMS BASED)

**NVH optimization procedure based on GA requires many FEA**

**Efficient Analysis Methodology needed**



# INTRODUCTION



Why this methodology?

**Efficient**

=

- **Fast**

- **Accurate** (as SOL108)

- **Cheap** (no supercomputers)

**Targets:**

- **Extend calculation range to mid freq**

- **Faster Damping & Shape optimization by GOLD**



# METHODOLOGY DESCRIPTION



Analysis methodology based on modal approach

Main Features:

Damped panel model

- Emerald calculates equivalent  $E_b(f)$ ;  $DLF_b(f)$ ;  $E_m(f)$ ;  $DLF_m(f)$
- $E_b$ ;  $DLF_b$ ;  $E_m$ ;  $DLF_m$  assigned in 2D shell



No DoF increment, easy to include damping

Correct values for membrane and bending DLF



# METHODOLOGY DESCRIPTION



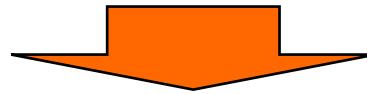
Analysis methodology based on modal approach

Main Features:

Modal basis calculation

Sub-structuring technique of MSC.Nastran ACMS:

- Model automatically divided into geometric sub-domains
- Sub-domains organized in a tree structure



Sub-domain calculation on standard workstation



# METHODOLOGY DESCRIPTION

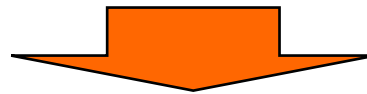


Analysis methodology based on modal approach

Main Features:

Distributed Memory Process

- Calculation per each sub-domain
- CPU dependent



Sub-domain calculation on standard workstation



# METHODOLOGY DESCRIPTION

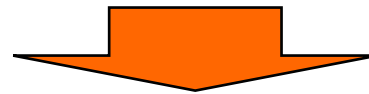


Analysis methodology based on modal approach

Main Features:

FRF calculation

- fastFRRD1 module
- Combination with previous features



Much faster FRF calculation



# VALIDATION

First trial on vehicle model

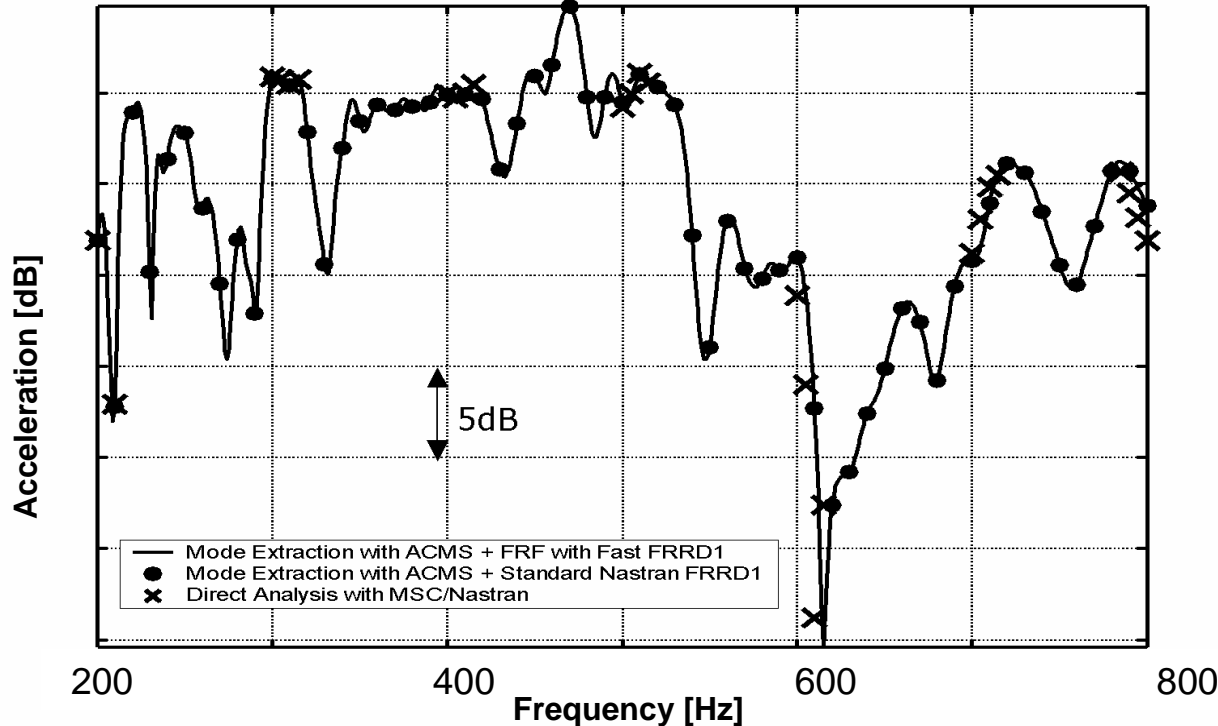
~1.5 mio. DoF

Modal base up to 1200Hz

5900 modes



### Comparison to SOL108





# FIRST RESULTS

Trimmed vehicle model

~3 mio. DoF

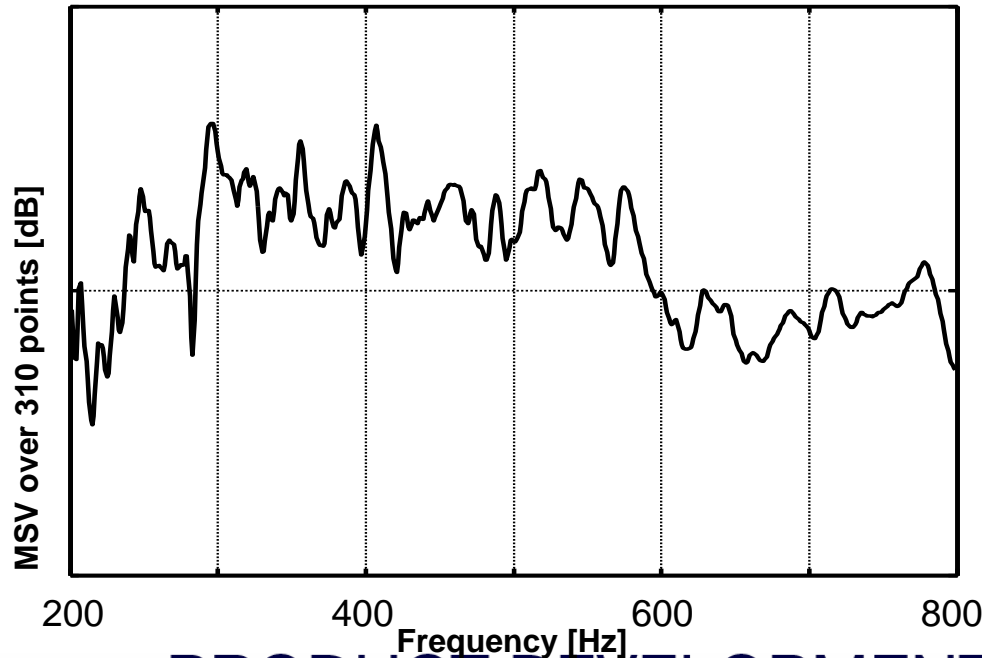
Modal base up to 1200Hz

14932 modes



Modal base calculation = 14 hrs.

Response at 310 nodes, step 1Hz = 20 hrs.



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# RIETER GOLD

**RIETER**

Special RIETER software (Matlab<sup>®</sup>+MSC.Nastran):  
**Automatic DAMPING & SHAPE panel optimization**

## Possible input variables

### Damping optimization:

- **panel material**
  - type
  - thickness
- **damping material** (freq,T)
  - type
  - thickness
- **temperature areas**
- **local damping distribution**

### Shape optimization:

- **panel shape**
  - flat
  - rib
  - embossment
  - soap-film
- **shape change areas**



# RIETER GOLD



Special RIETER software (Matlab®+MSC.Nastran):  
**Automatic DAMPING & SHAPE panel optimization**

## Main features:

Highly efficient automatic optimization method (GA)

Optimization input

**VARIABLES**

Possible damping type, thickness, shape, etc.

Response evaluation

Matlab®

Optimization criteria

MSC.Nastran

Automatic generation & selection of panel damping & shape

GA SEARCH ENGINE

Best damping+shape configurations selected



# RIETER GOLD

**RIETER**

Special RIETER software (Matlab®+MSC.Nastran):  
**Automatic DAMPING & SHAPE panel optimization**

## Main features:

Highly efficient automatic optimization method (GA)

Wide choice of optimization criteria



## Targets:

- weight
- performance
  - structural response (vibration)
  - acoustic response (SPL)

## Free user customization:

- optimization strategy (priority)
- targets
- constraints



# RIETER GOLD

**RIETER**

Special RIETER software (Matlab®+MSC.Nastran):  
**Automatic DAMPING & SHAPE panel optimization**

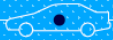
## Main features:

Highly efficient automatic optimization method (GA)

Wide choice of optimization criteria

Simple user steps →

- Easy-to-use interface text file
- Just FE model to prepare...
  - mesh
  - damping/shape areas
  - excitation(s)
- ... and input variables to define
- Then wait for the optimized solution



# RIETER GOLD



Special RIETER software (Matlab®+MSC.Nastran):  
**Automatic DAMPING & SHAPE panel optimization**

## Main features:

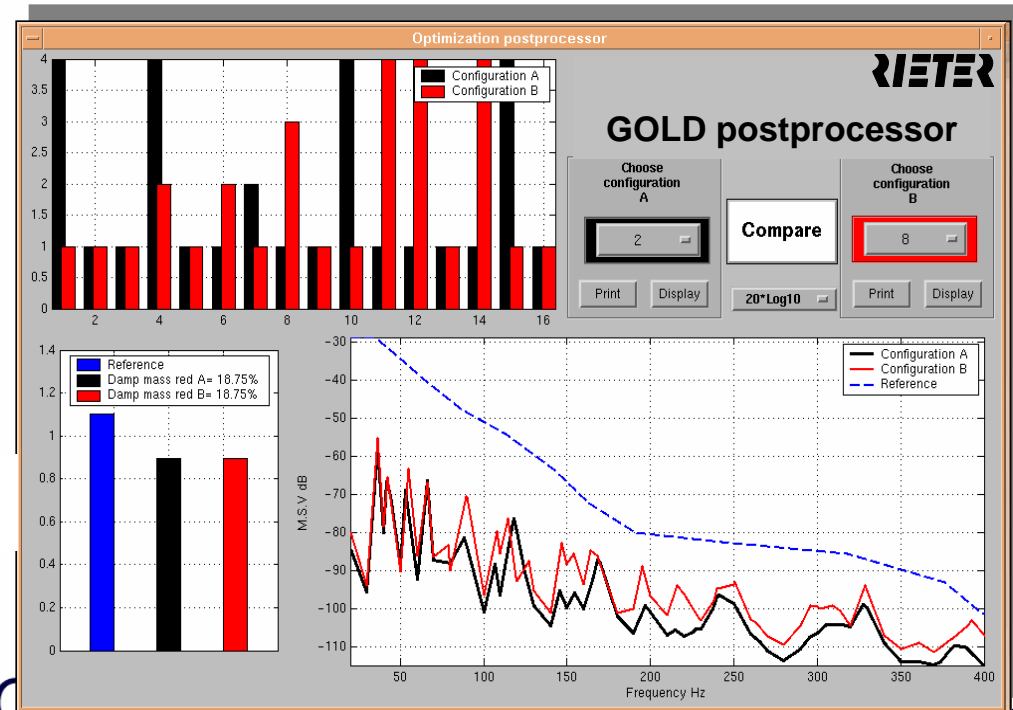
Highly efficient automatic optimization method (GA)

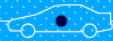
Wide choice of optimization criteria

Simple user steps

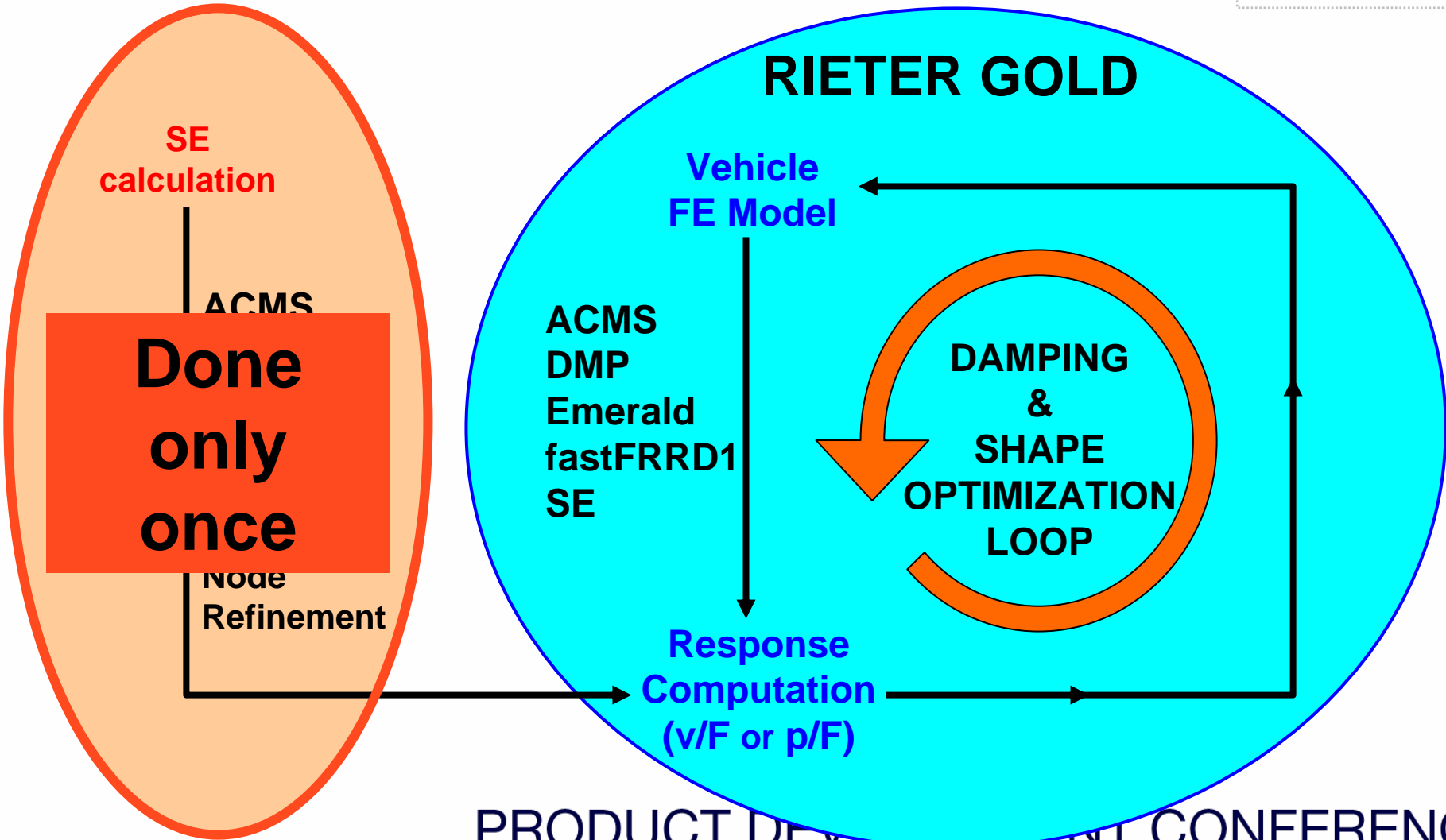
Control monitor

Postprocessing interface (best solutions)





# FE METHODOLOGY IN GOLD



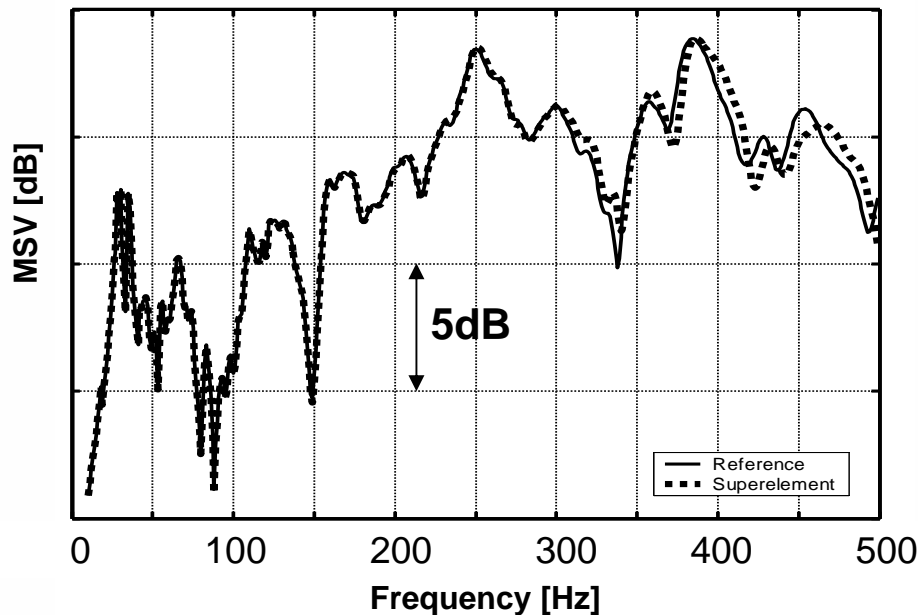


# FE METHODOLOGY IN GOLD



Complete vehicle FE model

Full run vs SE run



SE run: much lower calculation time

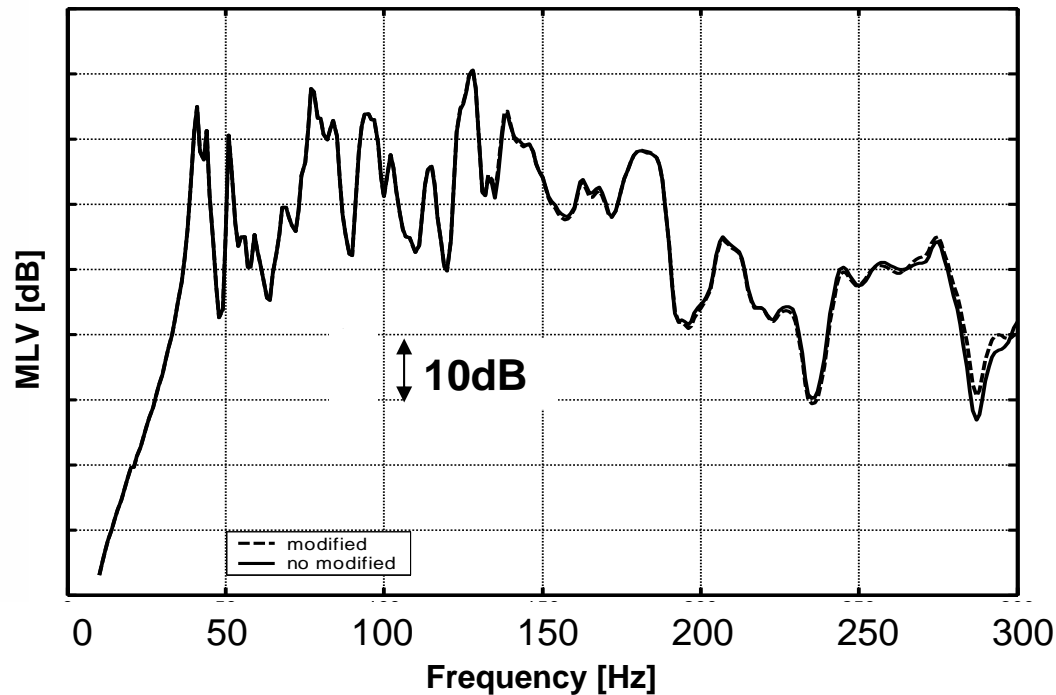
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# FE METHODOLOGY IN GOLD



Complete vehicle FE model  
Reduction nodes modified



Modified nodes: much lower calculation time

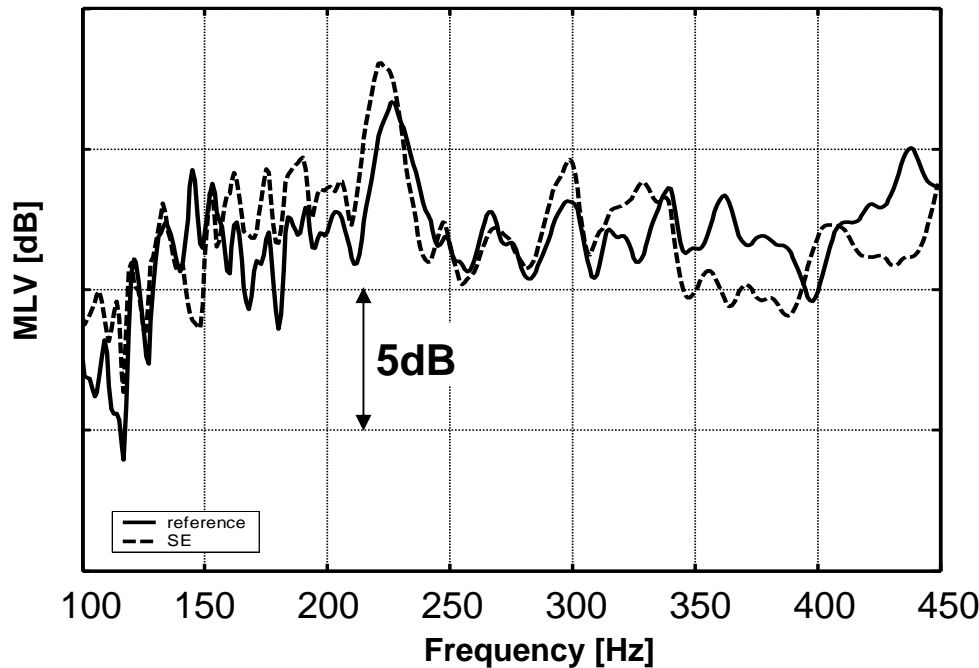
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# FE METHODOLOGY IN GOLD



Complete vehicle FE model  
Full run vs Reduced run



Full run: many days... → Reduced run: 45 minutes

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# DAMPING & SHAPE OPTIMIZATION OF TRIMMED VEHICLE



**Trimmed vehicle model (>3 mio. DoF)**

Multiple excitation (load case)

## **Target:**

- Floor, Dash, Tunnel panels
- MSV over 153 nodes until 450Hz improved
- Keep weight



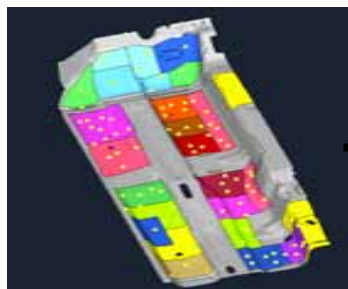
# DAMPING & SHAPE OPTIMIZATION OF TRIMMED VEHICLE



Trimmed vehicle model (>3 mio. DoF)  
Optimization variables

## Damping optimization:

- **Material1** {
  - thickness1
  - thickness2
- **Material2** {
  - thickness3
  - thickness4
- **Local damping distribution**



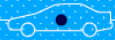
## Shape optimization:

- **Design options**
  - flat
  - 11 longitudinal ribs
  - 9 transversal ribs
  - 8 soap-film
- **Shape change areas**



**Total possible solutions**  
 **$\sim 3.6 \cdot 10^{19}$**

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# DAMPING & SHAPE OPTIMIZATION OF TRIMMED VEHICLE



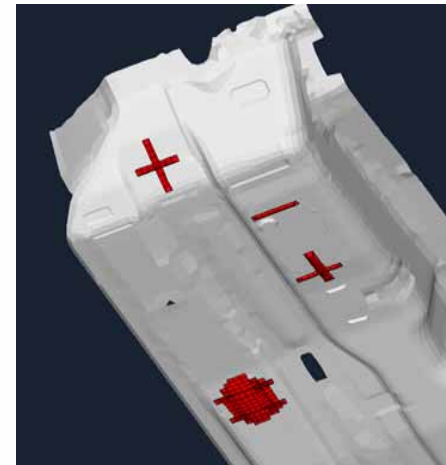
Trimmed vehicle model (>3 mio. DoF)

Final optimal solution found in ~1 week  
(many intermediate solutions meanwhile)

**Damping package**



**Shape design**

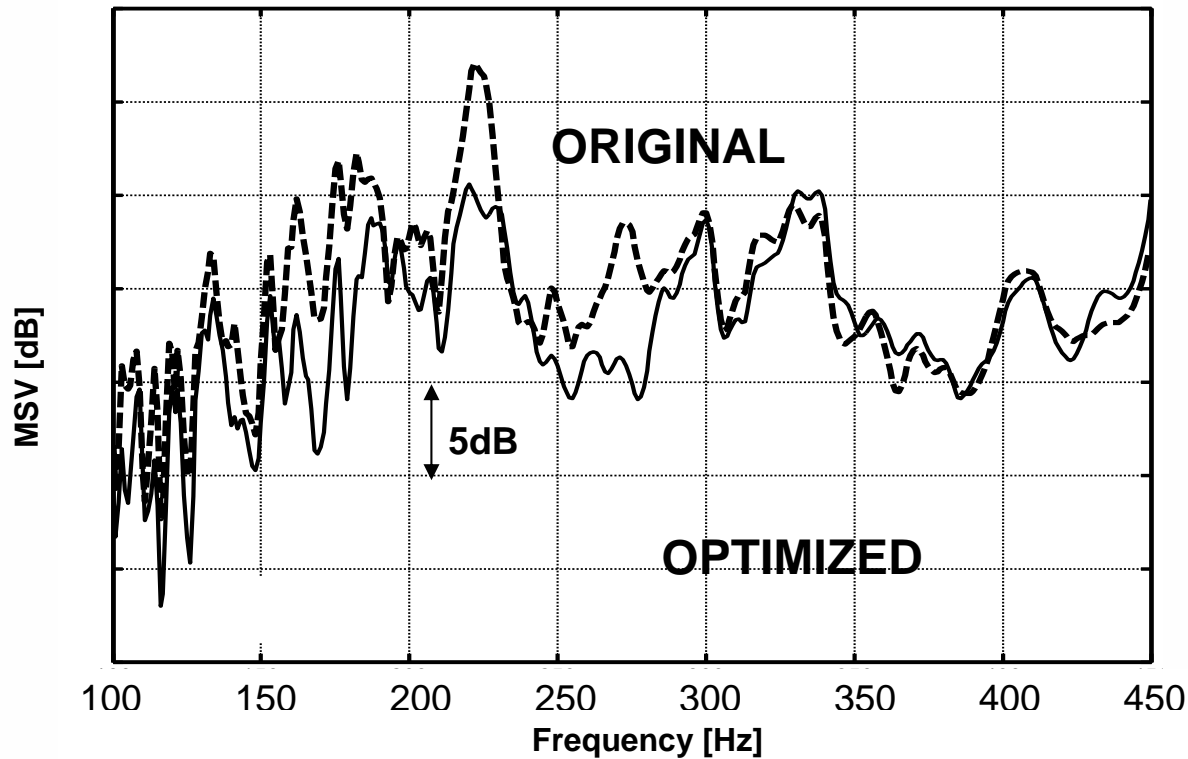




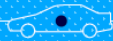
# DAMPING & SHAPE OPTIMIZATION OF TRIMMED VEHICLE



Trimmed vehicle model (>3 mio. DoF)  
Optimized vs Original panel configuration



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# CONCLUSIONS



- **New efficient methodology for FRF of large vehicle FE models**  
(ACMS, DMP, Emerald, fastFRRD1, Superelements, Reduction node modification...)
- **Positively tested against standard MSC.Nastran (sol108, sol111)**
- **Embedded into RIETER GOLD: automatic damping & shape optimization**
- **Successfully applied to trimmed vehicle FE models** → **45 min. on standard ws**  
(>3 million DoF, FRF 200~800Hz, modal basis ~1200Hz)
- **Practical example: damping & shape optimization**
- **RIETER standard for practical vehicle development (4 done, 4 ongoing)**