Engineering Center Steyr GmbH & Co KG (ECS)

Dynamic Simulation in Vehicle Engineering 10.-11. Mai 2012
Generating Verified Load Data Using Virtual Iteration Method

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Content

- **Motivation for Virtual Iteration**

- **General Approach of Virtual Iteration**

- **Example „8x4 Truck" (Full Vehicle) with invariant road excitation for fatigue and comfort**

- **Example „Suspension Test Rig" with invariant strains for test bench modifications**

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Motivation:

- to generate **external loads** based on internal, measured **response**

- to get invariant excitations for parameter variation

- for fatigue and comfort investigation

- for modification/optimization of test bench concepts

Virtual Iteration General Approach

Load (drive) $\quad$ Input u_n $\rightarrow$ **System (MBS)** $\rightarrow$ Output y_n $\quad$ **Desired (response)**
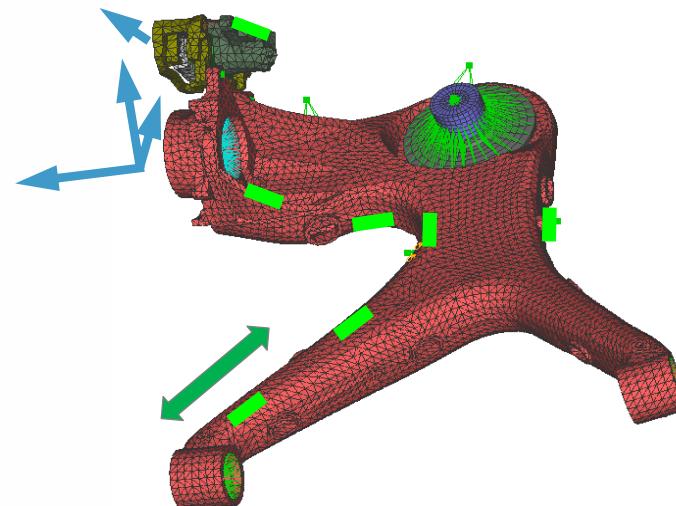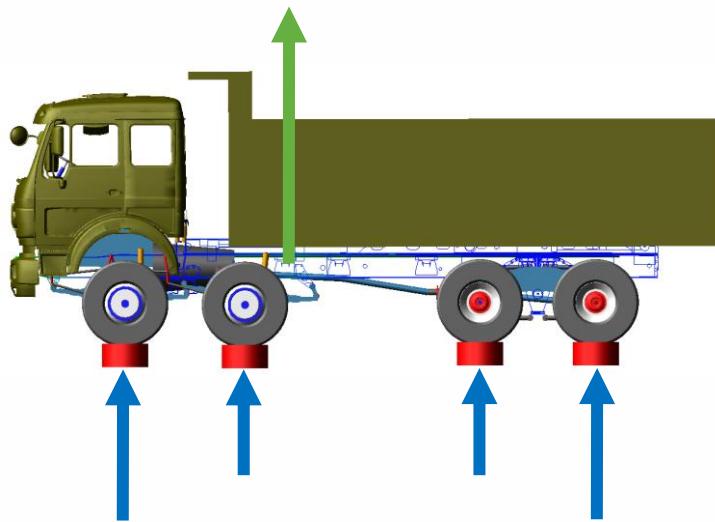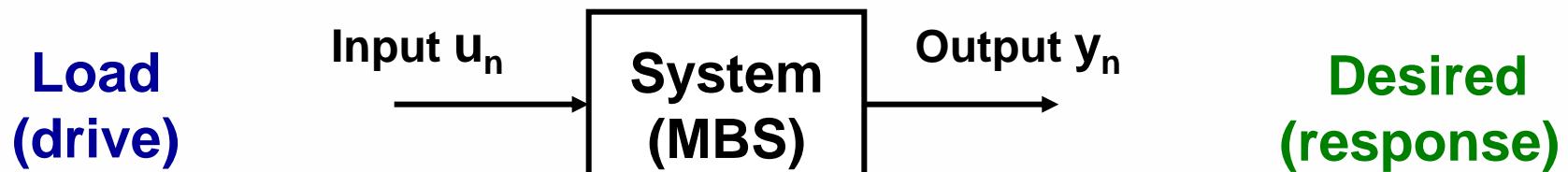
- **Inverse non-linear problem:** *find loads for given responses*

| Drive	Response

Drive
- **Forces (external)**
- **Displacements (absolute)**

Response
- **Accelerations**
- **Strains**
- **Displacements (relative)**
- **Forces (internal)**

Virtual Iteration
# General Approach

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1. Pink noise

u_{Noise}

y_{Noise}
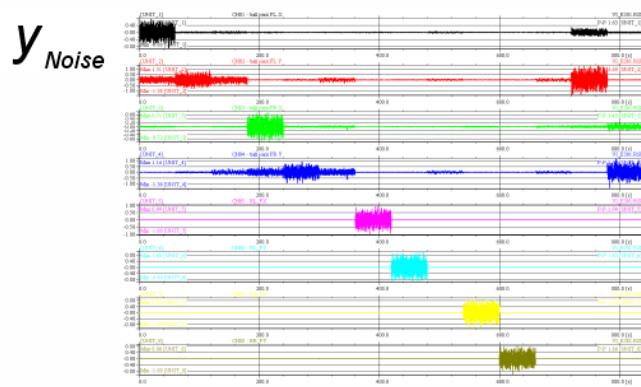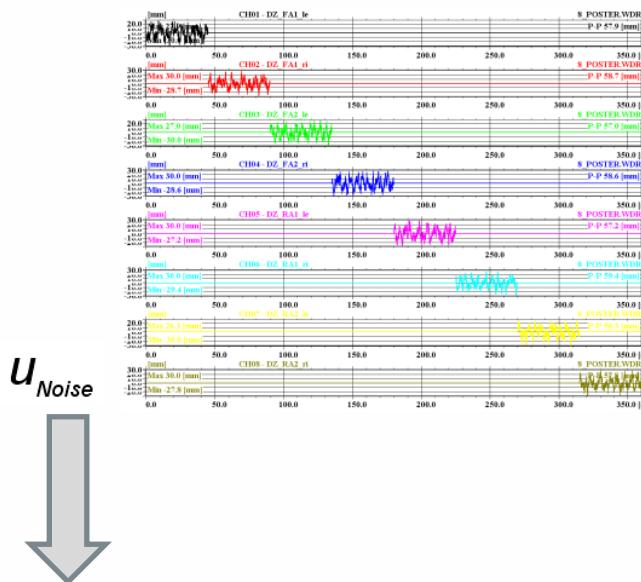
$$F = \frac{y_{Noise}}{u_{Noise}}$$
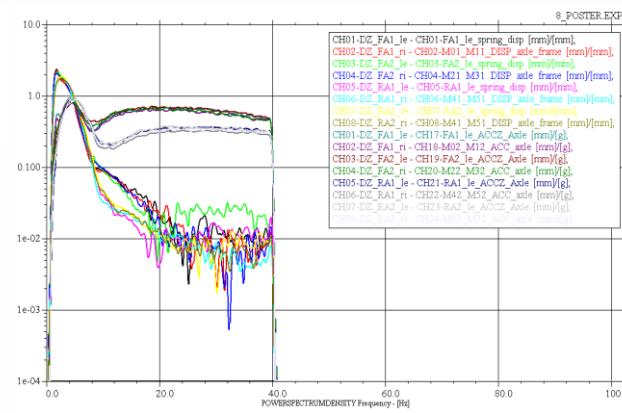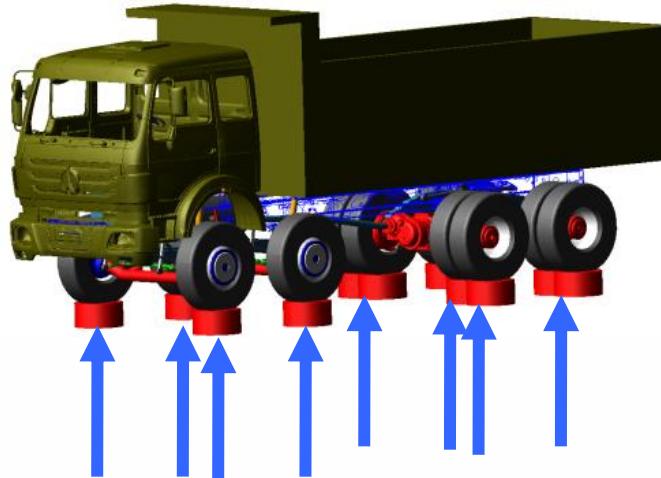
$$u_0 = F^{-1}\, y_{Desired}$$

2. Response of noise

3. Transfer function

6. Response = desired
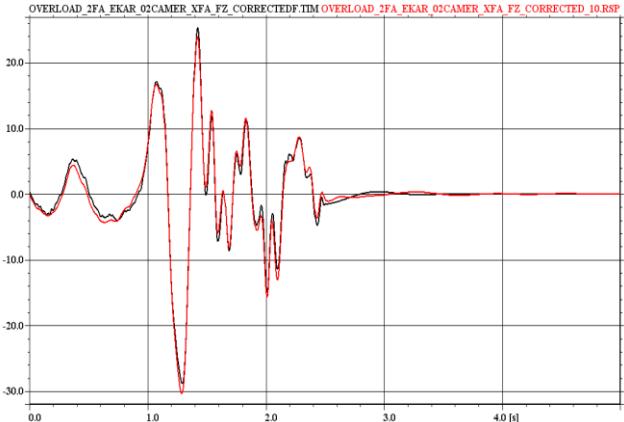
**5. Response**
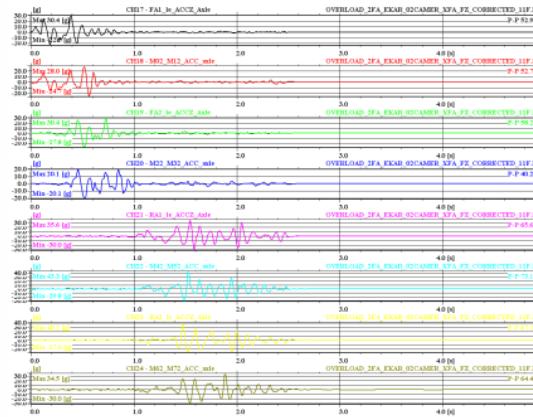
4. Drive signal
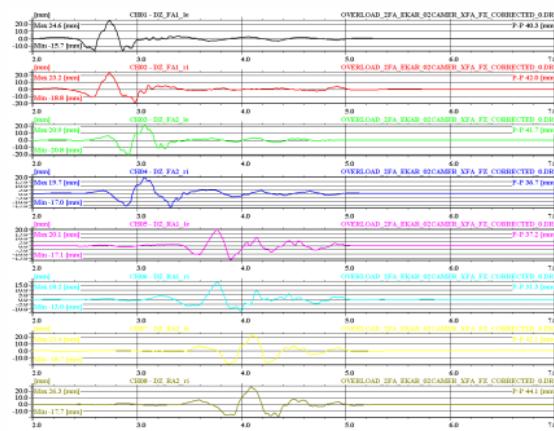
$$u_{n+1} = u_n + F^{-1}\left(y_{Desired} - y_n\right)$$

$$u_0 = F^{-1}\,y_{Desired}$$

Virtual Iteration
General Approach

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Result check during virtual iteration process basing on:

- signals in time domain (quality check)
- peak-to-peak values of signals in time domain (quantity check)
- signals in frequency domain (PSD)
- relative damage value of simulation compared to measurement

TIMEDOMAIN:

TIMEDOMAIN - ZOOM:

Relative damage comparison simulation to measurement

	Damper force	Bolt force lateral	Bolt force longitudinal	Tie rod force	Spring deflection
relative damage value	1,02	0,99	0,97	0,97	1,03

Axles

Attachment parts

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Example Projects

Fullvehicles

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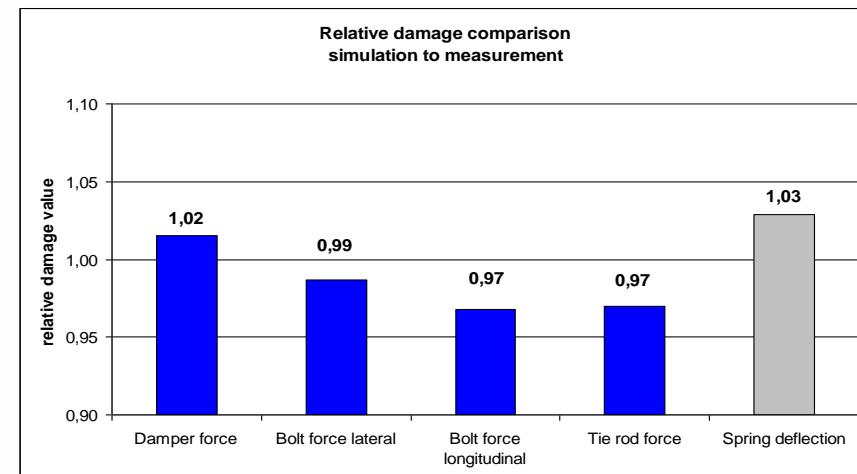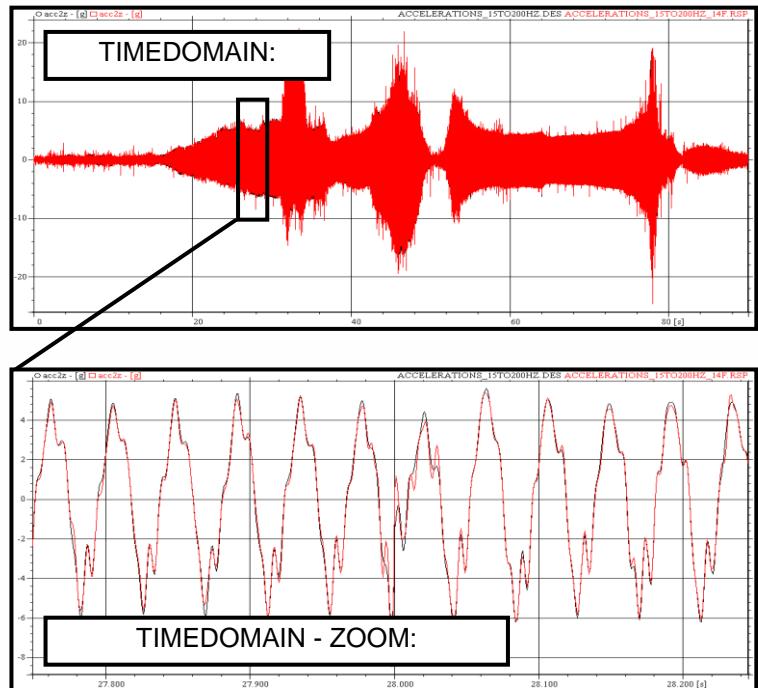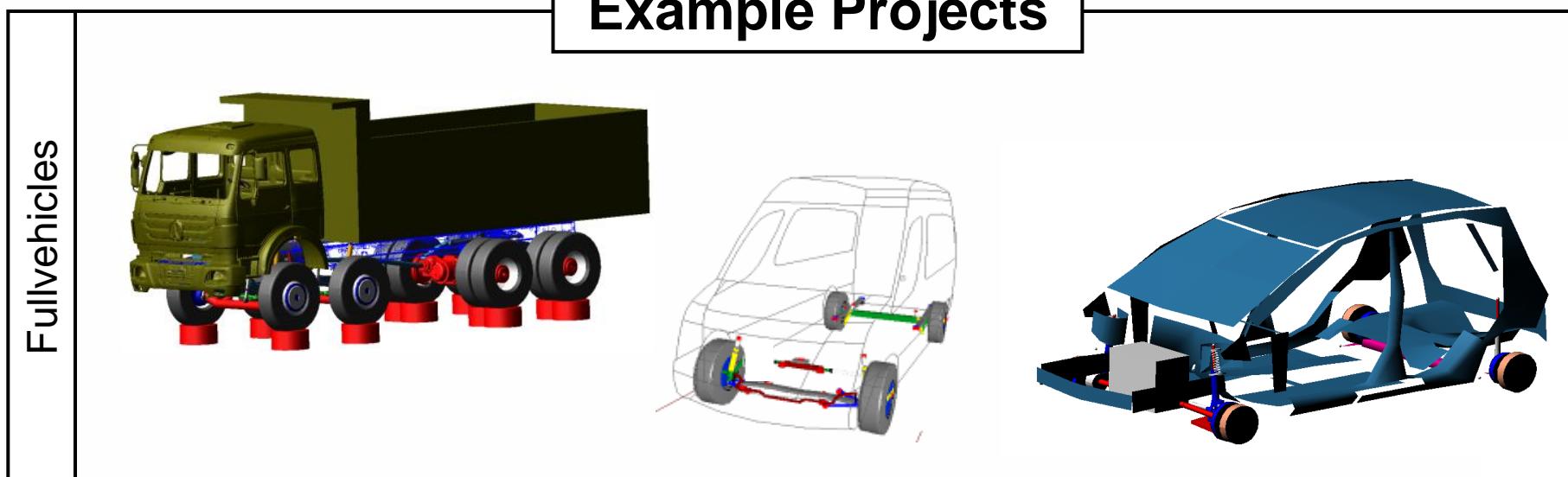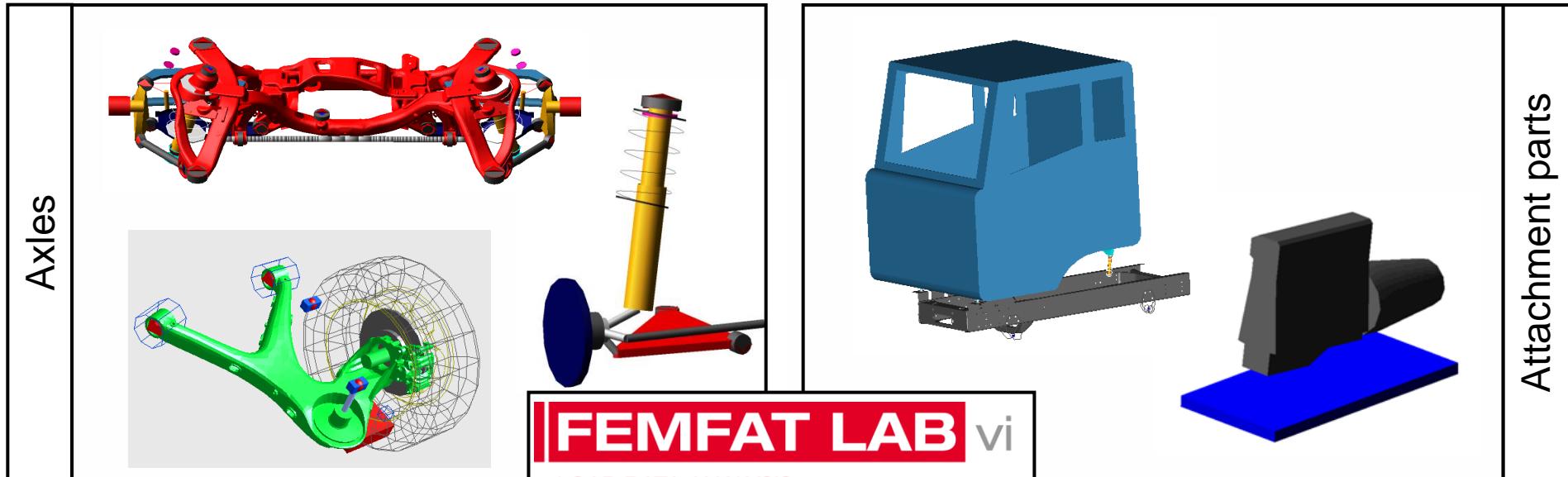
Road load data

Measurement vehicle
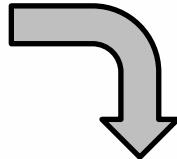
Virtual iteration of road surface

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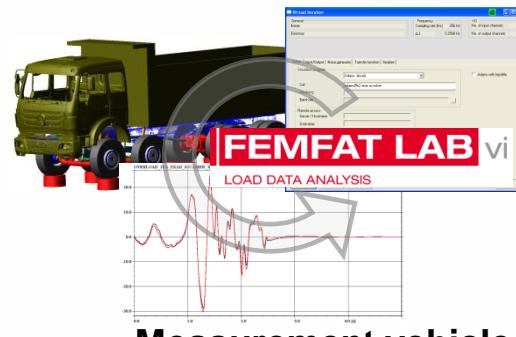
Measurement vehicle
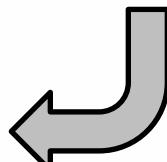
MBS- simulation with road surface
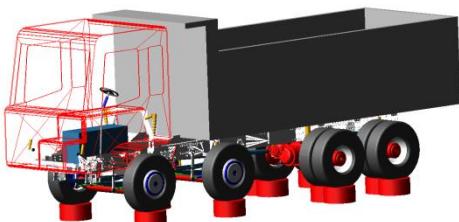
New developed vehicle

- **Road load data acquisition with benchmark vehicle**

- **Virtual iteration to invariant road excitation (8-poster)**

- **Transfer of invariant signals to different vehicle**

- **Analysis of vertical loaded parts or subsystems possible, e.g. frame (chassis parts not suitable)**

Virtual Iteration
8x4 Truck

Load (8 channels)		Desired (measurement)
• 8 vertical displacements at the posters		• Spring displacements • Vertical accelerations on axles

Model-check (measurement)

• Vertical forces at axle
• Damper forces

• **MBS model of measurement vehicle**
• **Virtual iteration of different test tracks (bumps, rough roads, washboards, twisting)**

Broken road

Bumps

Small washboard

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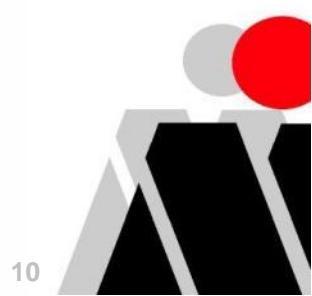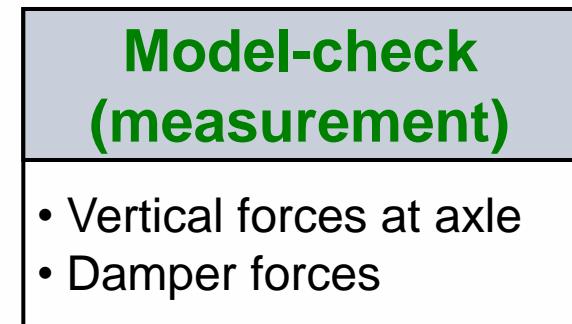
Response

Drive

spring displ.
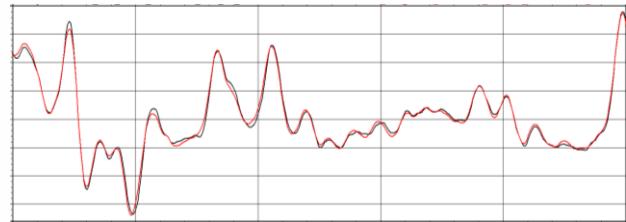
vertical acc.
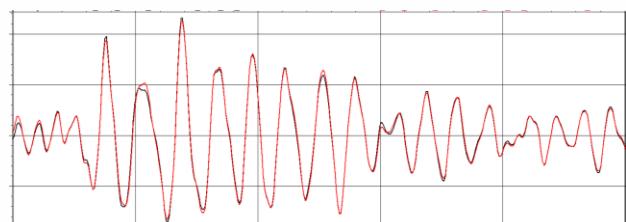
damper force (check)
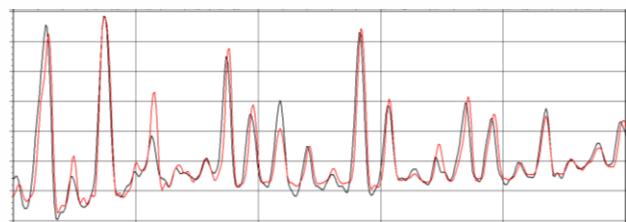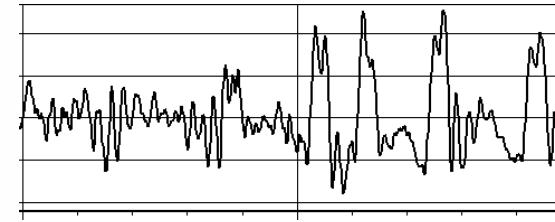
FA1 left

FA2 left

RA1 left

RA2 left

time [s]

time [s]

Virtual Iteration
8x4 Truck
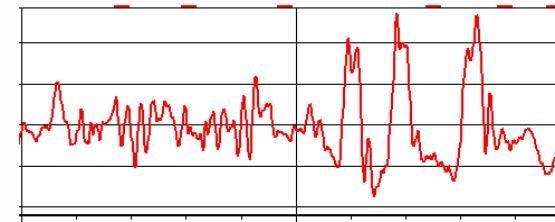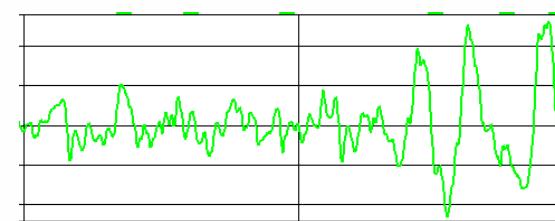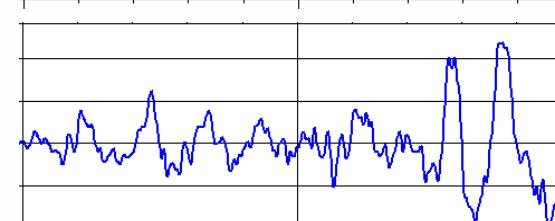
Results of this investigation can be used for:

- **Fatigue investigation investigating different concepts changing vehicle parameter allocate to concept vehicle**

- **Comfort investigation modifying suspension parameter modifying cab properties**

time

COMFORT VALUES A and B
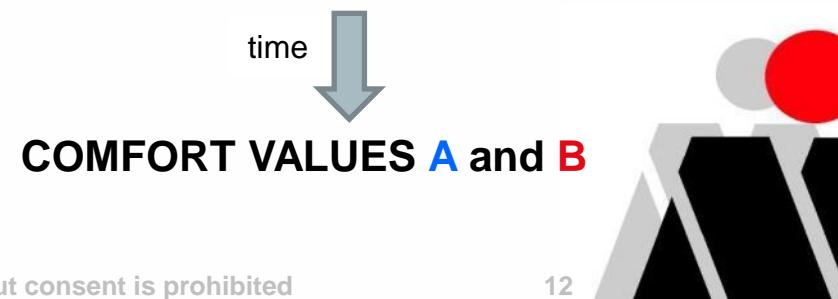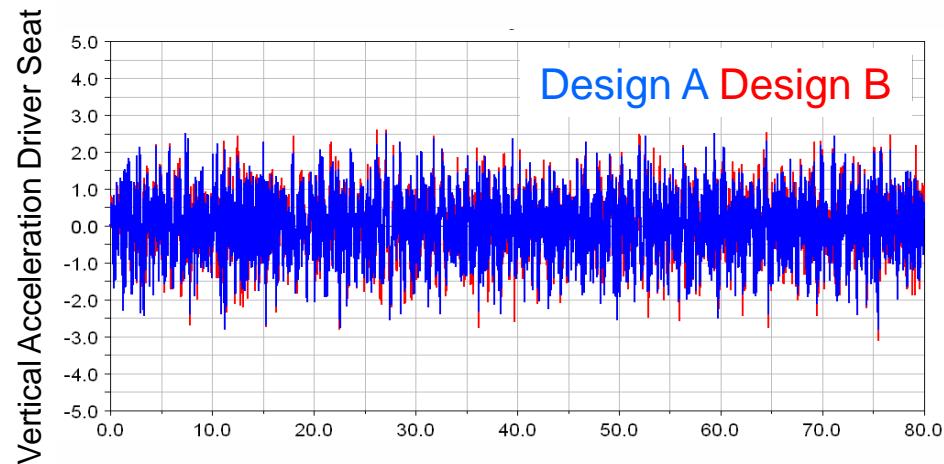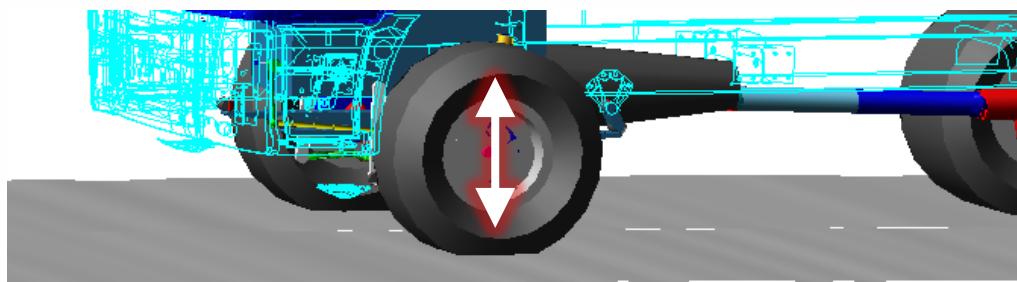
Virtual Iteration Suspension Test Rig

DAIMLER   Mercedes-Benz

- **Endurance strength verification of the chassis is based on proving ground testing (torture track and maneuver like braking, weaving, …) at Daimler AG**
- **Development of simplified test rig for semi-trailing arm**
- **Verification of damage distribution**

Virtual Iteration Suspension Test Rig
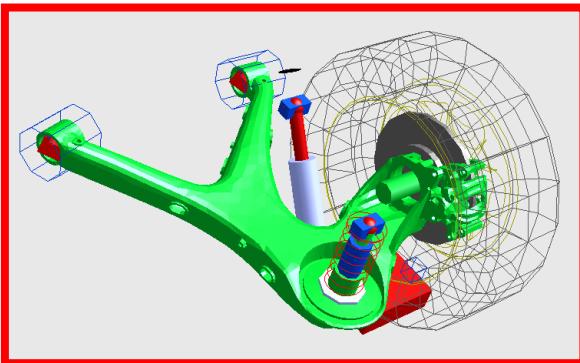
vehicle configuration:
spring and damper
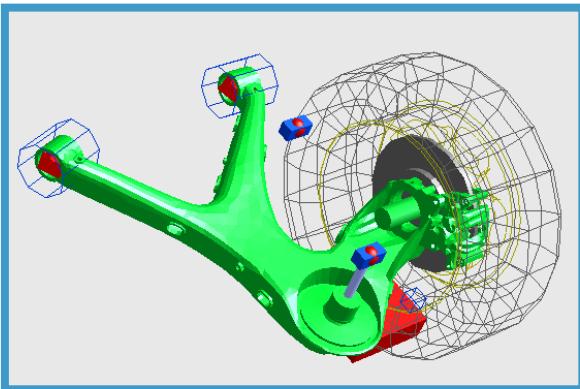
test rig configuration:
rigid rod, no damper

- **Efficiency improvement with a rigid spring/damper**
- **No cooling of damper necessary**
- **Replacement of elastomer omitted**
- **Target: Strain gauge signals unchanged**
- **Excitation: Torture track, braking, weaving**

**Virtual Iteration
Suspension Test Rig**

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Why do we need Virtual Iteration?


suspended
rigid rod
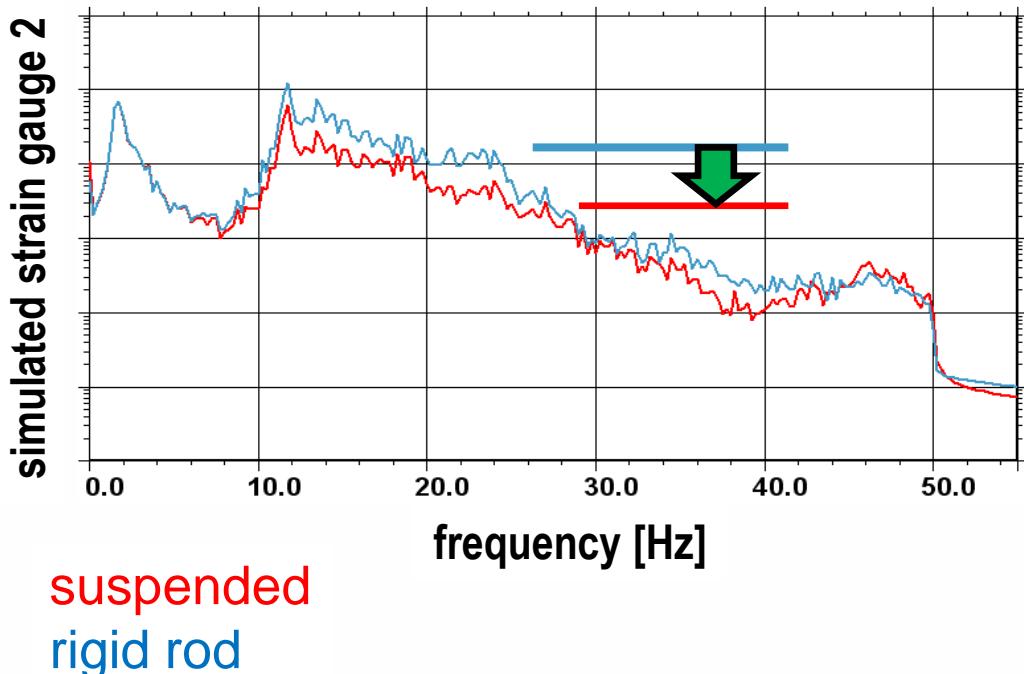
- **Different boundary conditions for test bench: suspended and with rigid rod**
- **Excitation of both systems with identical loads on wheel hub**
- **Different strain results inside semi-trailing arm due to changed boundary conditions**
- **Target: tuning of excitation to gain identical strains at semi-trailing arm**
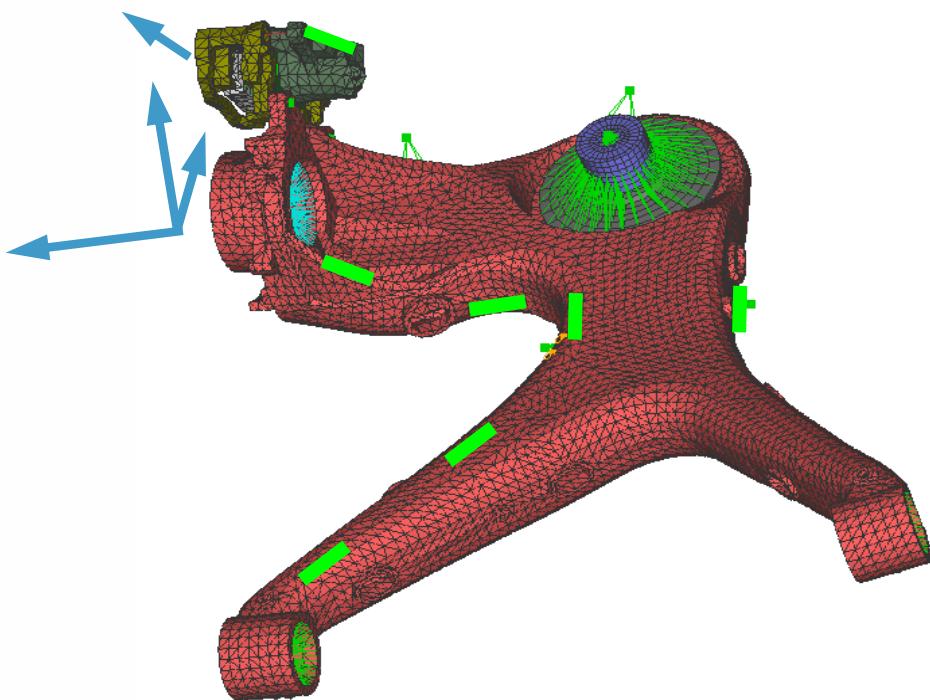
- **Drive**
  forces and torques applied on wheel hub

- Lateral torque not applied on wheel hub during driving

- Additional constraint during breaking maneuver

- **Response**
  seven strain gauges on semi-trailing link

Virtual Iteration Suspension Test Rig
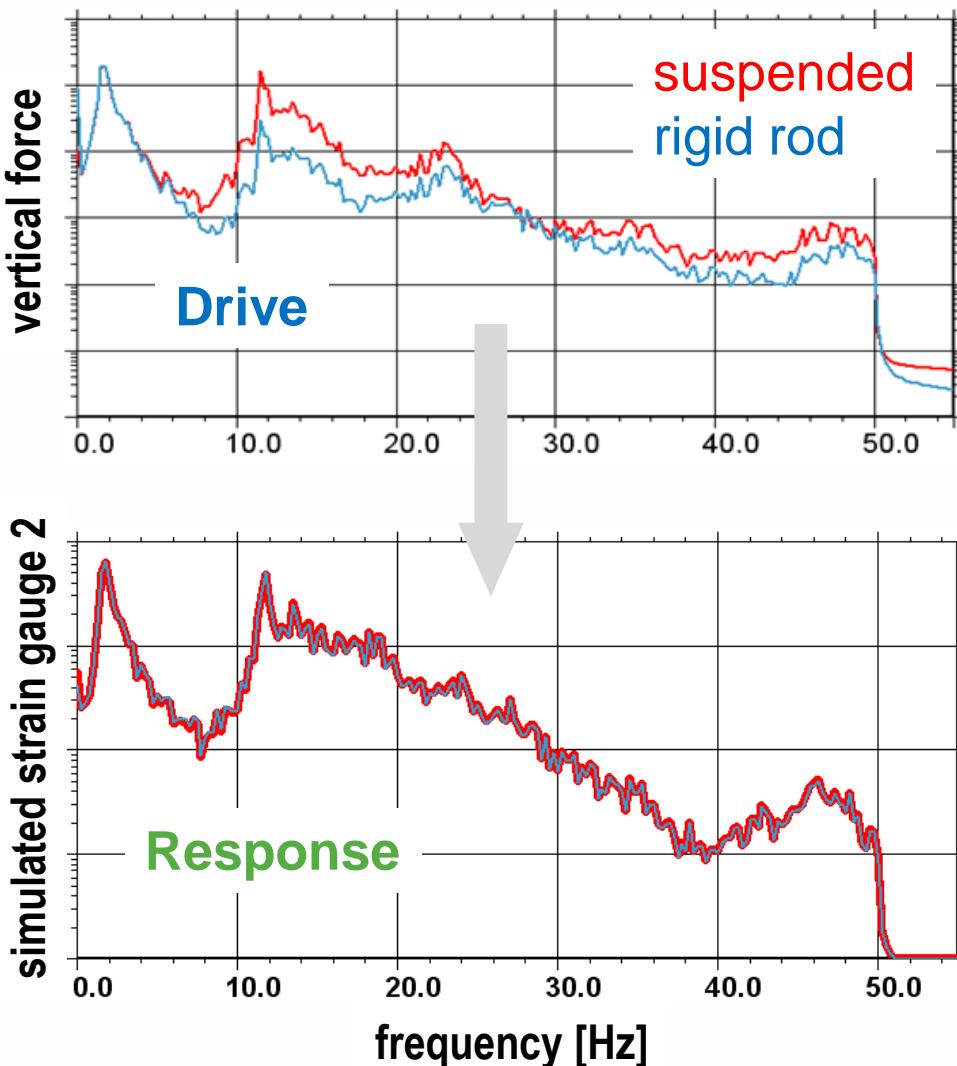
- **Iteration result:** Modified time signal for all forces and torques of rigid test bench

- **Simulation of strains by application of modified loads on model with rigid rod**

- **Goal accomplished:** Same strains in both models

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Channel 1

$F_V =$

Channel 2

$F_S =$

Channel 3

$F_L =$
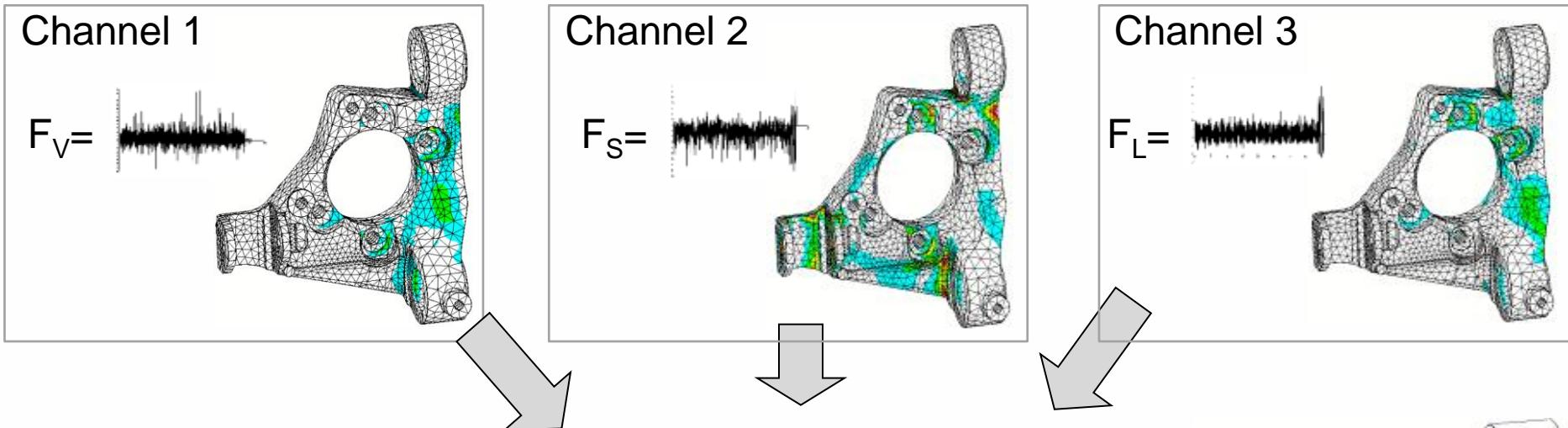
MAGNA
MAGNA POWERTRAIN

FEMFAT max
FINITE ELEMENT METHOD FATIGUE

Specimen Data
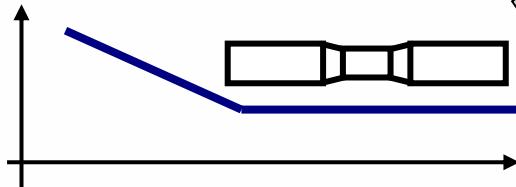
Results
- Damage
- Endurance Safety

Virtual Iteration
Suspension Test Rig

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suspended

rigid rod
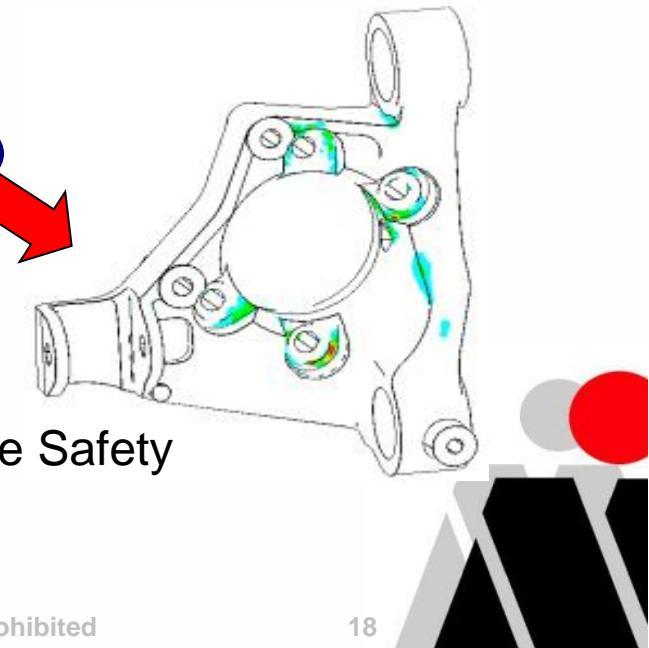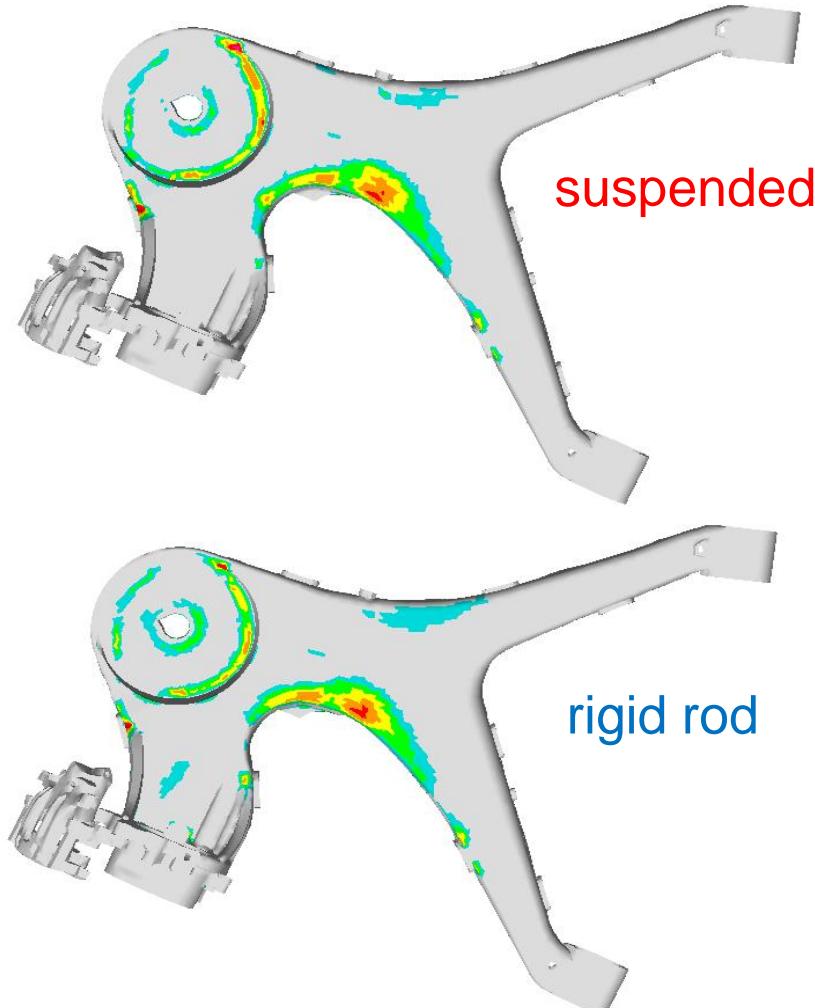
- **Verification of damage location with modified boundary conditions and loads**
- **Calculation of damage distribution based on simulation results for both models**

- **Comparison: Similar damage distribution with no additional hot spots**

Benefits of Virtual Iteration:

- **Simple and cheap measurements for vertical road excitations**

- **Efficient method to generate absolute displacements (e.g. wheel patch, frame movement)**

- **No complex tire model required for vertical load**

- **No road surface scanning required**

- **Model verification and trimming by additional checking signals**

- **Absolute fatigue life prediction possible**

- **Efficient parameter studies and transfer to similar vehicles**

- **Method applicable for wide range of vehicle components**

- **Assessment of test bench concepts (viability, simplifications)**