

# DAIMLERCHRYSLER

Analysis Commercial Vehicles, PBE/DAD

## **Set up of an Automotive Test Rig in SIMPACK**

# Overview

- **1. Introduction**
  - Durability Testing
  - Calculation of Cutting Forces
  - Problem Clarification
- **2. Set Up of the Virtual Test Rig**
- **3. Parameter Variation**
- **4. Results**
- **5. Outlook**

## Durability Testing

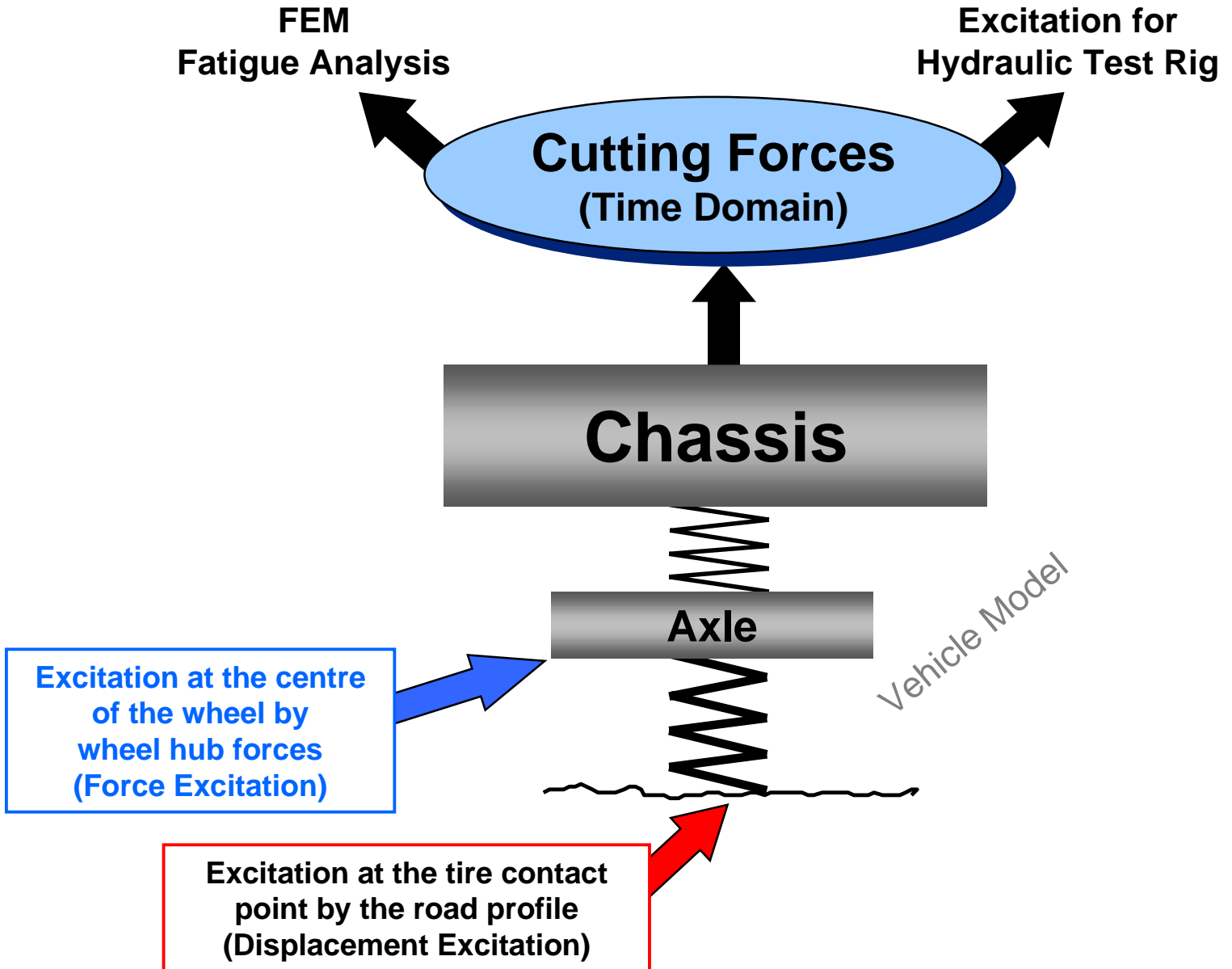
- Proving Ground Test



- Hydraulic Test Rig

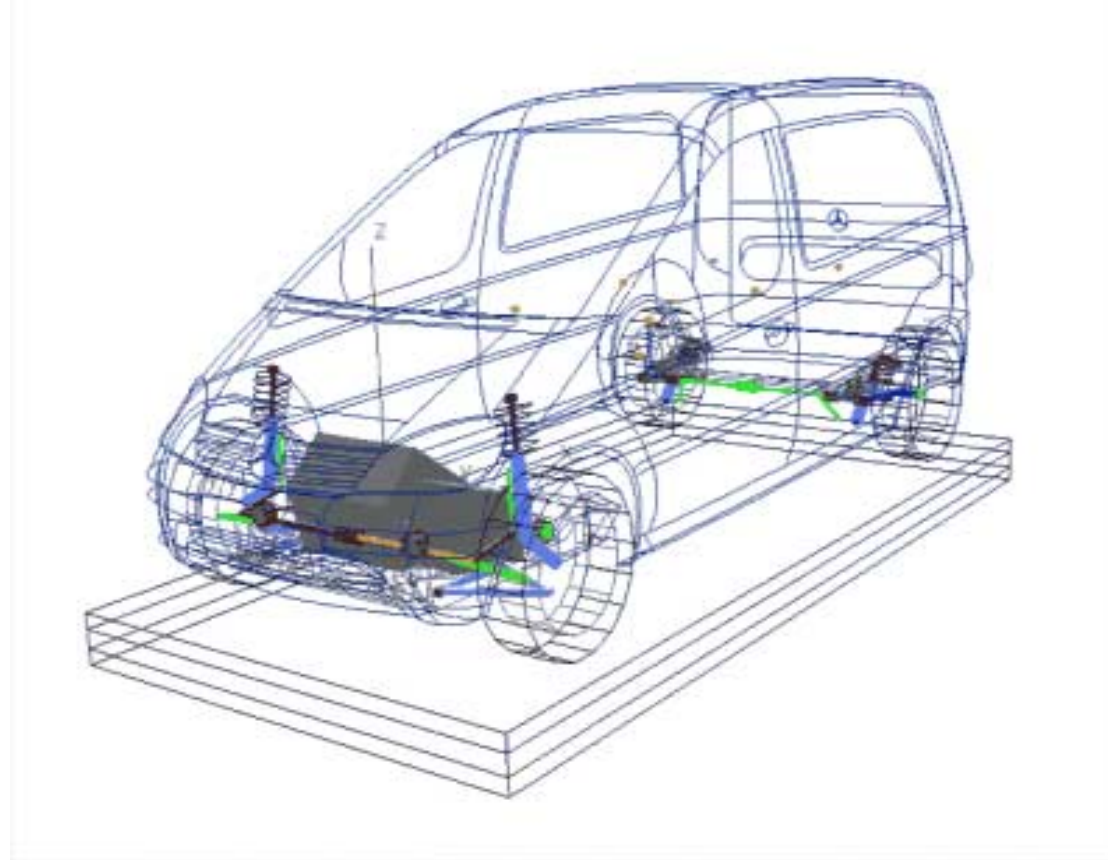


# Calculation of Cutting Forces



## SIMPACK-Modell of the Vaneo

SIMPACK model excited with wheel hub forces  
without feedback control



⇒ Model drifts after a short time

## Causes of Drift:

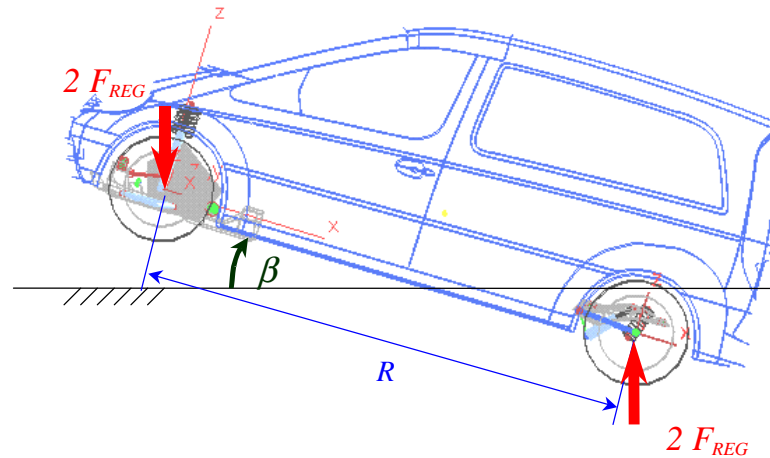
- Inaccuracies in the wheel hub forces
- Missing initial states (position, velocity, acceleration)
- Inaccuracies in the model parameters (mass, inertia, stiffness, damping)

## Stabilization Methods:

- Restraining the vehicle body using spring and damper elements
- Vehicle stabilization using feedback control (control input: Position of the car body)

# Control Layout

## Position of vehicle body for control input



conservation of

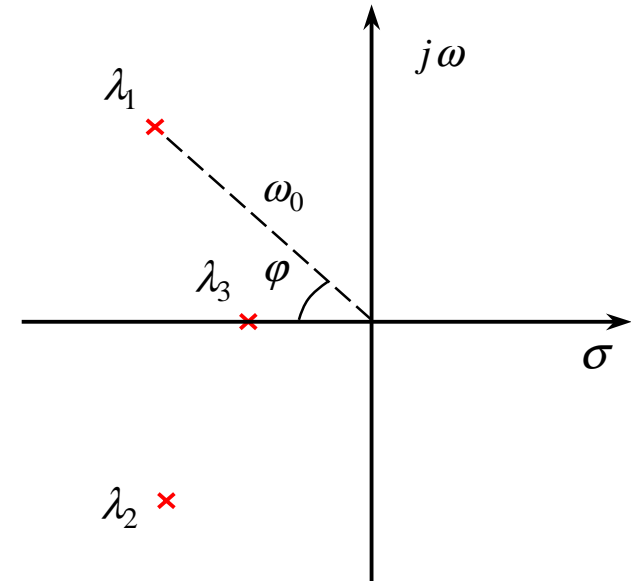
angular momentum:  $J_{YY} \cdot \frac{d^2}{dt^2} \beta = -2 \cdot R \cdot \cos(\beta) \cdot F_{REG}$

control law (PID-control):  $F_{REG} = c_{IR} \cdot \int \beta dt + c_{PR} \cdot \beta + c_{DR} \cdot \frac{d}{dt} \beta$

$\Rightarrow$  char. polynomial:  $s^3 + \frac{2 \cdot R \cdot c_{DR}}{J_{YY}} \cdot s^2 + \frac{2 \cdot R \cdot c_{PR}}{J_{YY}} \cdot s + \frac{2 \cdot R \cdot c_{IR}}{J_{YY}} = 0$

**Eigenvalues:**  $\lambda_1, \lambda_2$  and  $\lambda_3$

**Eigenvalues in the s-plane:**



**Choice of eigenvalues:**

$$D=0,71$$

$$\text{with } \cos(\varphi) = D \implies \text{Re}(\lambda_{1,2}) = -\text{Im}(\lambda_{1,2})$$

$$\text{natural frequency: } \omega_0 = 2\pi \cdot f = \sqrt{\text{Re}(\lambda_{1,2})^2 + \text{Im}(\lambda_{1,2})^2}$$

## Restraining the Vehicle Body with Spring and Damper Elements:

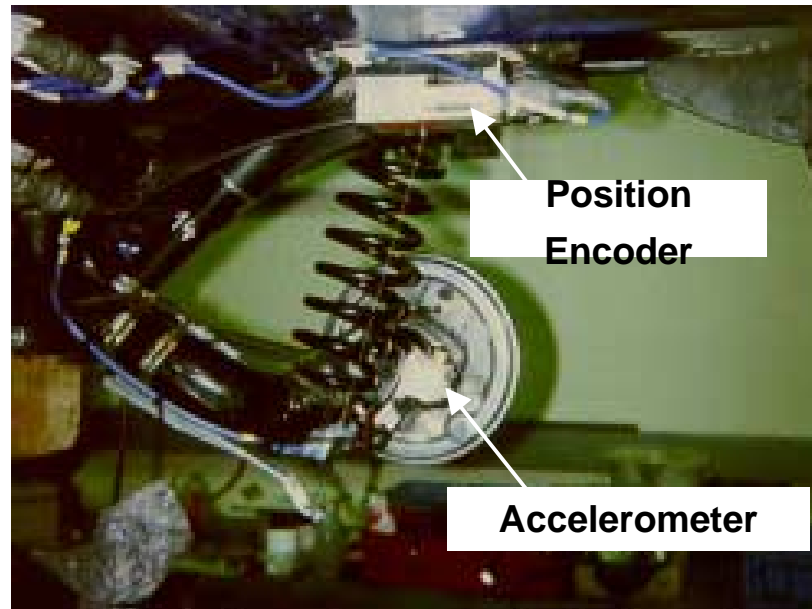
- Coupling of the vehicle body to a stationary reference system
- The spring and damper elements are attached to the c.g. of the vehicle body.

**Translation:** 
$$m_F \cdot \frac{d^2}{dt^2} z = -(c \cdot z + d \cdot \frac{d}{dt} z)$$

**Rotation:** 
$$J_{XX} \cdot \frac{d^2}{dt^2} \alpha = -(c_{Dreh} \cdot \alpha + d_{Dreh} \cdot \frac{d}{dt} \alpha)$$

## Reference Measurements (empirical Data)

- **Vertical hub acceleration of the right hand side** ( $az\_VA\_r$ ,  $az\_HA\_r$ )
- **Distance between wheel and vehicle body** ( $sz\_VA\_r$ ,  $sz\_VA\_l$ ,  $sz\_Ha\_r$ ,  $sz\_HA\_l$ )



## Reference Measurements (empirical Data)

### ■ Vehicle accelerations

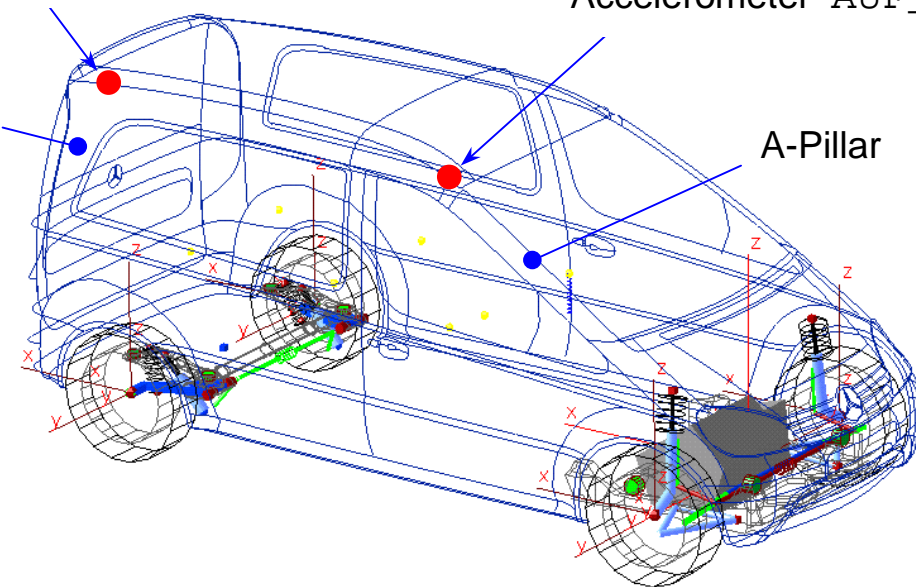
( $ax_{AUF\_vor}$ ,  $ay_{AUF\_vor}$ ,  $az_{AUF\_vor}$ ,  $ay_{AUF\_hro}$ ,  
 $az_{AUF\_hro}$ )

Accelerometer AUF\_hro

Accelerometer AUF\_vor

D-Pillar

A-Pillar



## Quality Criteria:

Standard deviation of the difference between the measured and simulated data

Standard deviation for  $n$  function values  $x_i$ :

$$s = \sqrt{\frac{1}{n-1} \left( \sum_{i=1}^n (x_i - \bar{x})^2 \right)} \quad \text{with} \quad \bar{x} = \frac{1}{n} \sum_{j=1}^n x_j$$

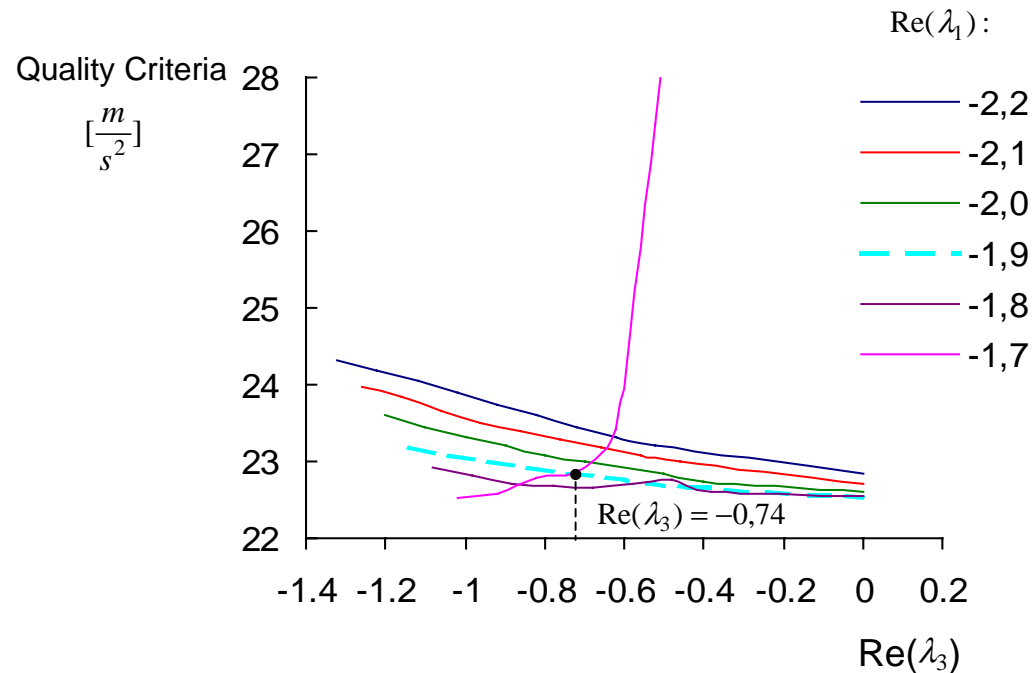
## Parameter Variation

- Variation by a batch file (\*.bat). The variables in the parameter file are changed. A SIMPACK simulation is carried out and the quality criteria are stored in a result file.
- Variation of the real part of the eigenvalue  $\lambda_1$  and  $\lambda_3$
- 15 seconds realtime simulation

## Results of the Parameter Variation

- Feedback control delivers a better overall result
- Choice of control parameters for the example of the acceleration

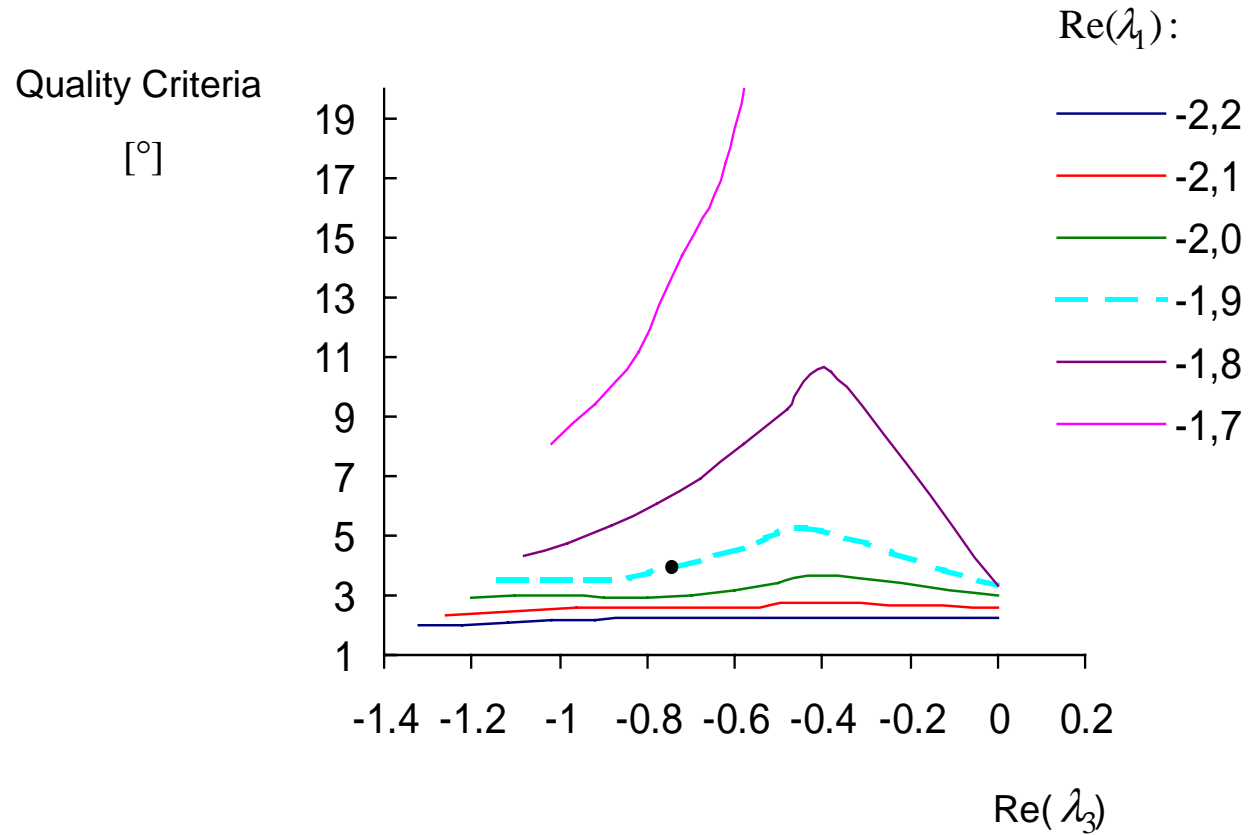
$a_{z\_VA\_r}$ :



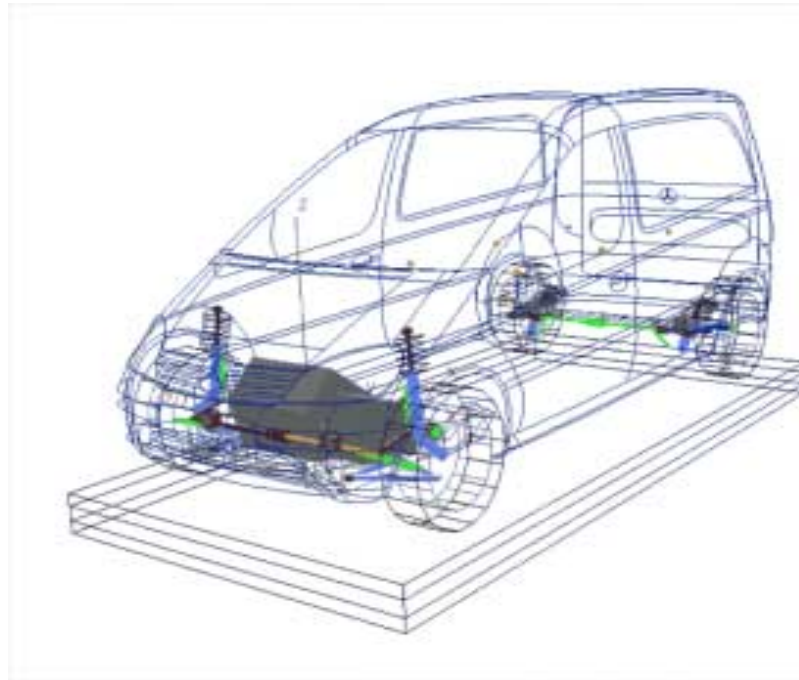
**Chosen eigenvalues:**

$$\begin{aligned} \lambda_1 &= -1,9 + 1,9i \\ \lambda_2 &= -1,9 - 1,9i \\ \lambda_3 &= -0,74 \end{aligned} \quad \Rightarrow \quad \begin{aligned} c_{IR} &= 2350 \\ c_{PR} &= 2020 \\ c_{DR} &= 4464 \end{aligned}$$

## Results of the Quality Criteria of the x-Axis Rotation

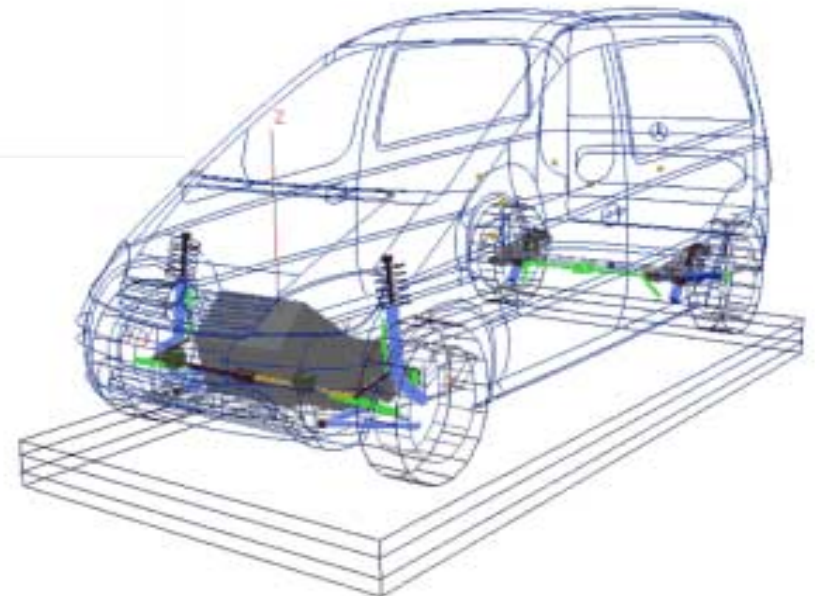


## SIMPACK- Model excited by Wheel Forces



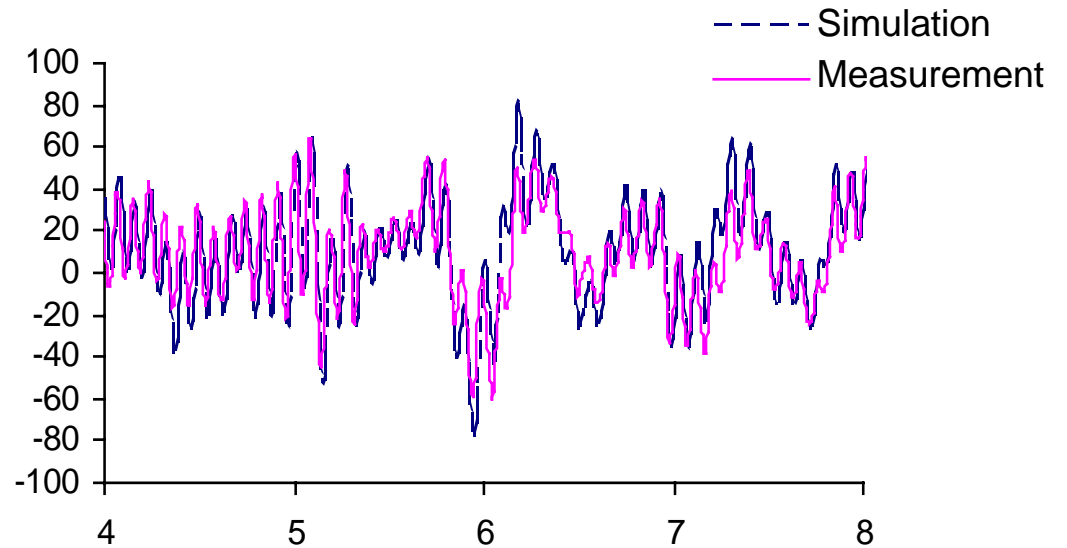
without feedback  
control  
⇒ Model drifts

with feedback control  
⇒ no drift

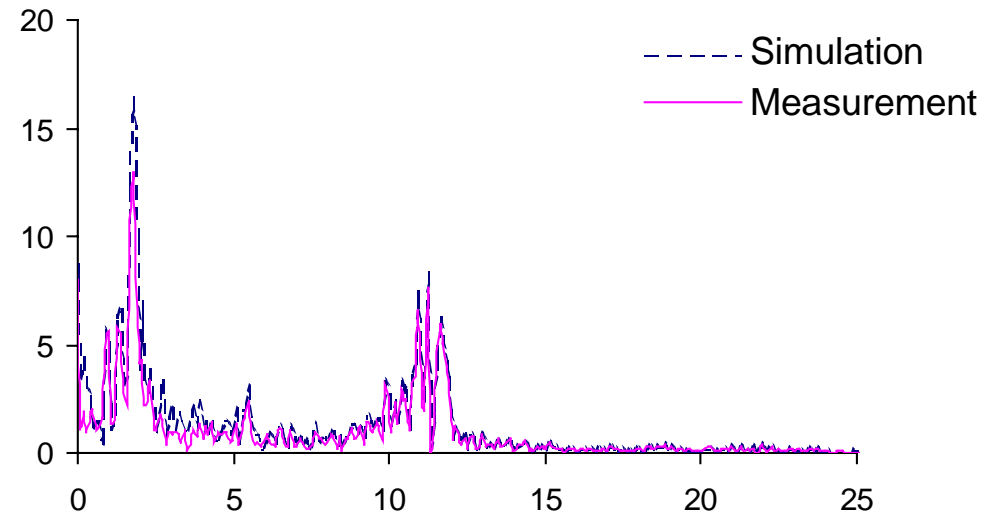


# Results

## Comparison of the relative displacement $sz\_VA\_r$

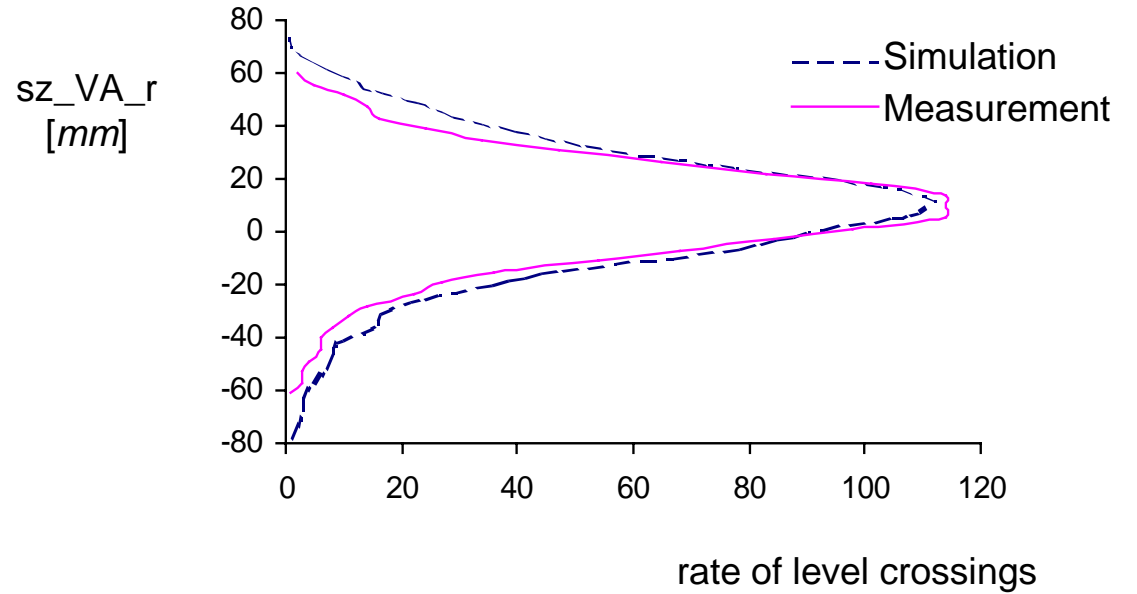


## Fast-Fourier-Transformator of the signals

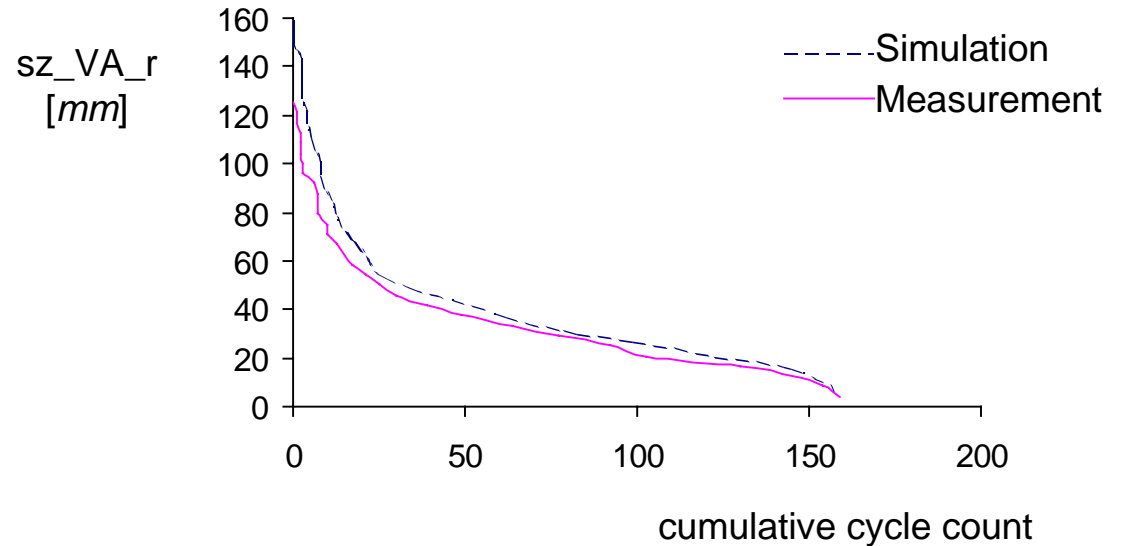


# Results

## Level crossing counting (30 classes)

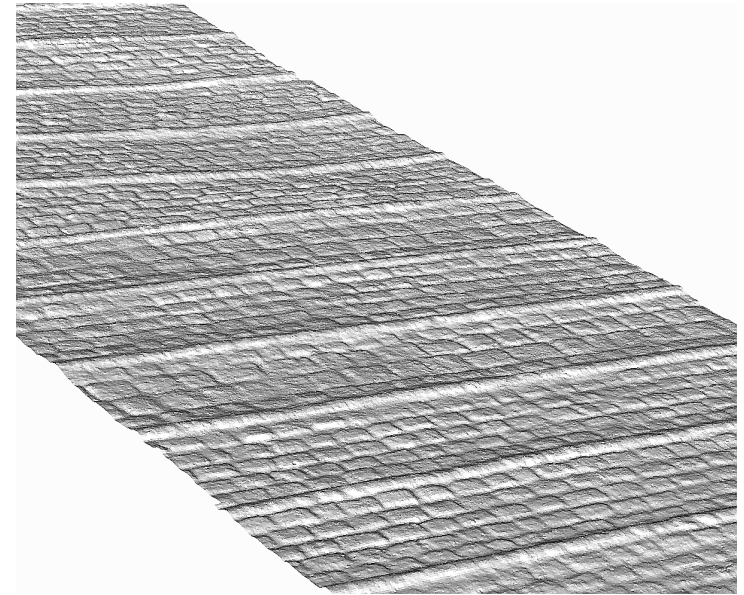


## Range pair counting (30 classes)



# Outlook

Modelling of the elastic vehicle body



3D measured proving ground surface (Africa):

Simulation with RMOD-K:

