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Title: Investigation of the Comfort Behavior of a Commercial Vehicle in ADAMS

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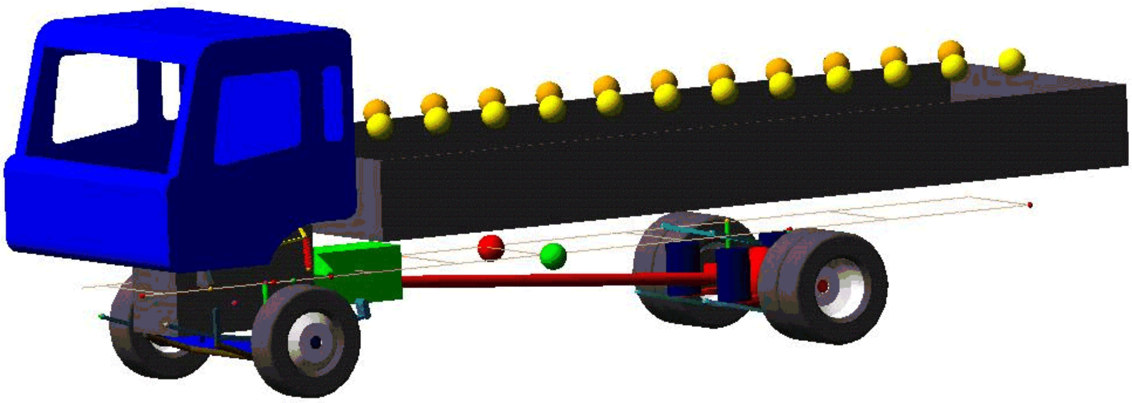


Fig. 1: Full vehicle model

Abstract:

Since the comfort is becoming increasingly important in commercial vehicles it should be considered in the design stage, which factors are needed to be successful. On this occasion the simulation will give assistance. To investigate the comfort in vertical direction, a full vehicle model (Fig. 1) was built up in ADAMS/View. To improve comfort several versions were modeled and compared to each other. Different spring systems and suspension types were tested in the full vehicle model by simulation. In a co-operation with MDI a Macro was written to generate a stochastic excitation in the center of tire contact. In this case the road surface is defined by the PSD (power spectral density) and will result in the comfort value of the driver's cabin in vertical direction.
At the same time a commercial vehicle was tested on the company's testing track to obtain reference values of vertical acceleration and roll angle of the driver's cabin.

Introduction:

This paper is about modeling a commercial vehicle of the 12 tons class. The reference vehicle uses conventional rigid axles, parabolic leaf springs and a typically cabin suspension with rubber elements. In this case it was possible to compare the simulation results with measuring data established on our testing track. Further some modifications on front axle (independent suspension), spring system (air springs) and cabin suspension (spring/damper elements) of the simulation model were realized. The main target of this modifications was to improve dynamic comfort behavior of the driver’s cabin. The used parameters were vertical acceleration and roll angle of the cabin near the driver’s seat. With a stochastic excitation the comfort value was established.

Vehicle Modeling:

Front Axle + Parabolic Leaf Springs

The front axle (Fig. 2) is modeled with rigid bodies. Revolute joints connect the wheel carrier with the axle body. Kingpin inclination and caster angle are the inclinations of the revolute joints against the vertical. Tie rod and wheel carrier are connected by spherical joints. For excitation of vertical dynamic the steering movement is deactivated. The leaf springs at the front axle generated by a Macro consisted of ADAMS beam elements. As shock absorbers are used ADAMS damper elements, where the characteristic is specified by a spline. The anti roll bar is built up by five flexible links. The tires are modeled as GFORCE with linear stiffness because only vertical dynamics of the full vehicle model were investigated.

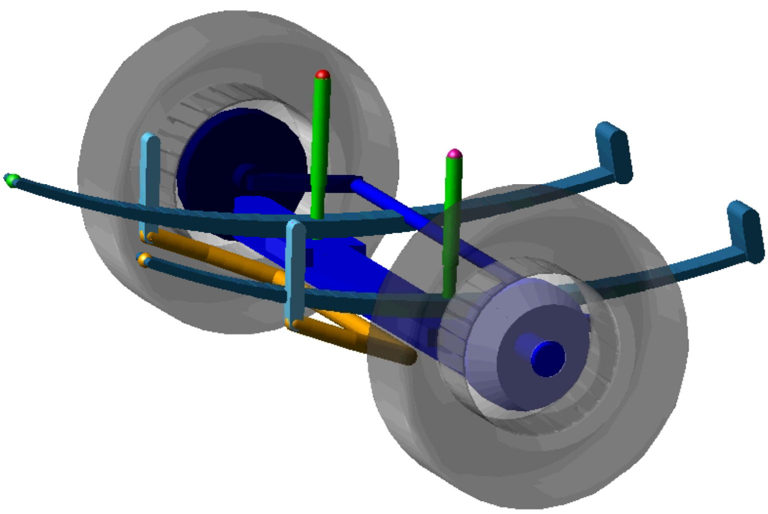


Fig. 2: Complete front axle with leaf springs and anti roll bar

Rear Axle + Air Springs

The rear axle (Fig. 3) is modeled rigid. The guidance of the axle is managed by a upper A-arm and two lower trailing arms. All arms are connected to the axle housing and to the frame by spherical joints. Air springs are modeled as GFORCEs with splines of Force versus Displacement. The anti roll bar is built up by five flexible links. Tires are modeled as GFORCEs with linear stiffness because only vertical dynamics of the full vehicle model were investigated.

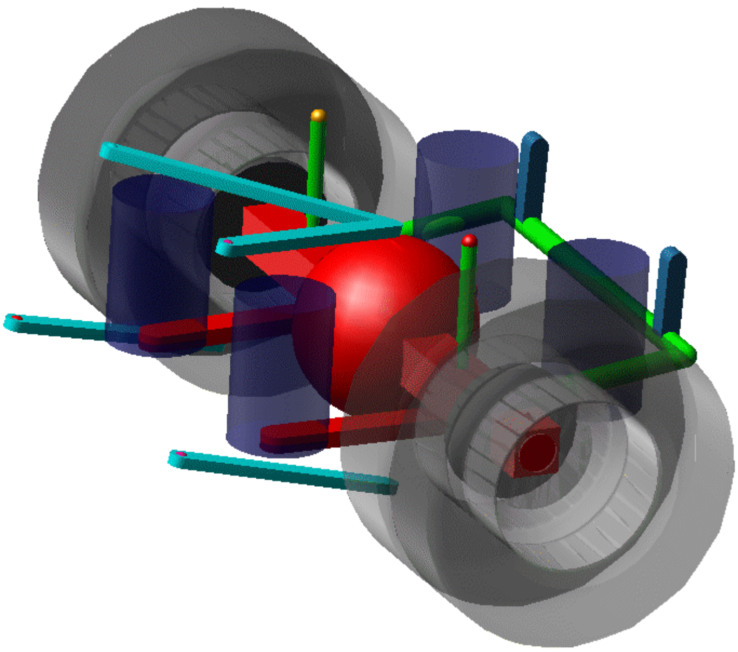


Fig. 3 Complete rear axle with air springs and anti roll bar

Vehicle’s Frame + Payload

The vehicle’s frame is modeled as a flexible body. The frame was integrated as a flexible body, modeled in NASTRAN by our finite element department. To keep the simulation time within reasonable limits the natural modes were reduced to 500 Hz.
Measurement and also the simulation were done with a payload of 7.8 tons. This payload was subdivided into 24 masses on the simulation model. This point masses were fixed to the frame’s longitudinal main beams distributed evenly to the left and right side. The weight and height of the masses was parameterized with design variables.

Cabin + Suspension

The driver's cabin (Fig. 4) was modeled as a rigid body. The cabin front suspension consisted of bushings and the rear suspension of spring/damper elements.

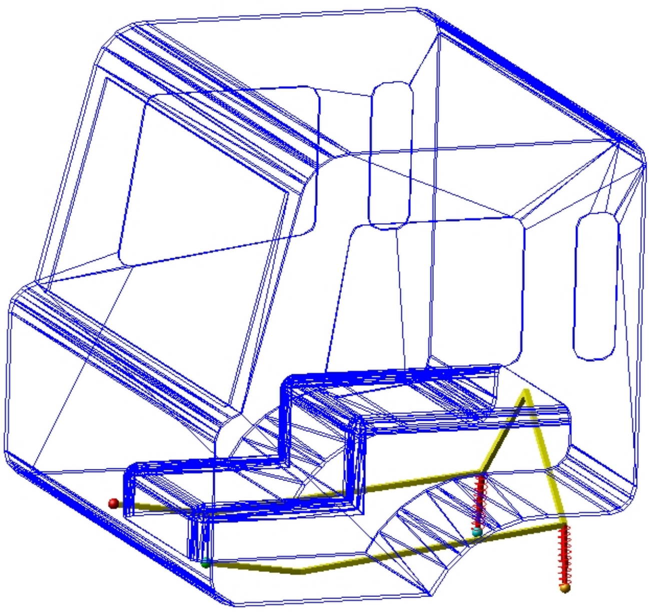
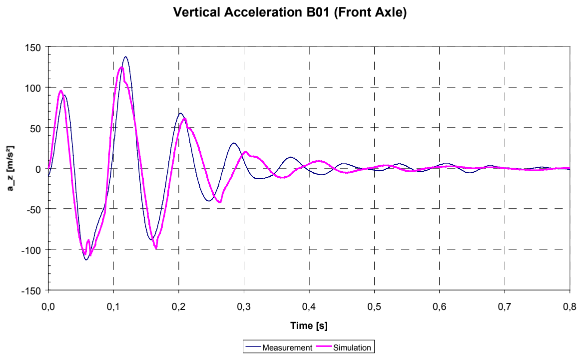


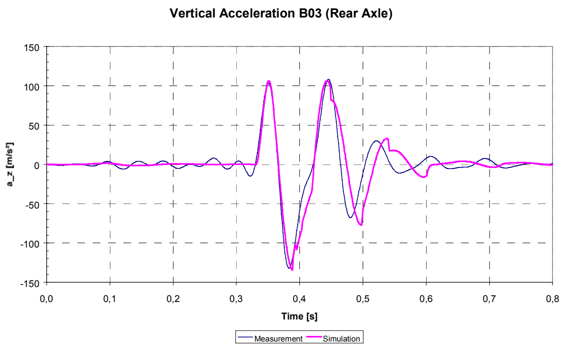
Fig. 4 Driver's Cabin with Cabin Suspension

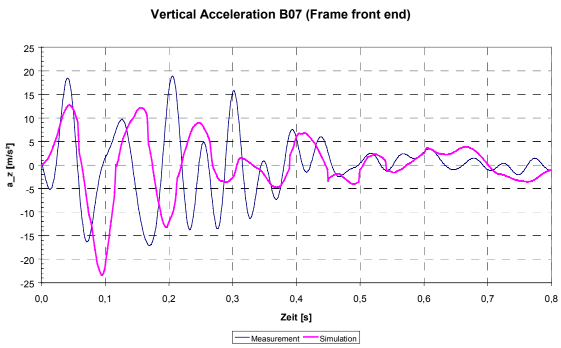
Comparison with measuring data:

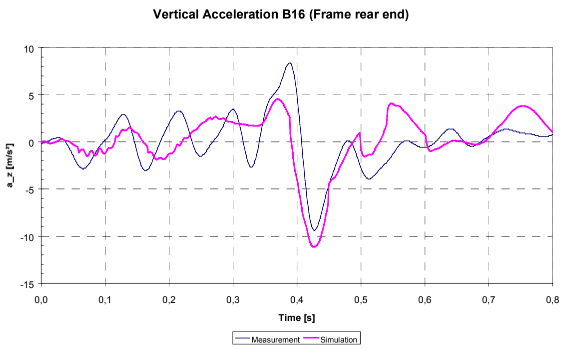
At the same time the real vehicle with a conventional rigid front axle and leaf springs was tested on the company's testing ground to obtain reference values. A gyroscopic sensor was situated near the center of gravity of the driver's cabin to measure its roll, pitch and yaw angles. Additionally vertical accelerations were measured on the front and rear axles, front and rear end of the frame and on the cabin near the driver's seat. A predefined obstacle was used for various maneuvers and speeds to find out vertical accelerations. The 40 mm high obstacle had ramps of 15 and 30 degree slopes. Shift of left and right sides obstacle was varied in vehicle's longitudinal direction between 0 and 2.3 meter.

To adjust the simulation model the accelerations in vertical direction on the axles, on the frame and on the driver's cabin were used. The following figures (Fig. 5 – 9) show the comparison of the measuring data with simulation results.









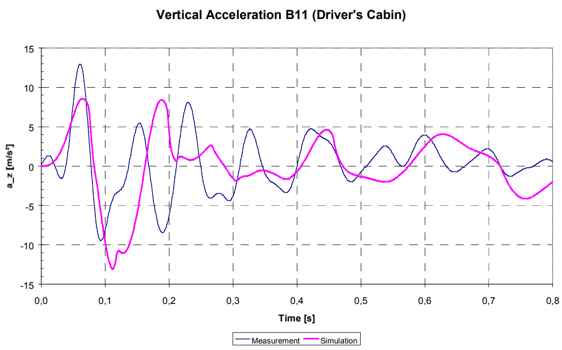


Fig. 5 – 9 Vertical accelerations of measurement points (front and rear axle, front and rear end of the frame, cabin) in comparison with simulation.

Modified Vehicle Models:

To improve comfort in vertical direction several variants were modeled and compared with the reference vehicle model:

Rigid Axle - Independent Suspension

In this case there was a comparison between conventional rigid axle and independent front suspension (Fig 10). The independent front suspension was kinematically optimized in ADAMS/Car to minimize tire wear, rolling resistance and fuel consumption for economic operation of the vehicle [2].

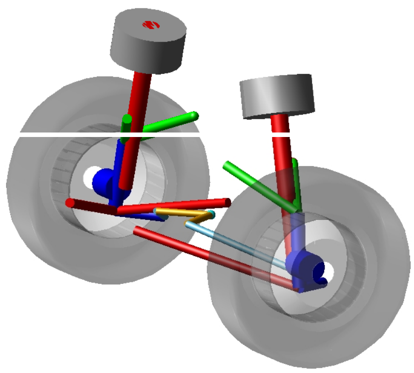


Fig. 10 Independent Front Suspension

Leaf Spring - Air Spring

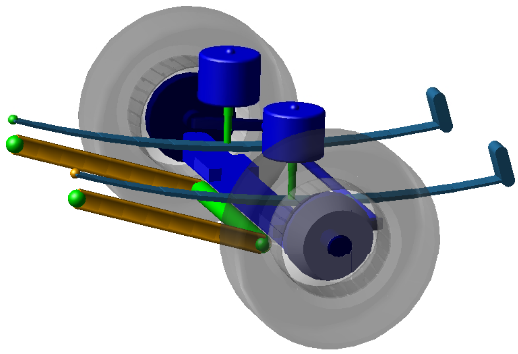


Fig. 11 Modified Front Axle

A further attempt at increasing vertical comfort was to use air springs at the front axle instead of multileaf springs (Fig. 11). The air spring characteristics was described by non-linear splines. The rigid front axle had to be modified by a single-leaf spring and a anti roll bar to guarantee exact wheel control.

Cabin Suspension Bushing - Spring/Damper Elements

For investigating the modified cabin suspension an extra model was built up in ADAMS/View. The kinematics of the cabin suspension (Fig. 12) was varied to minimize roll angle at cornering and to improve vertical dynamics.

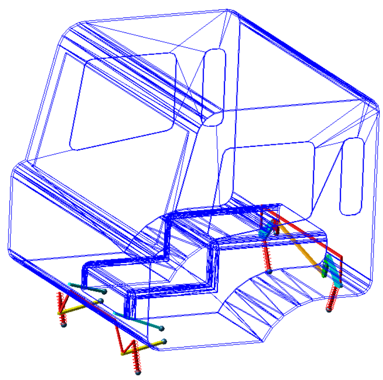


Fig. 12 Modified cabin Suspension

Comfort study:

In co-operation with MDI a Macro was written to generate a stochastic excitation in the center of tire contact. In this case the road surface is defined by the PSD (power spectral density) and will result in the comfort value of the driver's cabin in vertical direction.

Theory

Usually road irregularities are of stochastic matter. Measured PSD of different road surfaces look like very similar (Fig. 13): they can be analytically approximated as hyperbolas and with a logarithmic scale they are stretched to straight lines. The approximation formula can be modified in reference power spectral density, reference angular spatial frequency and the slope of the straight line. The time domain signal is made available by the method of RICE [1]: The idea of this method is to superimpose a large number of cosines functions with different frequencies and phases to get a stochastic signal. The spectrum is subdivided into frequency bands with the same average power. The frequency and amplitude has to be determined in a way, that the cosines function has the same power as the concerning frequency band. The phase is generated by a random signal.

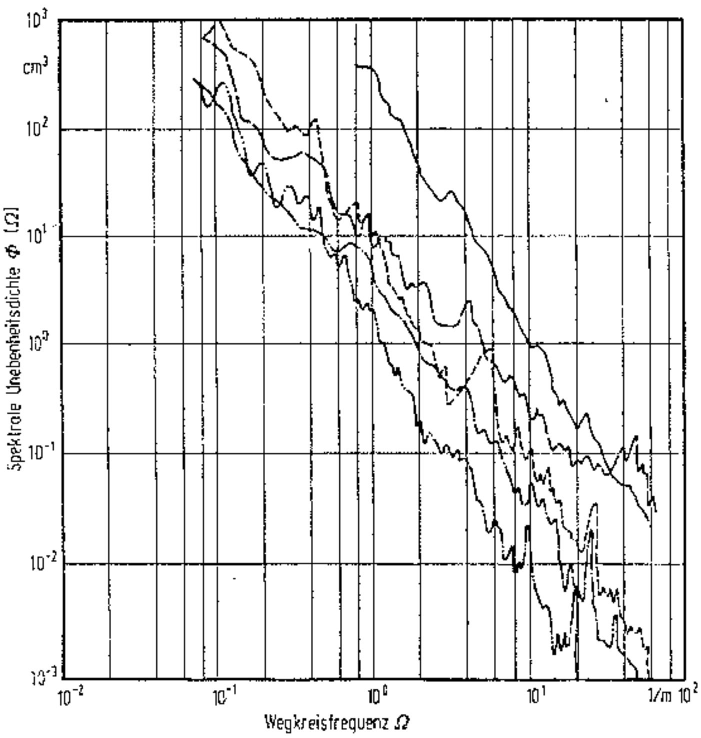


Fig. 13 Power Spectra of typical road surfaces

For a two track vehicle it is possible to make different stochastic signals for each wheel track considering the correlation of left and right side. The rear axle gets the signal of the front axle time-delayed by the quotient of wheel base and vehicle speed.

The following figure (Fig. 14) shows as a possible result the dynamic comfort value in vertical direction of the driver's cabin. This simulation was made for a road between class C and D according to ISO TC108 (reference spectral density = 2.0E-05 m^3) and a vehicle speed of 15 m/sec.

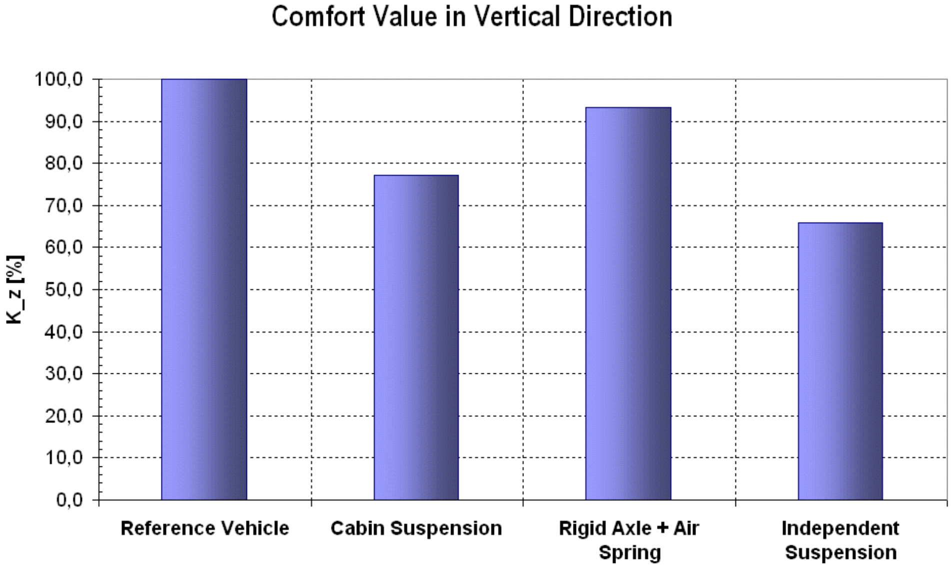


Fig. 14 Results of Investigating the Comfort Value

Conclusions:

This paper describes the modeling of a full vehicle model for simulating vertical dynamic. The task of this work was to vary some components of the vehicle like front wheel suspension, spring system and cabin suspension to improve comfort behaviour. In this case it was possible to adjust the reference model with measuring data established on our testing track. All results of the following simulations like vertical acceleration and roll angle of the driver's cabin were declared with refer to the adjusted model. The used obstacle was 40 mm high with ramps on both sides.
For investigating the dynamic comfort value a stochastic excitation in the tire contact area was generated according to the theory of RICE. The power spectra of different road surfaces are really similar and can be approximated by a straight line in a logarithm scaled diagram.

References:

[1] RICE, S. O.: Mathematical Analysis of Random Noise, Selected Papers on Noise and Stochastic Processes (Dover Publication, New York 1954)

[2] MARZY, MRAZEK, BRAMBERGER: Dynamiksimulation für die Entwicklung einer Nfz-Einzelradaufhängung (Paper ÖIAV, Vienna 2000)

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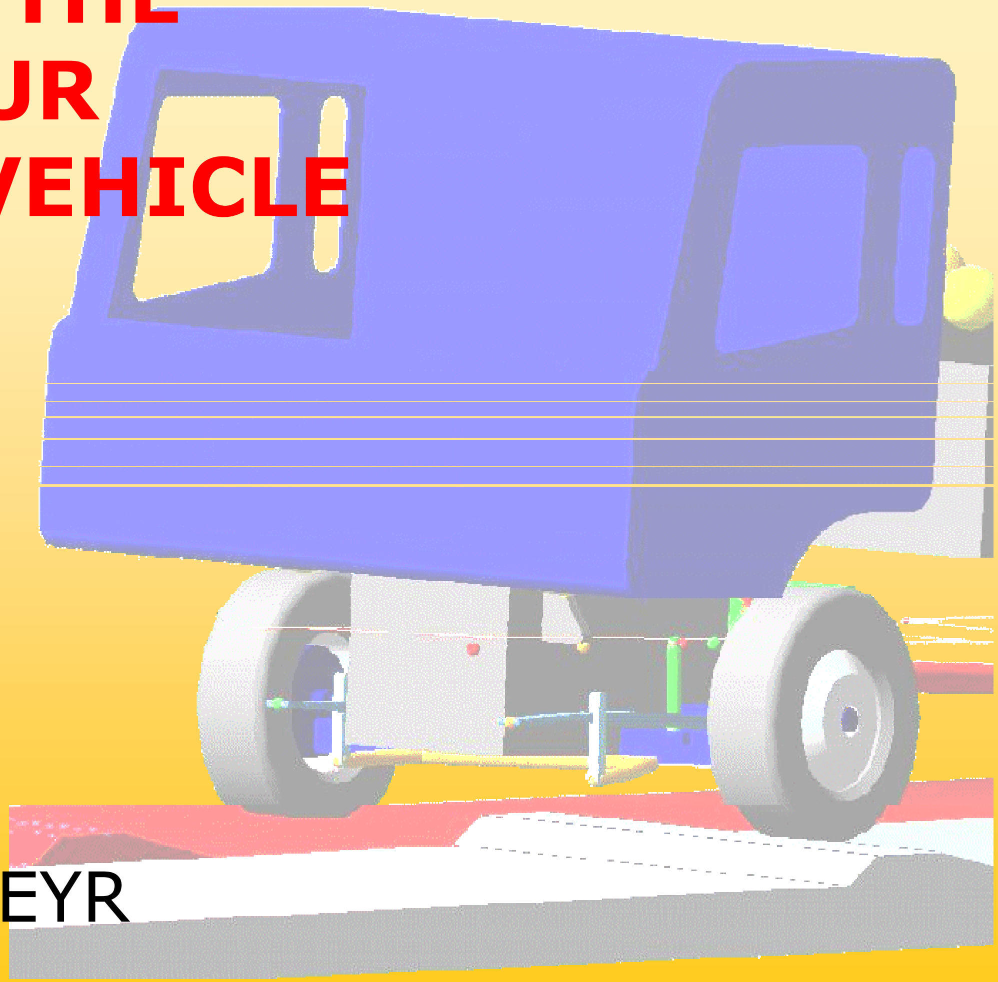
INVESTIGATION OF THE COMFORT BEHAVIOUR OF A COMMERCIAL VEHICLE IN ADAMS/View



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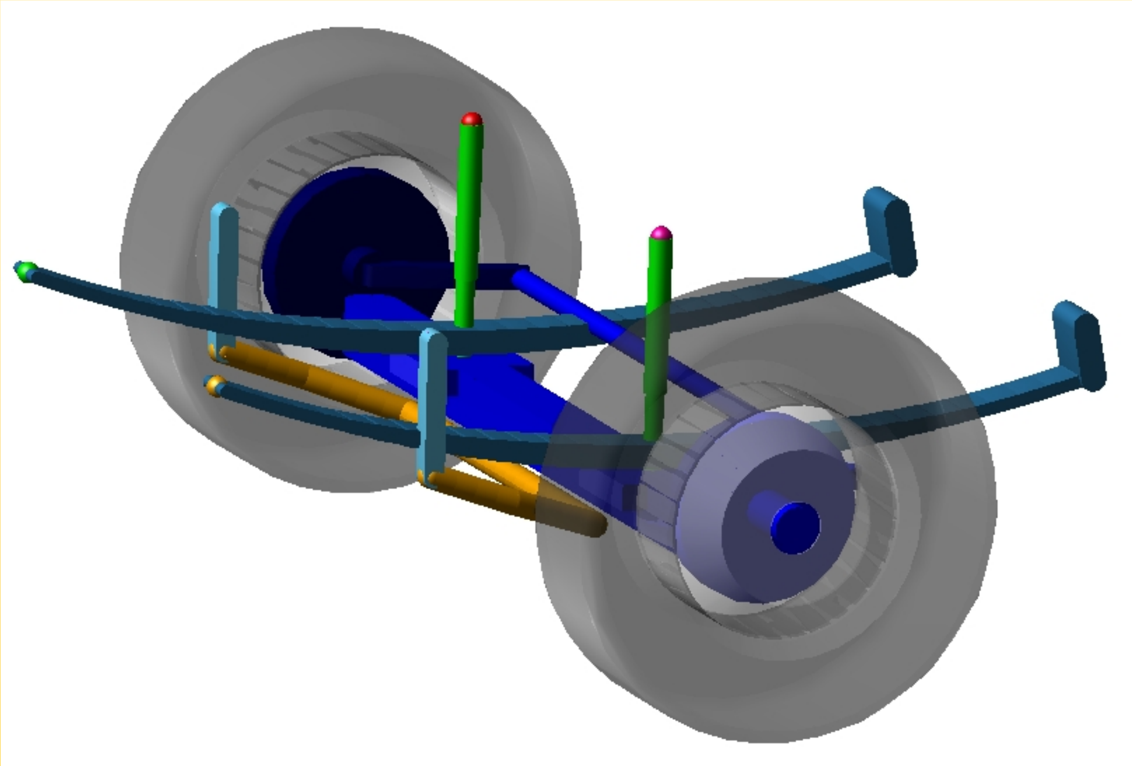
CONTENTS

Vehicle Modeling

RIGID FRONT AXLE

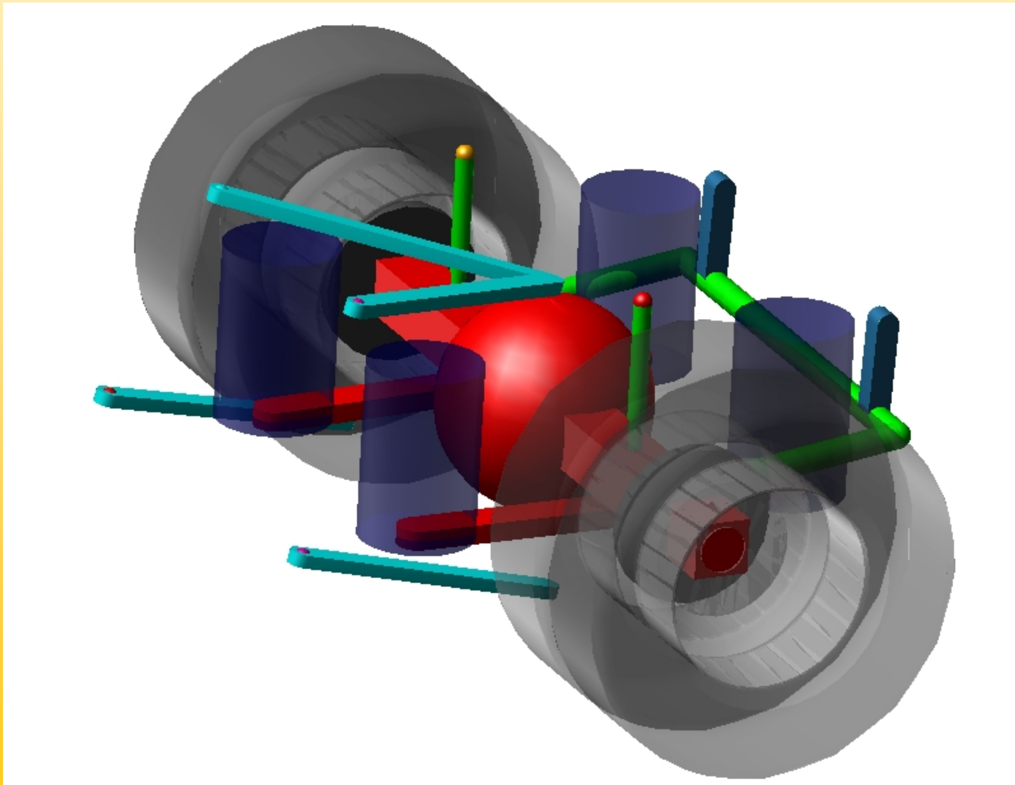
- Rigid Axle Body
- Parabolic Multi-Leaf Springs
- Shock Absorber
- Anti Roll Bar
- Simple Tire Model



Vehicle Modeling

RIGID REAR AXLE

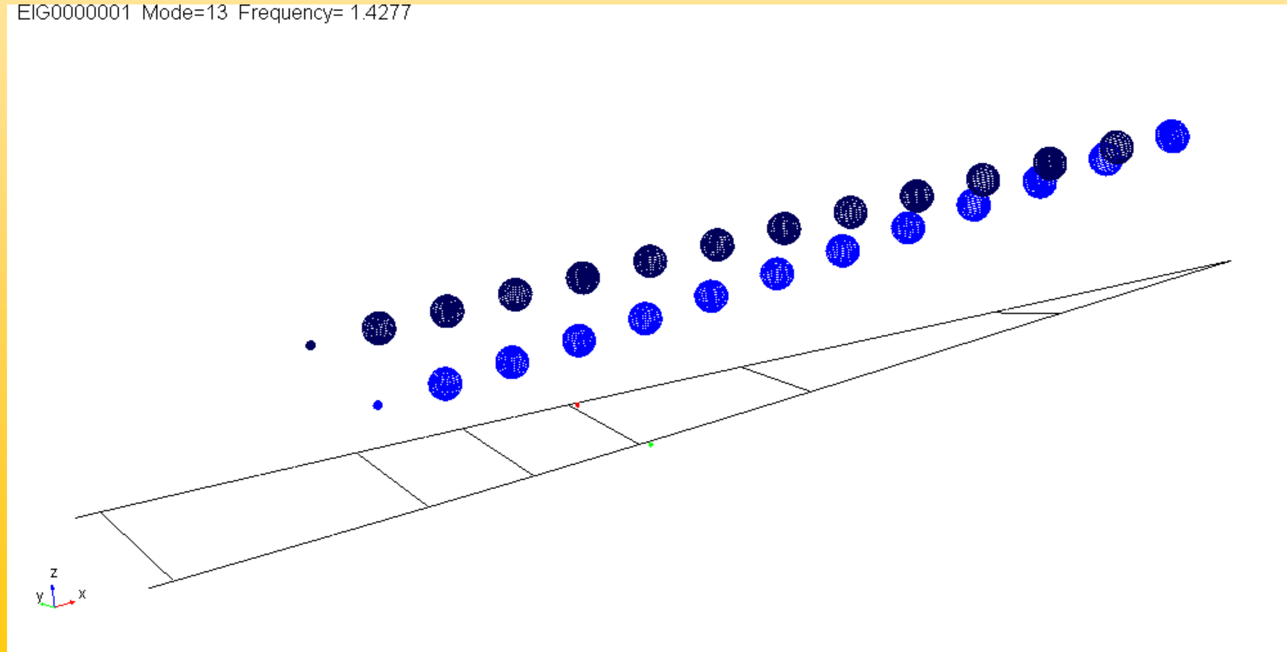
- Rigid Axle Body
- Air Springs
- Shock Absorber
- Anti Roll Bar
- Simple Tire Model



Vehicle Modeling

MAIN FRAME with PAYLOAD

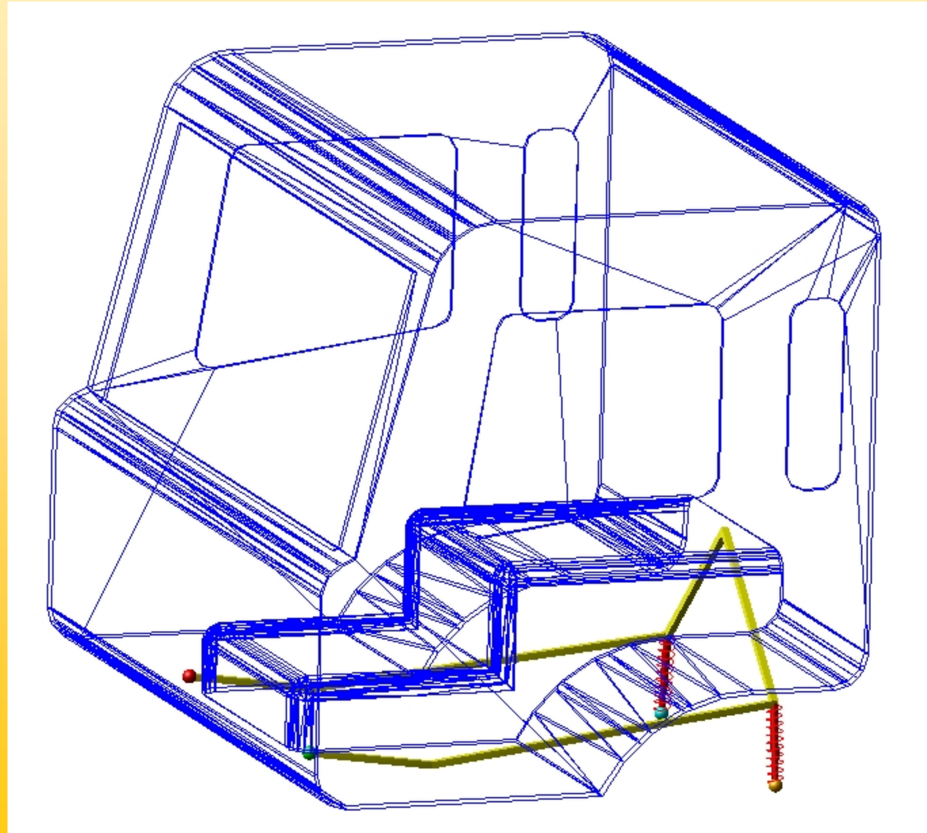
- **Frame as Flexible Body**
- **Payload**
  24x325 kg
- **Payload**
  fixed to Frame



Vehicle Modeling

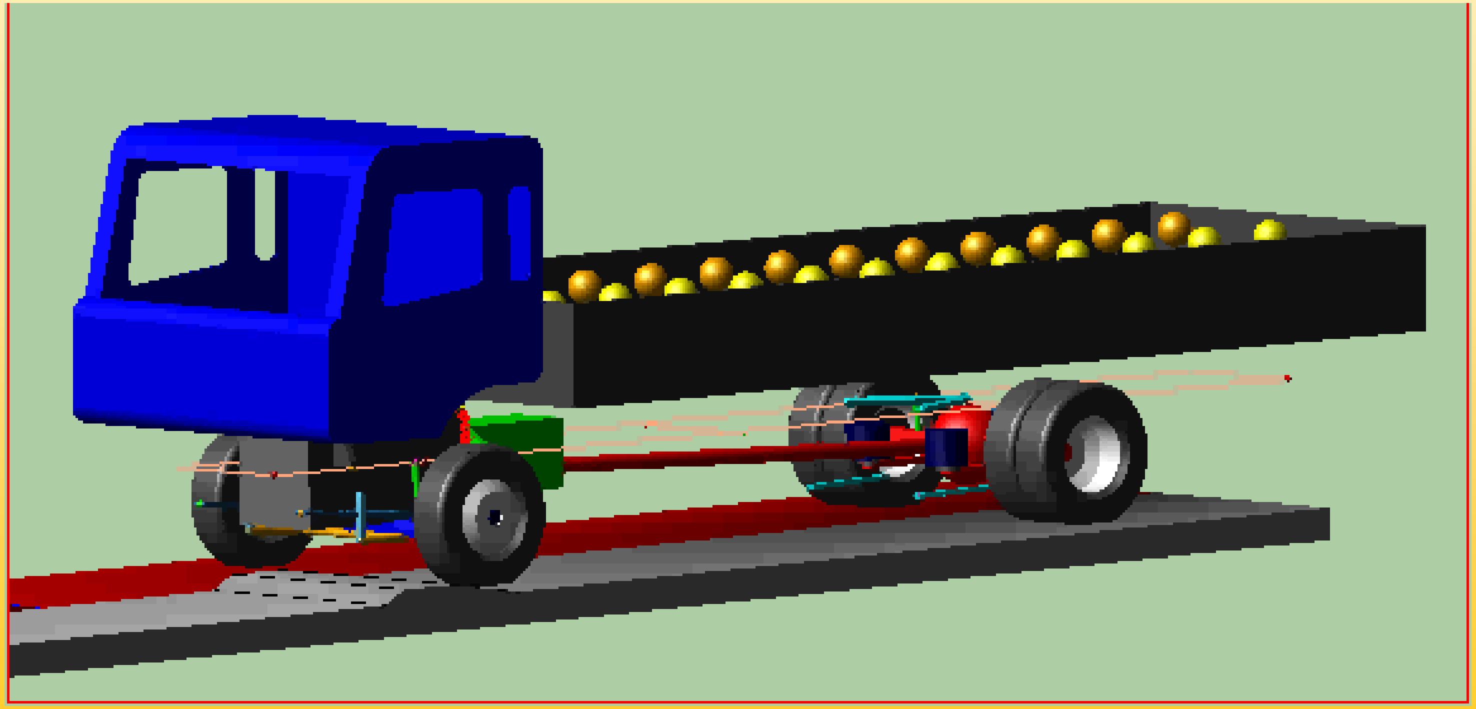
CABIN with SUSPENSION

- Cabin as rigid body
- Bushings as front suspension
- Spring/Damper as rear suspension



Vehicle Modeling

FULL VEHICLE MODEL



Comparison with measuring data

TESTING TRACK

- Gyroscopic Sensor for roll, pitch and yaw angle of the Driver`s Cabin
- Acceleration Sensors on Axles, Frame and Cabin

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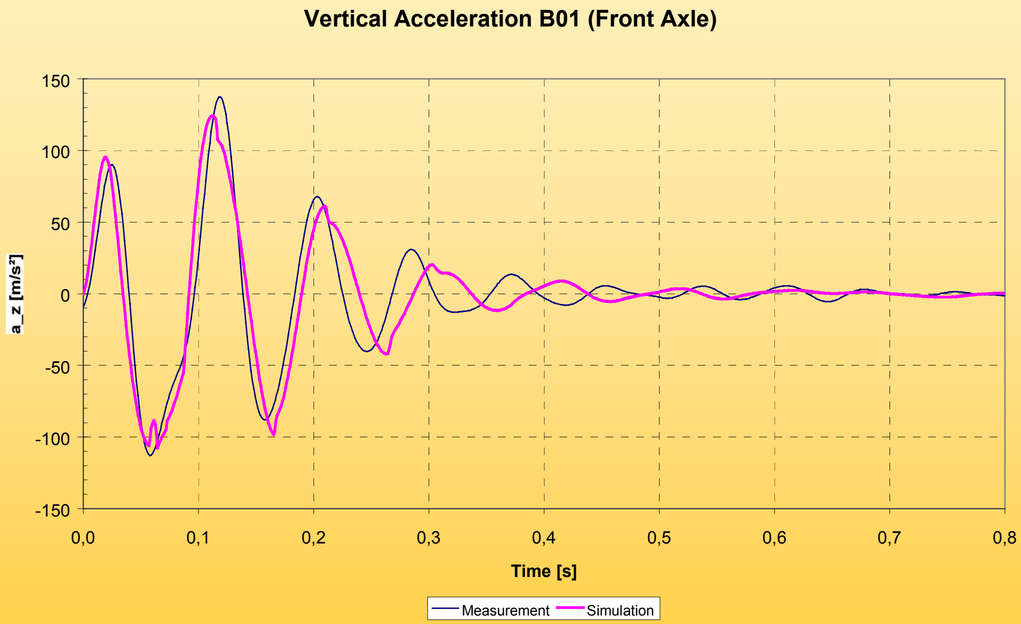
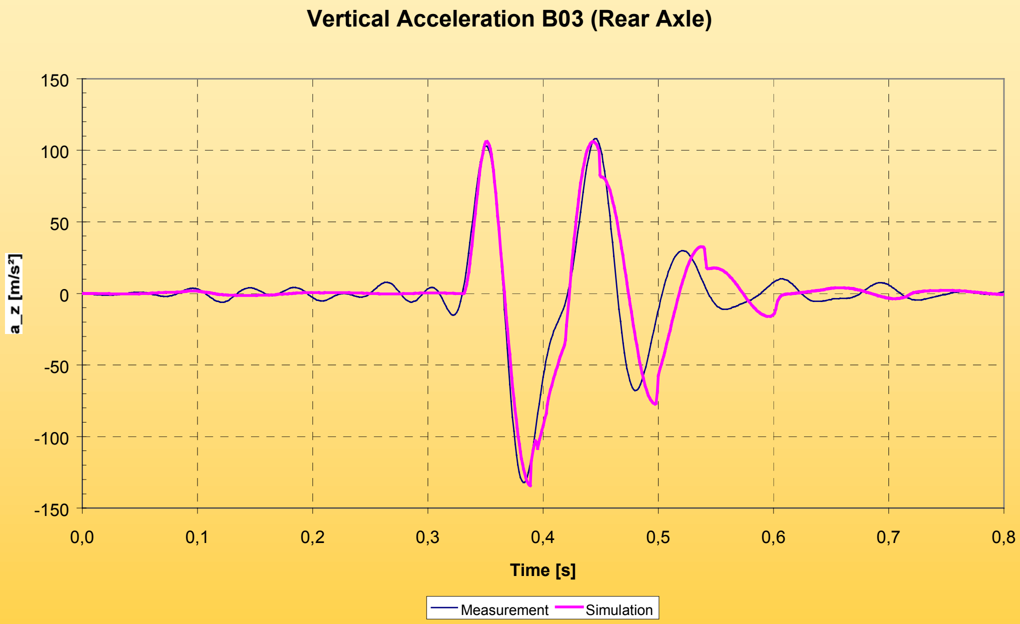
Comparison with measuring data

Vertical Acceleration Front and Rear Axle

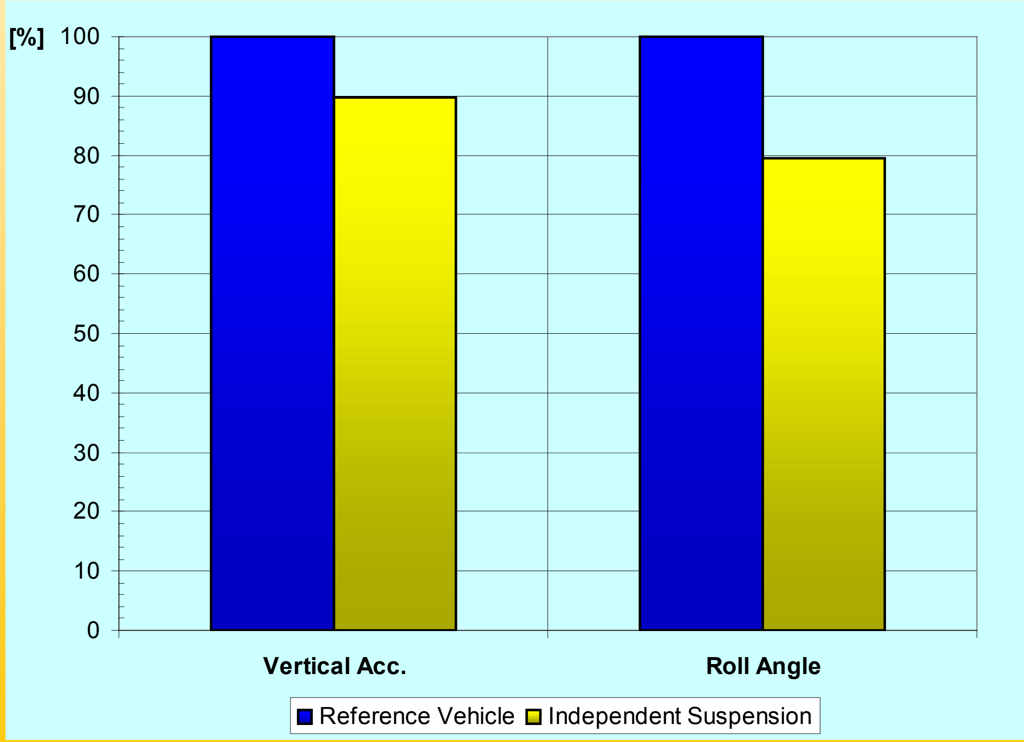


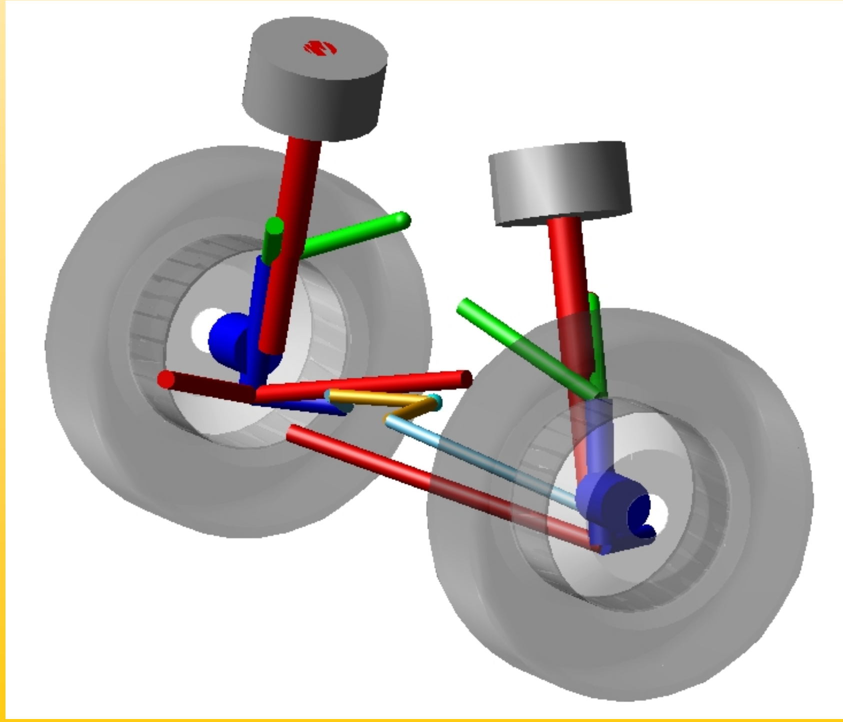


Payload 7800 kg
Obstacle 40 mm
Speed 50 km/h

Modified Vehicle Models

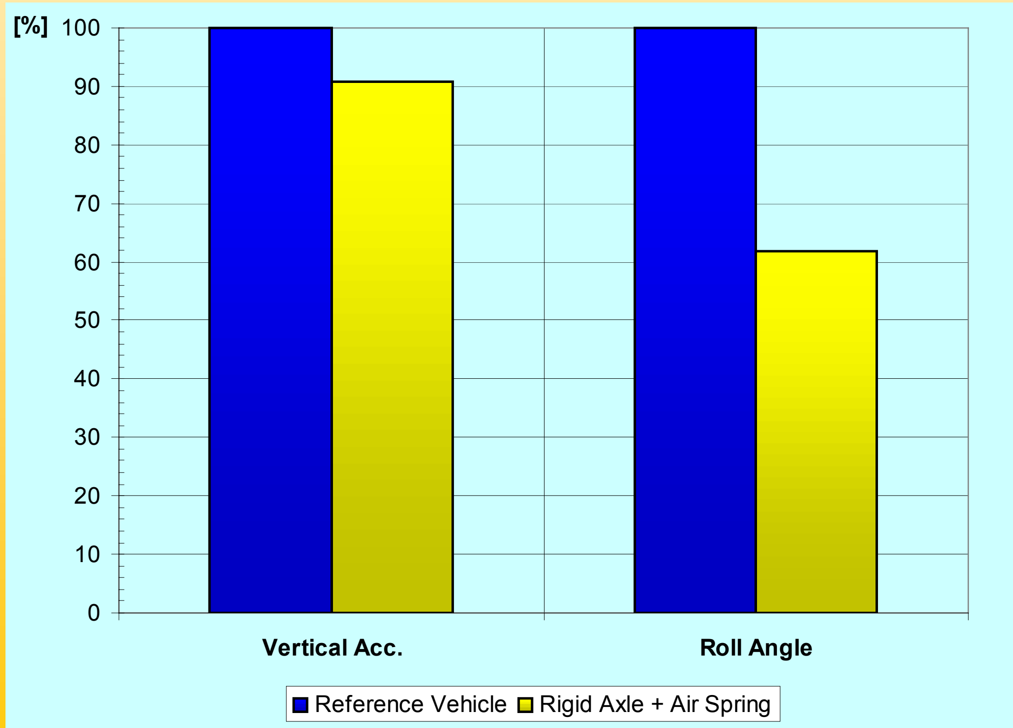
MODIFIED FRONT SUSPENSION

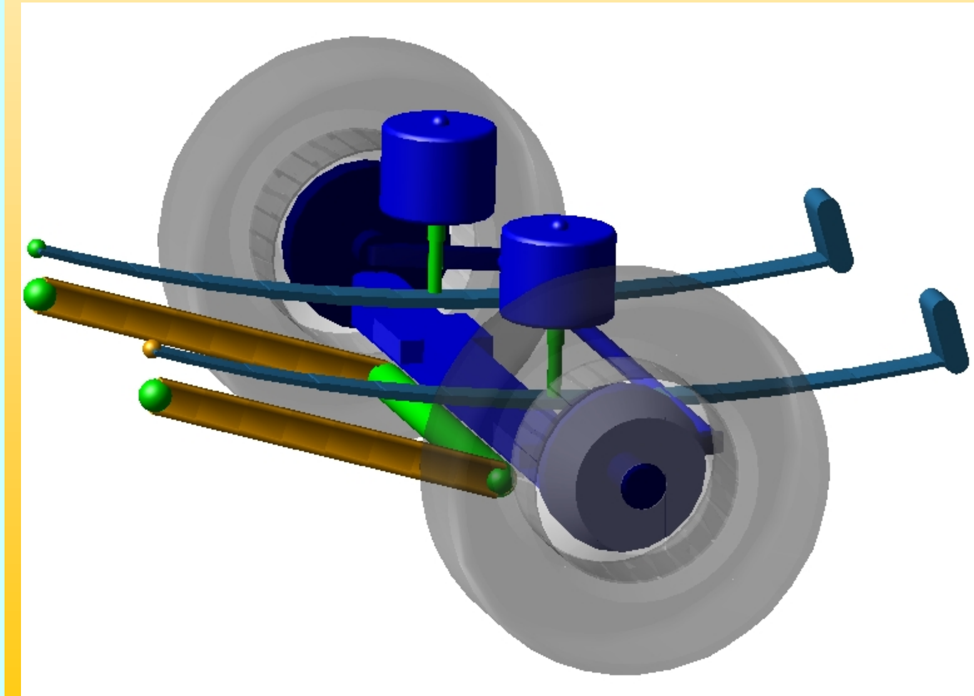




Modified Vehicle Models

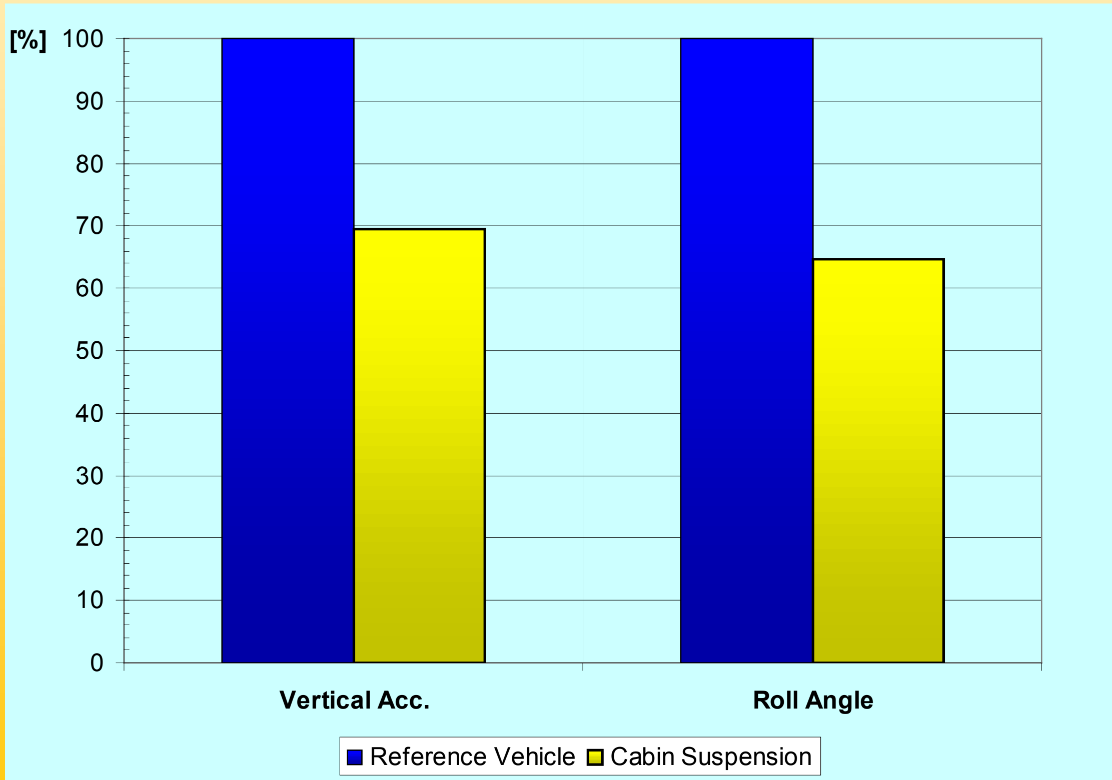
MODIFIED SPRINGS

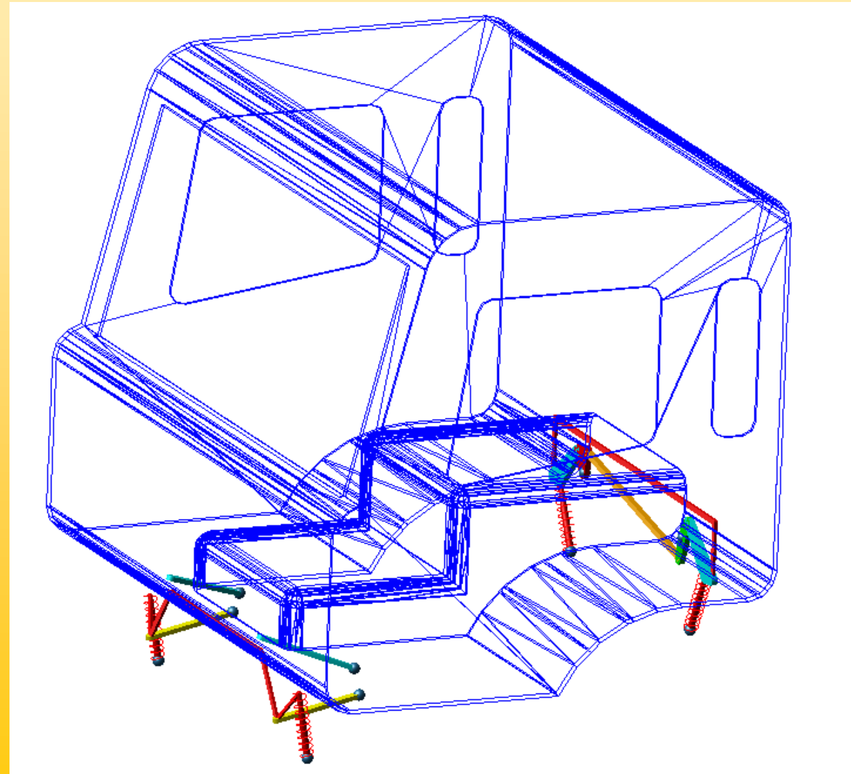




Modified Vehicle Models

MODIFIED CABIN SUSPENSION

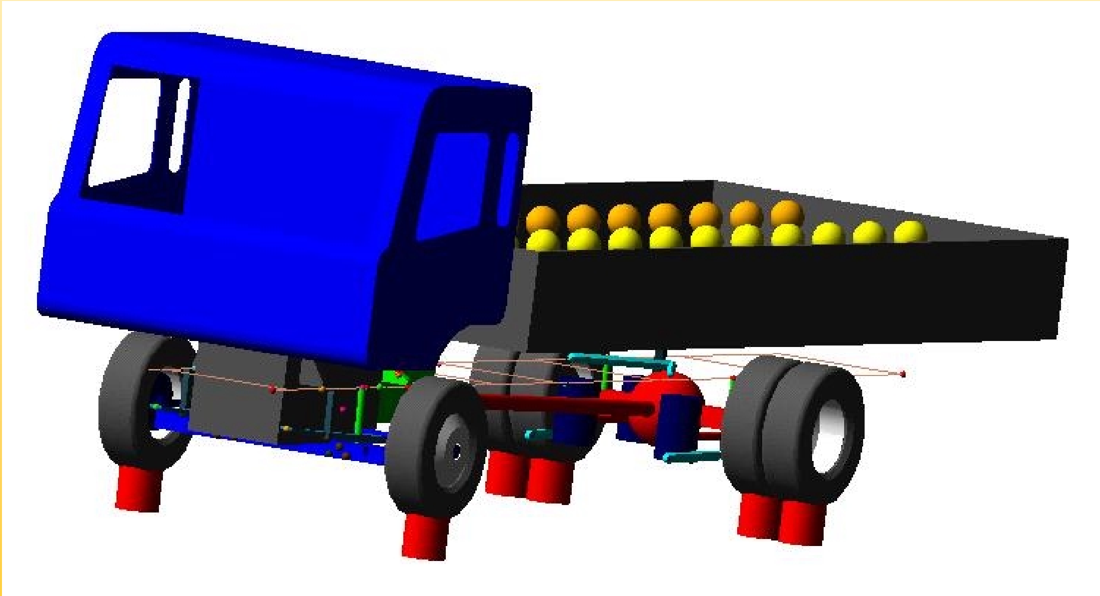




Comfort Study

INVESTIGATION OF COMFORT MODELS

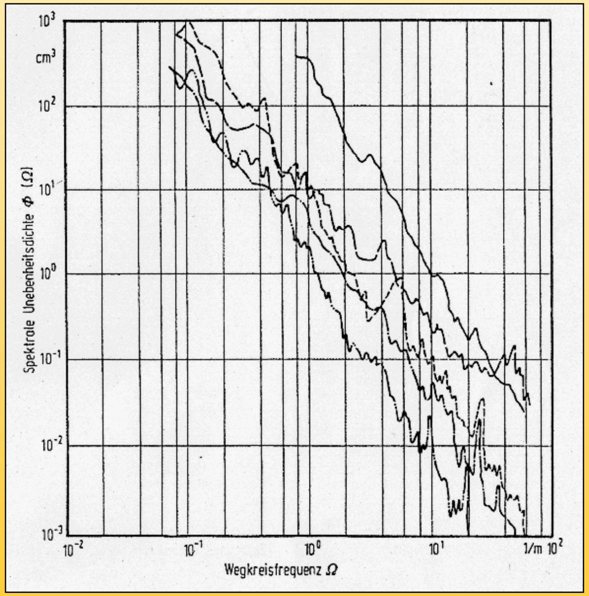
Input:
- Road surface
- Load condition
- Vehicle speed
- Wheel base
- Wheel track



Output:
- Accelerations
- Amplitude response
- K-Value

Comfort Study

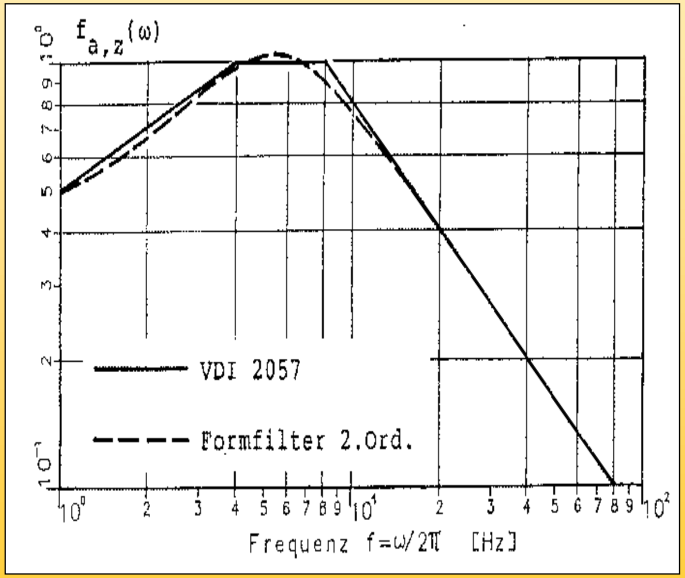
Road Spectral Density:



Approximation Formula:

$$\Phi(\Omega) = \Phi_0 \left(\frac{\Omega_0}{\Omega} \right)^{w}$$

Weight Shape Filter:



Result: Comfort Value

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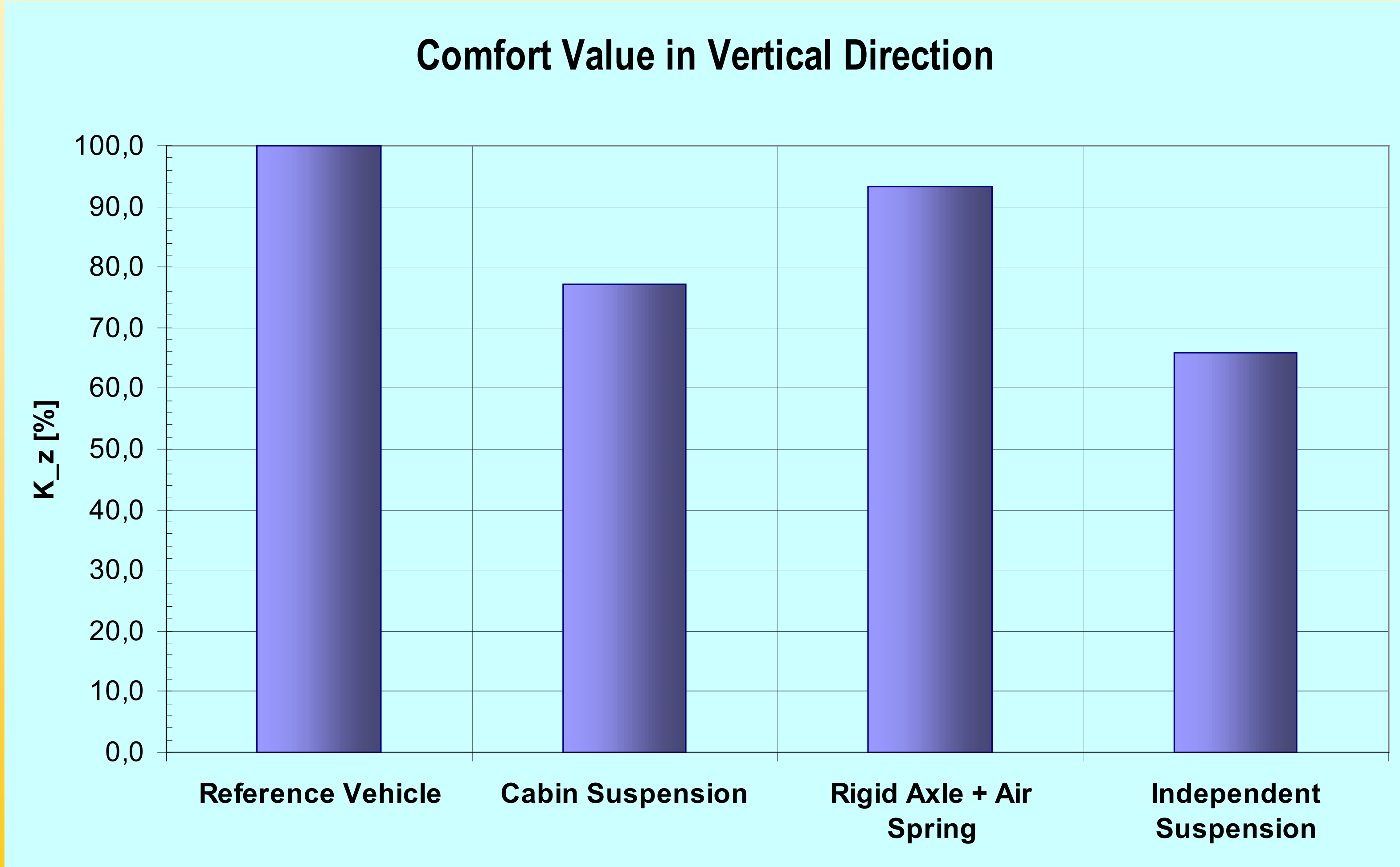
Comfort Study



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FURTHER PROCEEDING

- Implementation of a Tire Model
- Defining Obstacles as rdf-Files
- Modeling a Subframe for the Payload
- Improving flexible Frame
- Modeling dynamic behaviour of Leaf Springs
- Changing to ADAMS/Car to simulate Vehicle Dynamics