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Tyre Models in Vehicle System Dynamics:

RMOD-K and SIMPACK

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Overview

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Introduction and Tyre Modelling

- classification of tyre models and RMOD-K's model system
- driving dynamics model: running on flat roads
- ride comfort model: crossing obstacles

Model Parameter and Validation

- determination and optimisation
- required measurements
- validation of tyre model and full vehicle system

Examples

- RMOD-K's terrain model: parametric and digital surfaces
- questions related with road measurement and modelling
- data reduction in relation to accuracy of simulated forces

Futher Development

Summary

Classification of Tyre Models

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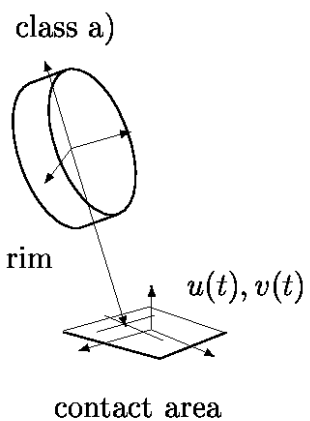
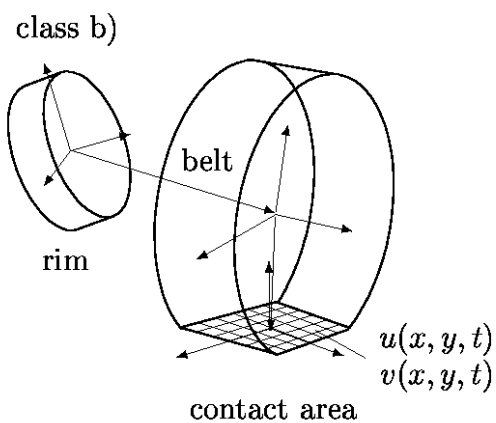
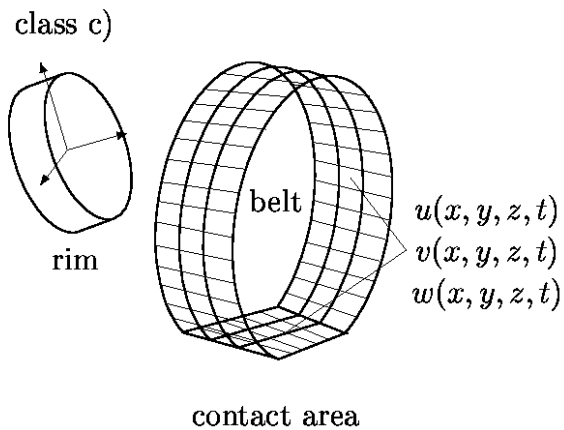
properties	class a)	class b)	class c)
slip definition used	yes	no	no
discretizated contact	no	yes	yes
discretizated belt	no	no	yes
frequency range	< 2 Hz	< 80 Hz	< 300 Hz







RMOD-K Driving Dynamics Model

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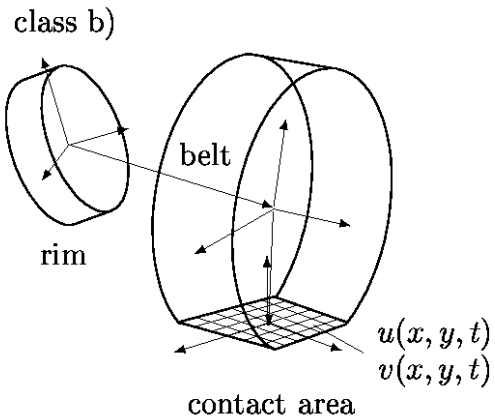
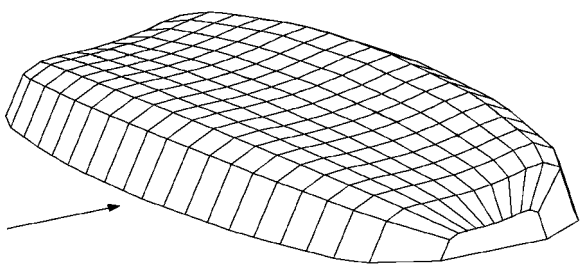
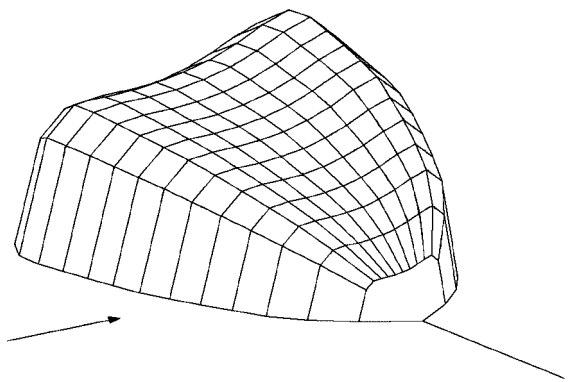
- Euler formulation of contact displacements
- rigid body belt modes
- elastic coupling between belt and rim
- belt loaded by contact forces
- contact area pressure and shape simulated



simulated pressure distribution without camber and with camber





RMOD-K Ride Comfort Model

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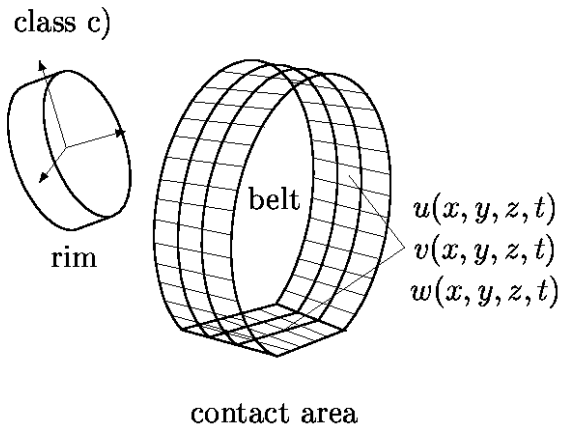
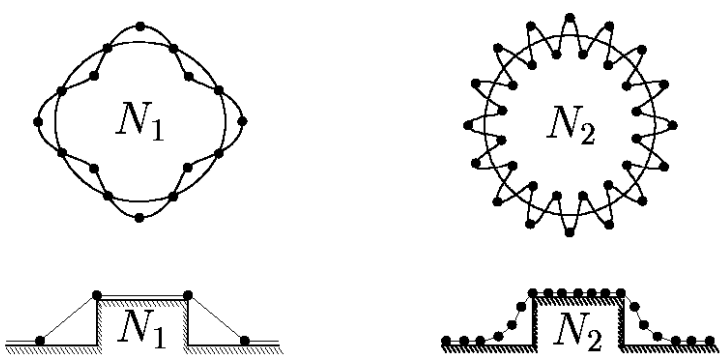
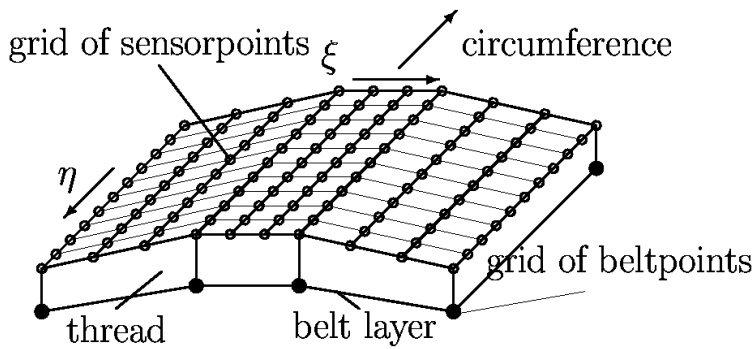
- Lagrange formulation of equations of motion
- belt as dynamic structure
- membran sidewall model
- contact layer between belt and road surface
- contact area pressure and shape calculated



conflict between eigenfrequency and wavelength solved by sensorpoints





RMOD-K Ride Comfort 3D Model

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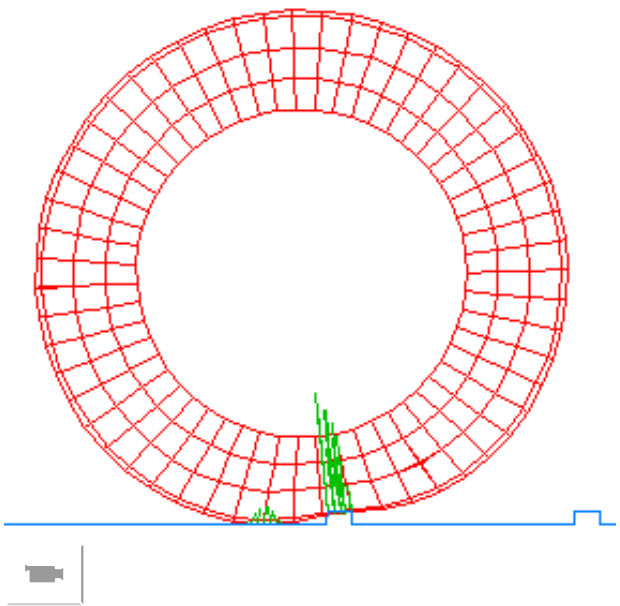
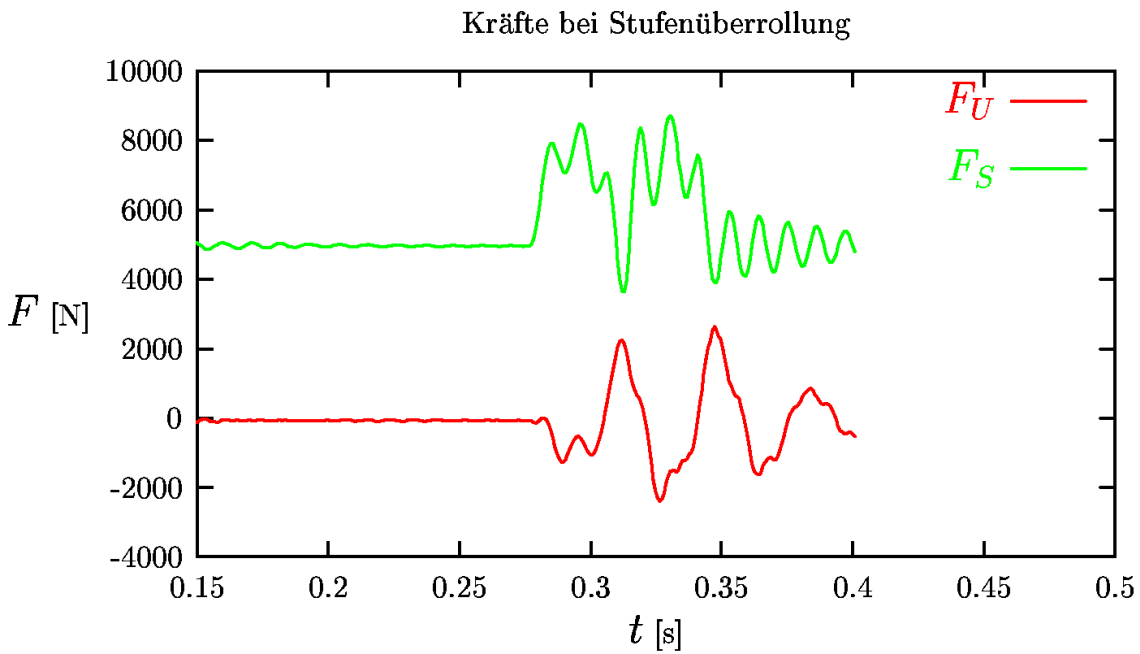
example 1: tyre crossing cleats





Parameter Determination, Optimisation

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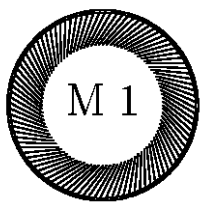
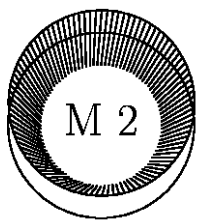
determination of model parameter

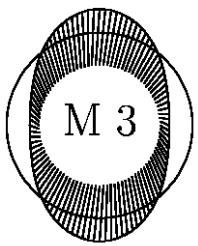
- data from tyre construction like tyre size and mass
- data from measurement like eigenfrequencies or radial stiffness used directly
- data from measurement like pressure distribution used for approximation

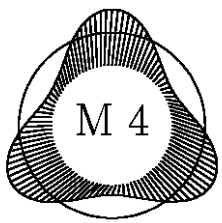
optimisation and validation

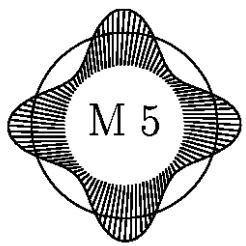
- comparison of eigensystem (eigenfrequencies and mode shapes)
- comparison of cleat test rim force measurement
- comparision of full vehicle experiments/calculations











measured	-	88.2	115.9	141.2	169.3
calculated	60.17	88.19	115.38	142.47	172.45

Validation by Cleat Tests

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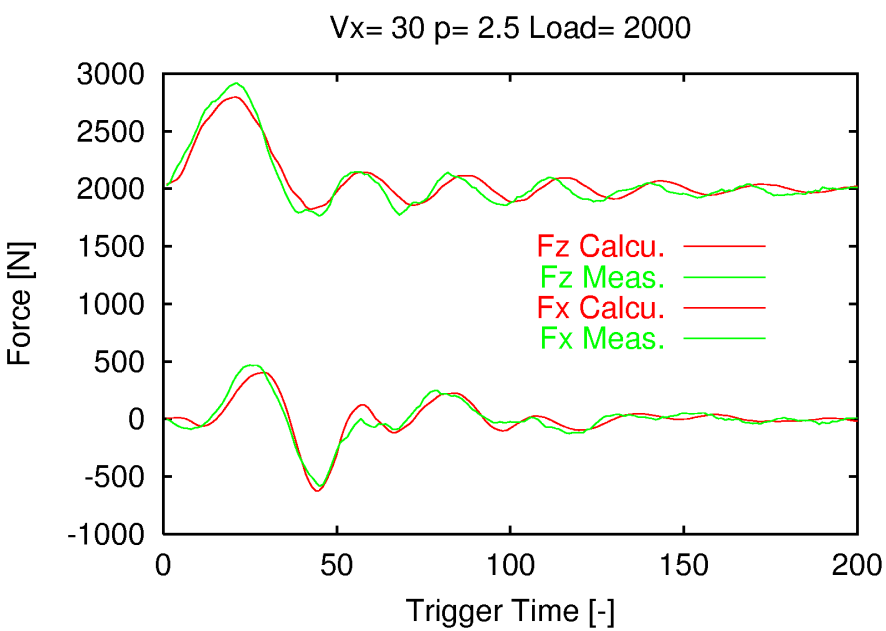
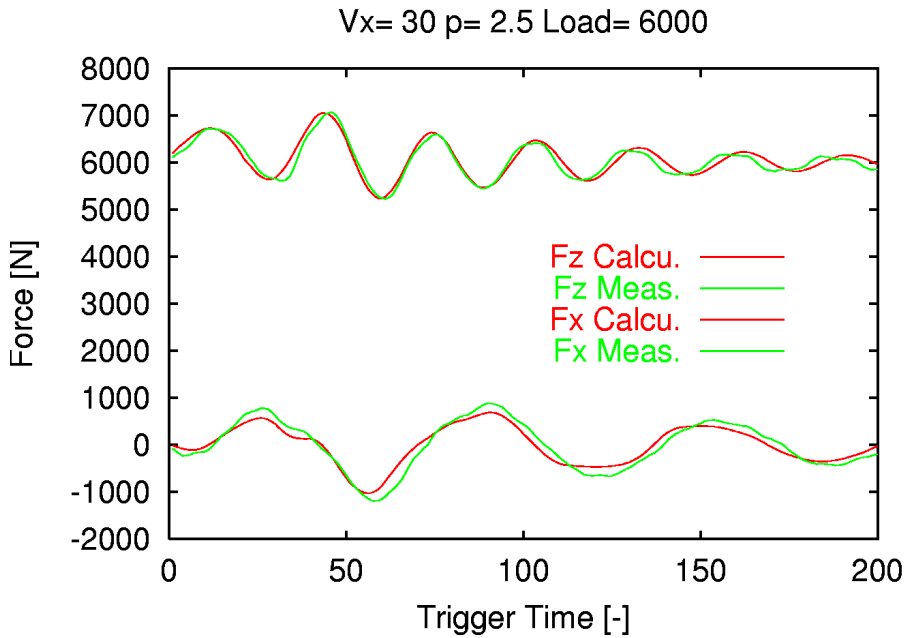
- cleat — 5 mm at 0^0
- environment — drum
- varied parameters — load, velocity, inflation pressure
- model used — 2D inplane elastic belt
- target data — rim force (time domain)





Validation by Full Vehicle Test

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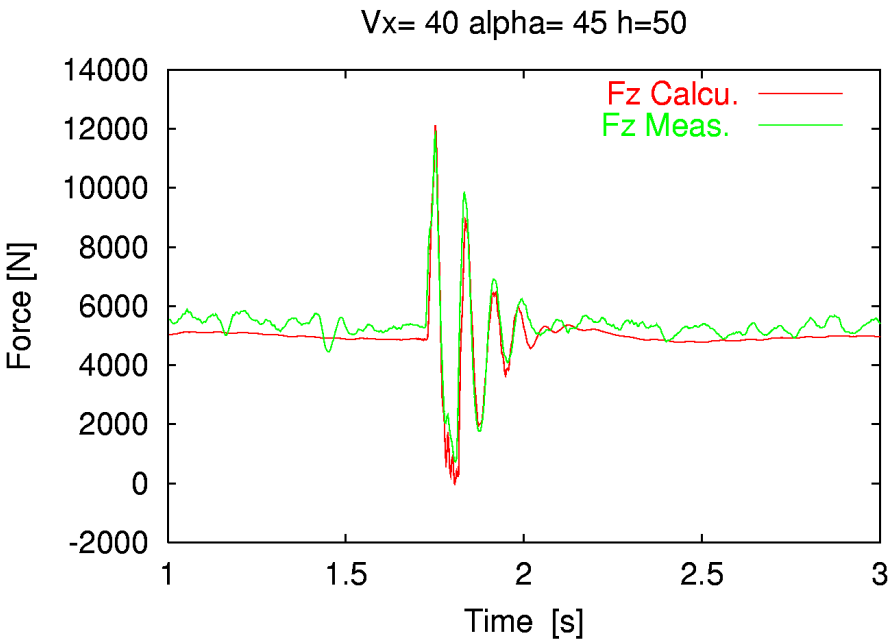
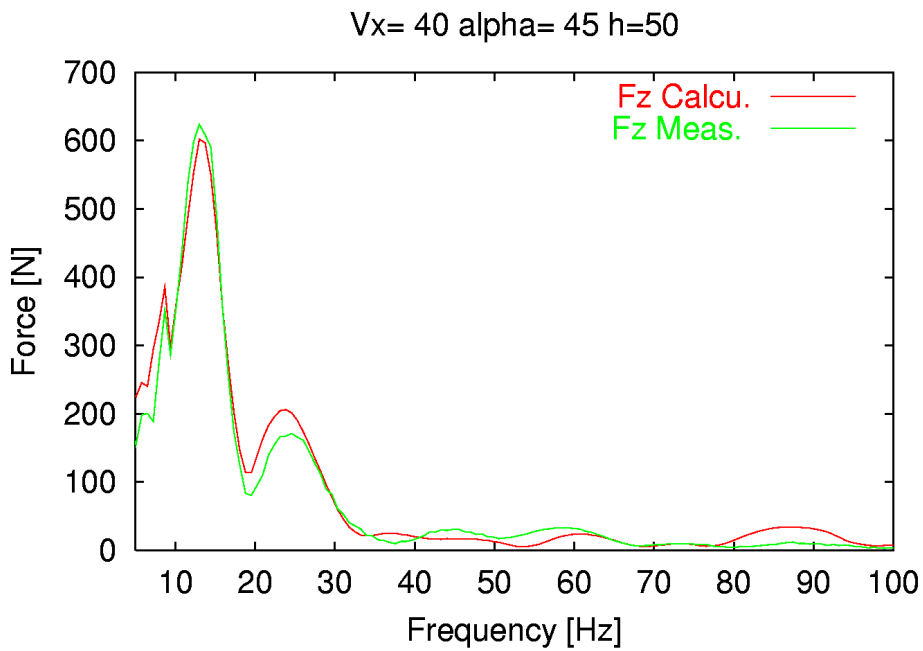
•cleat	50 mm at 45^0
•environment	road
•varied parameters	velocity, inflation pressure
•model used	3D elastic belt
•target data	rim force (time and frequency domain)





RMOD-K Terrain Models

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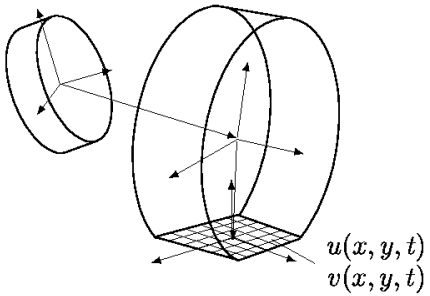
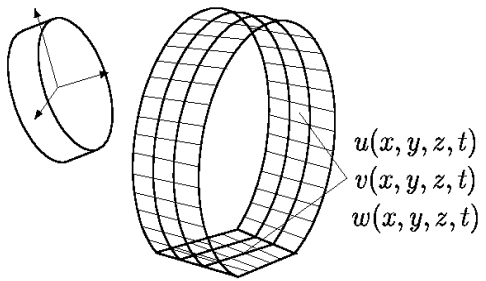
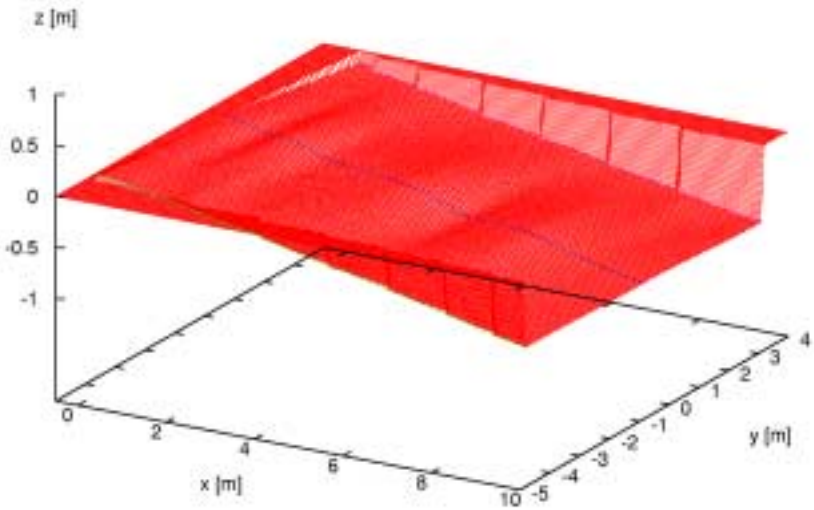
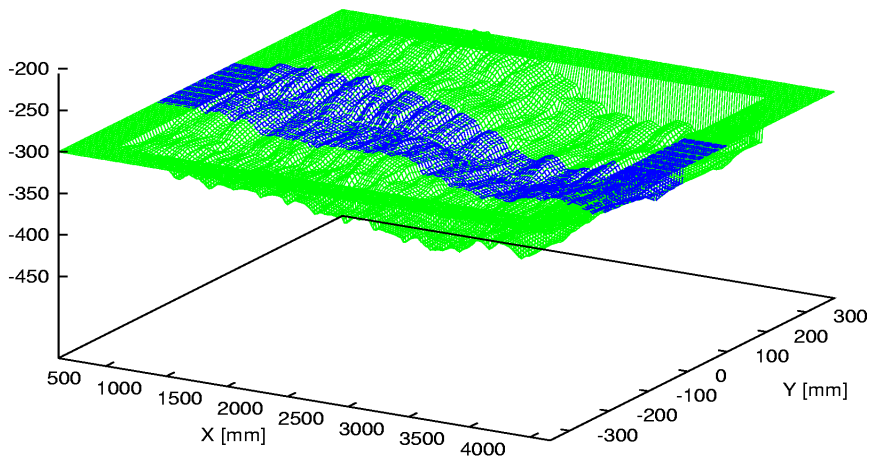
driving dynamics - load collectives - missuse - life time









Investigation of Data Reduction Principles

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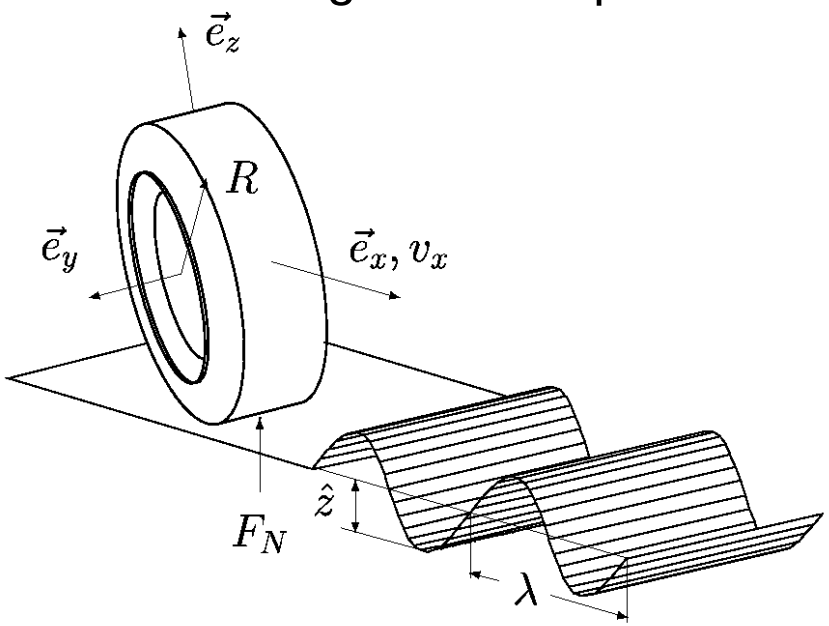
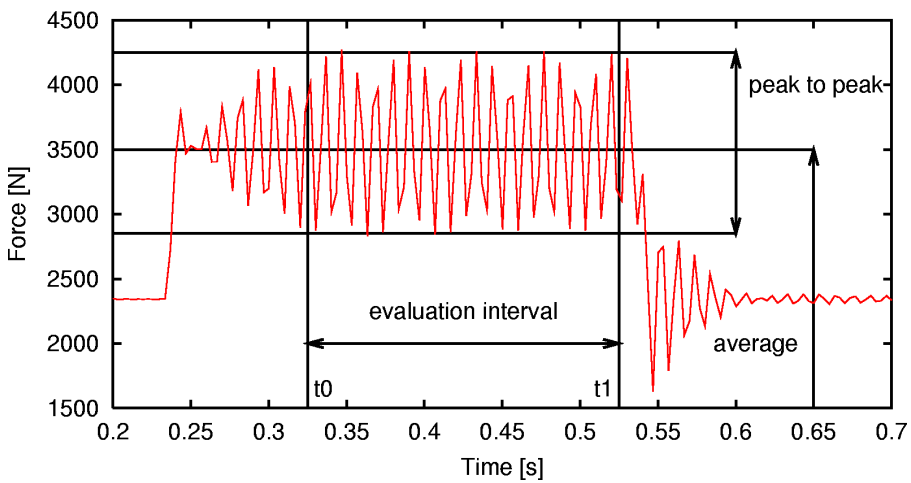
required information: wavelength boundary as function of tyre load, velocity and size, influence of obstacle's shape

sinusodial pertubations with varied wavelength and amplitude



evaluation of average and peak to peak amplitude



Dependency on Wavelength

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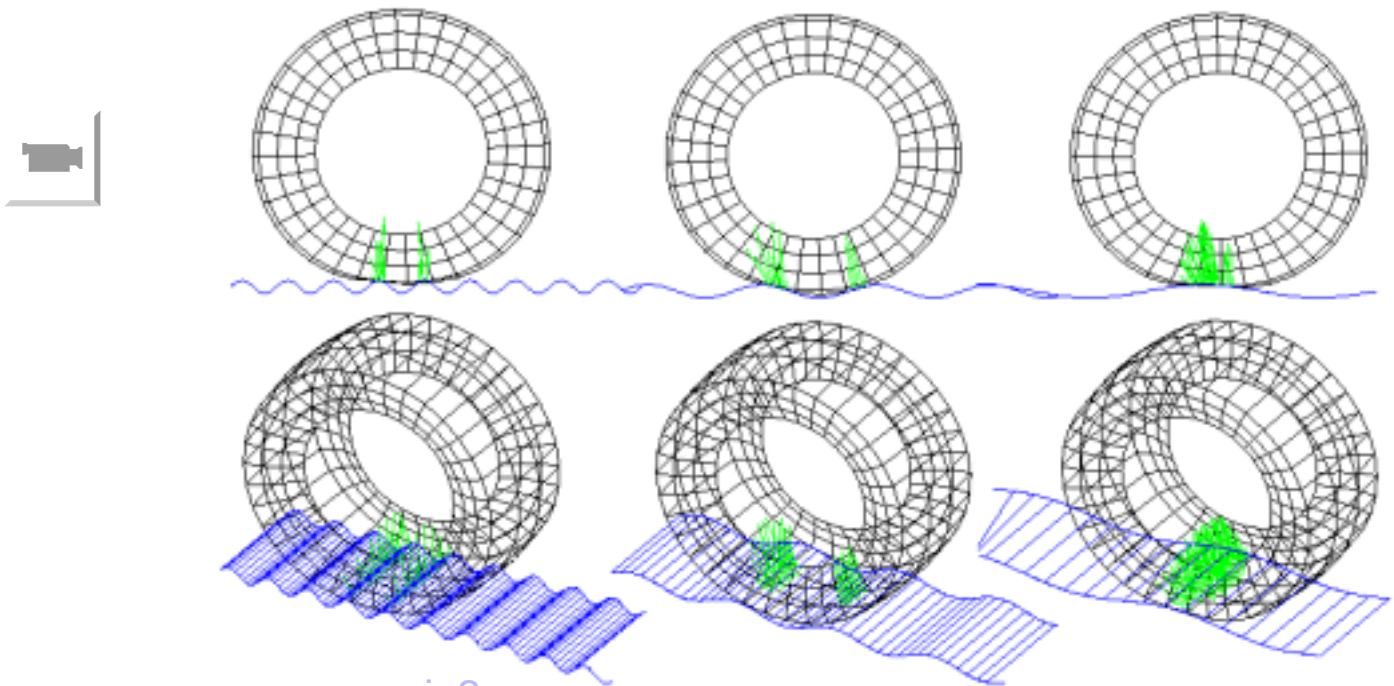
example 2: 3D elastic belt model on sinusodial surfaces



movie2

Road Surface at Different Reduction Rates

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consequences: data reduction rules

- disturbance wavelength boundary λ_b can be calculated
- negative small obstacles (gaps) can be neglected
- positive small obstacles (peaks) have to be keped
- waves with $\lambda < \lambda_b$ can be replaced by plane surfaces of height z

$\Rightarrow$ preprocessing algorithm to reduce measured data of road profils

Road Surface at Different Reduction Rates

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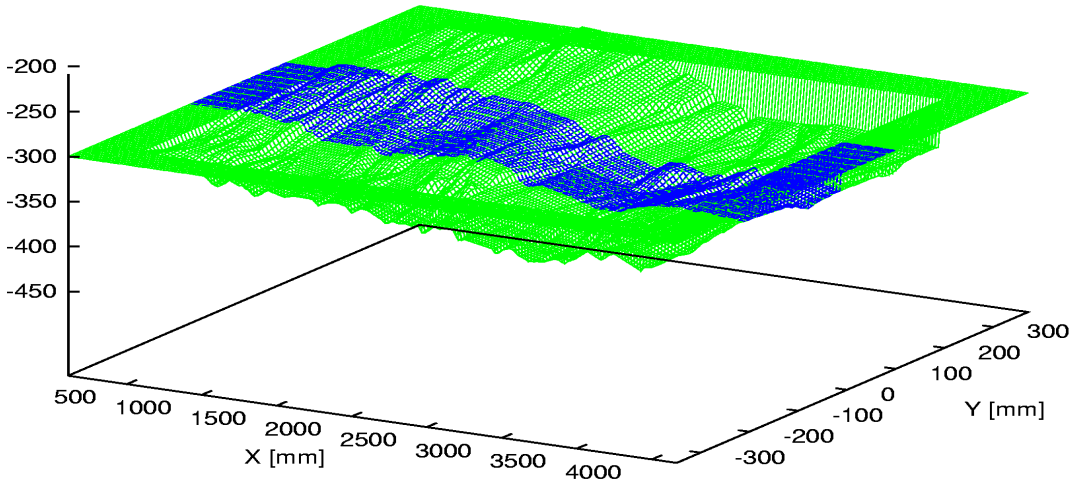
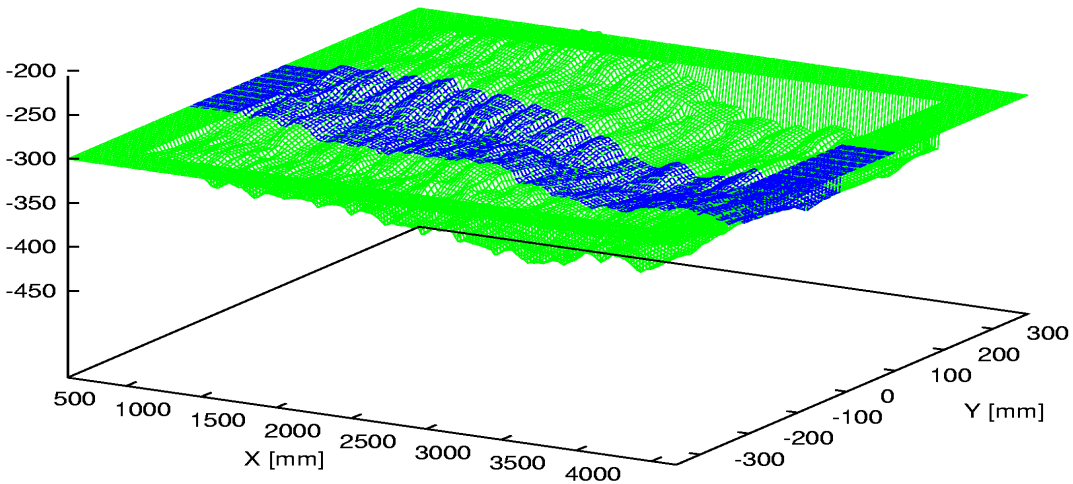
3935 points

7154 triangles





12270 points

23298 triangles

Choice of Optimal Reduction Rate

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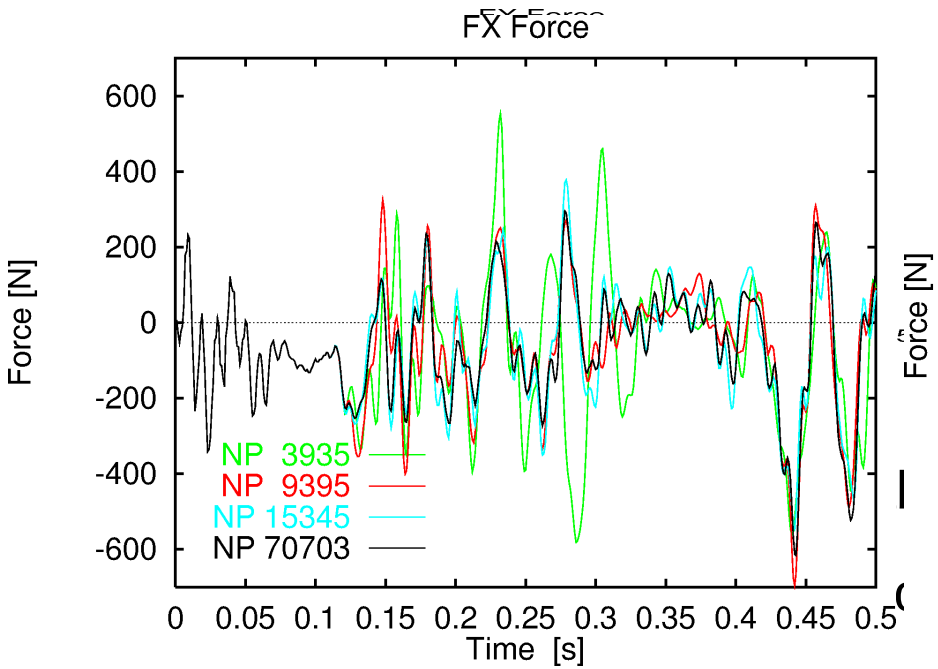
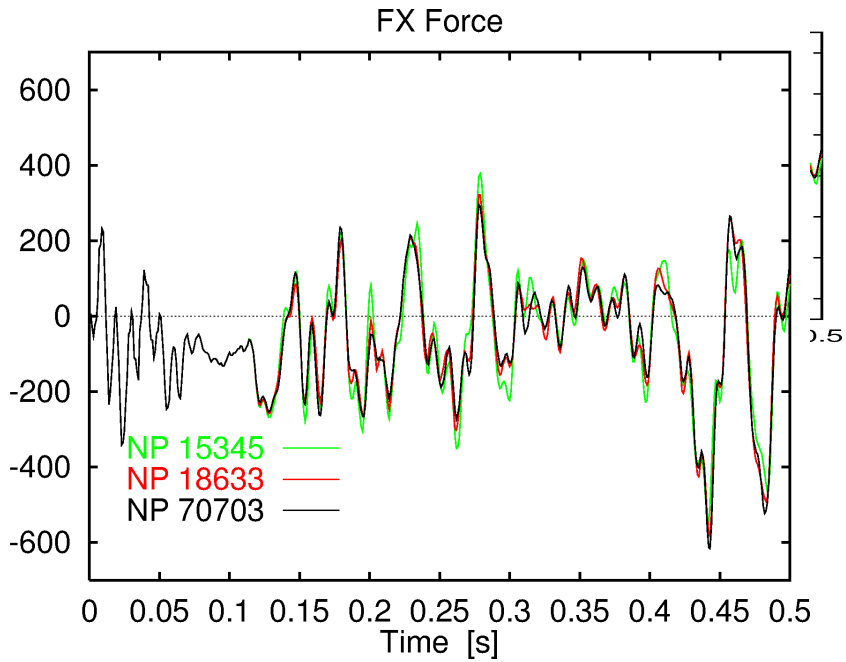
- calculation of rim forces at road profils with different reduction rates
- comparison of rim forces to get to optimal reduction rate





$\Rightarrow$ rim force differences less than 3 %

Further Development

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user driven development

RMOD-K new models at 7.0

rigid ring model:

- new solver and contact-algorithm
- adaptive numerics
- new interfaces

flexible model:

- based on FE model
- response surfaces
- more flexible discretization

Further Development

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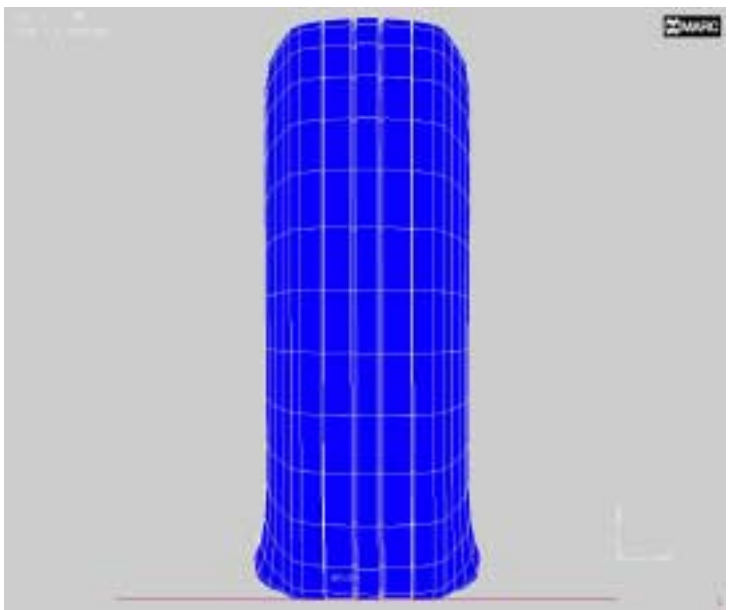
consideration of tyre inhomogene assembly by several layers

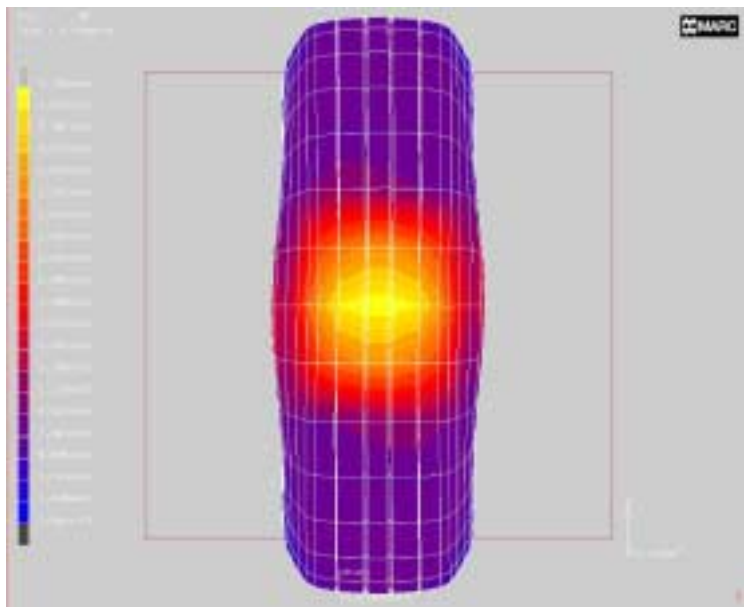
capability of short waved road surfaces in the area of millimeters

dynamics of elastic modes higher than 100 [Hz]

} based on FE model



deformation under internal pressure



structure deformation

Summary

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RMOD-K tyre and terrain modelling system

model system with several models of different complexity
standard parameter determination and validation procedure
costumers: AUDI, BMW, DaimlerChrysler, Porsche, Volkswagen ..

methodical approach concerning road profil measurement

determination of boundary values concerning grid with RMOD-K (2D)
principles of data reduction and organisation
choice of optimal reduction rate with RMOD-K (3D)
benefits in data handling and computational effort