



**4TH INTERNATIONAL TYRE COLLOQUIUM: TYRE
MODELS FOR VEHICLE DYNAMICS ANALYSIS**

**20TH AND 21ST APRIL 2015 | UNIVERSITY OF SURREY,
GUILDFORD, UK**



***FTire* and Puzzling Tire Physics: Teacher, not Student**

Michael Gipser

Esslingen University of Applied Sciences
& **cosin** scientific software



Why is *FTire* a teacher?

What can *FTire* teach?

How does *FTire* teach?



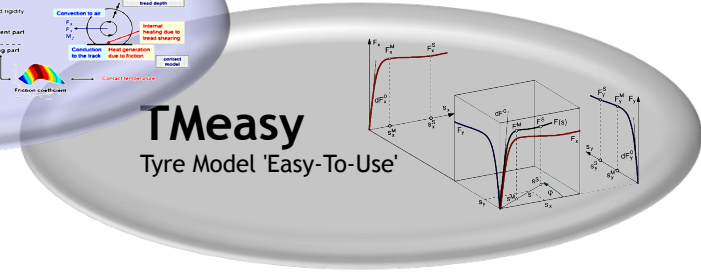
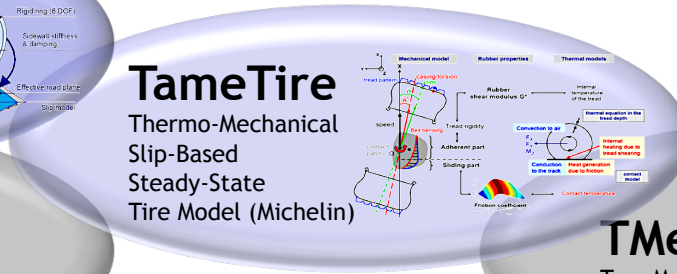
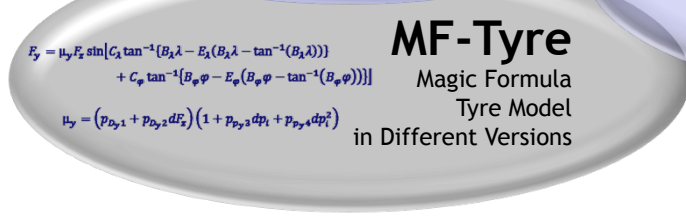
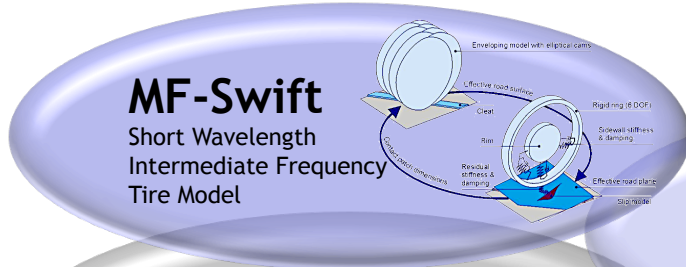
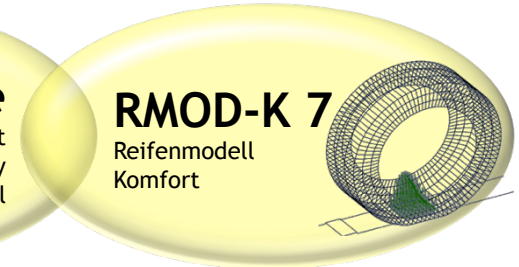
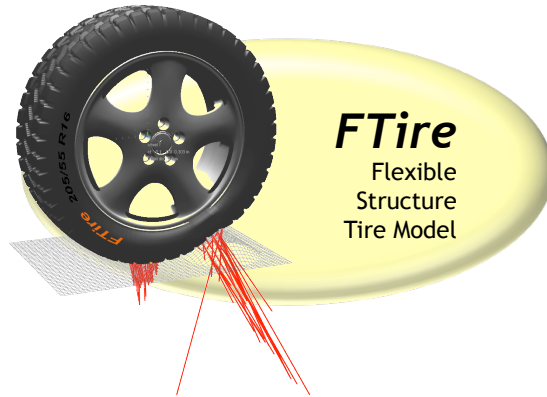
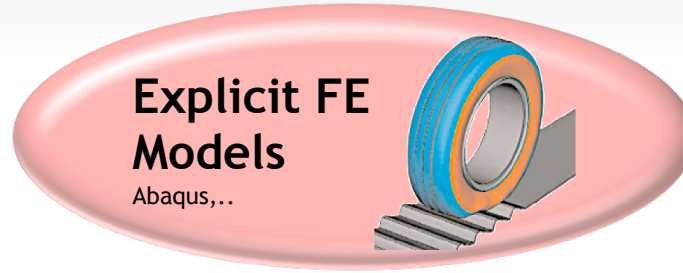
Why is *FTire* a teacher?

What can *FTire* teach?

How does *FTire* teach?



Complexity & Potential Application Range



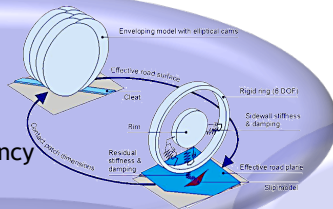


the **descriptive** approach: 'focus on **effect** rather than on **cause**'

- **mathematical quantitative** description of most important but isolated properties
- combination by **assumed superposition** of nonlinear properties with nonlinear cross-correlation

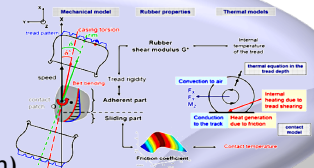
MF-Swift

Short Wavelength
Intermediate Frequency
Tire Model



TameTire

Thermo-Mechanical
Slip-Based
Steady-State
Tire Model (Michelin)



MF-Tyre

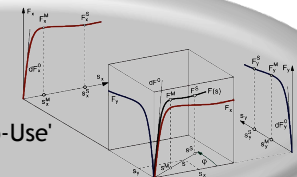
Magic Formula
Tyre Model
in Different Versions

$$F_y = \mu_y F_z \sin[C_1 \tan^{-1}\{B_1 \lambda - E_1(B_1 \lambda - \tan^{-1}(B_1 \lambda))\} + C_2 \tan^{-1}\{B_2 \phi - E_2(B_2 \phi - \tan^{-1}(B_2 \phi))\}]]$$

$$\mu_y = (p_{0y1} + p_{0y2} dF_z^2)(1 + p_{0y3} d\mu_x + p_{0y4} d\mu_x^2)$$

TMeasy

Tyre Model 'Easy-To-Use'



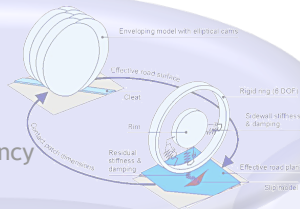


Tire model is **student**;
the developer must teach his model its complete behavior

‘you get what you have programmed’

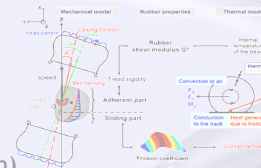
MF-Swift

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MF-Tyre

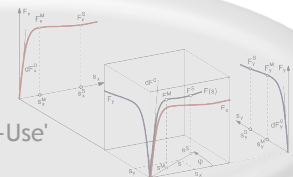
Magic Formula
Tyre Model
in Different Versions

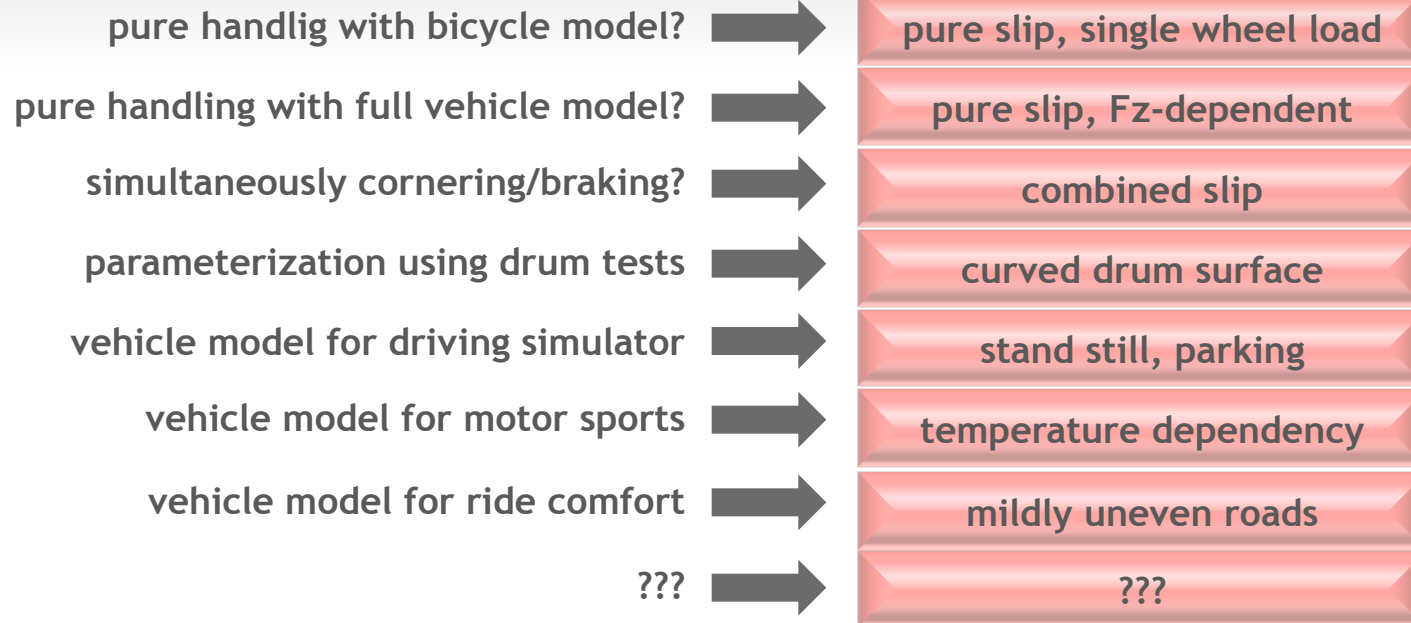
$$F_y = \mu_y F_z \sin[C_1 \tan^{-1}\{B_1 \lambda - E_1(B_1 \lambda - \tan^{-1}(B_1 \lambda))\} + C_2 \tan^{-1}\{B_2 \phi - E_2(B_2 \phi - \tan^{-1}(B_2 \phi))\}]]$$

$$\mu_y = (p_{0y1} + p_{0y2} dF_z) (1 + p_{0y3} dp_1 + p_{0y4} dp_1^2)$$

TMeasy

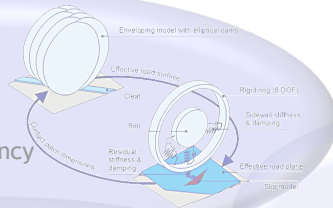
Tyre Model 'Easy-To-Use'





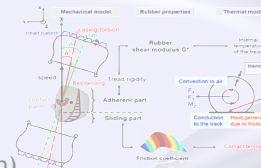
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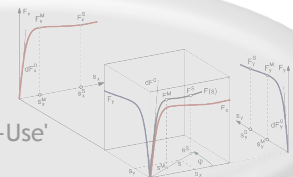
Magic Formula
Tyre Model
in Different Versions

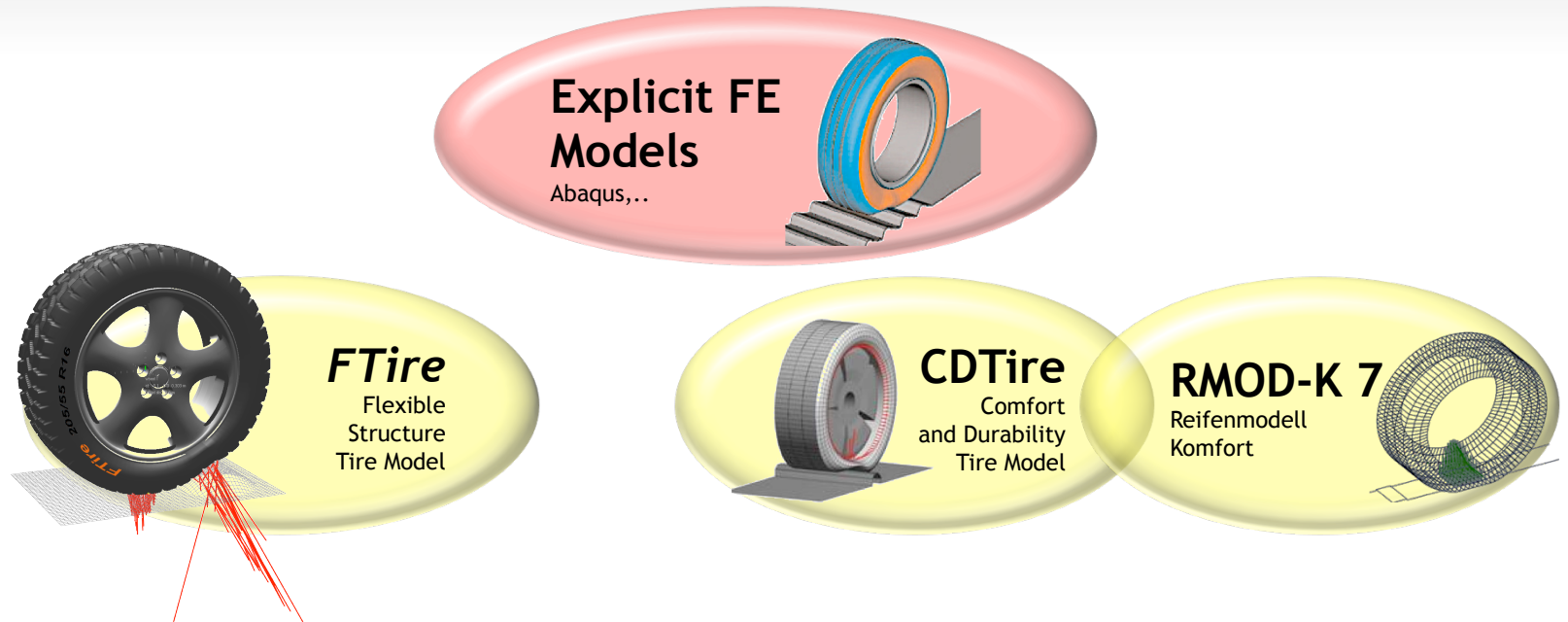
$$F_y = \mu_y F_z \sin[C_s \tan^{-1}\{B_s \lambda - E_s(B_s \lambda - \tan^{-1}(B_s \lambda))\} + C_\phi \tan^{-1}\{B_\phi \phi - E_\phi(B_\phi \phi - \tan^{-1}(B_\phi \phi))\}]]$$

$$\mu_y = (p_{0y1} + p_{0y2} dF_z) (1 + p_{0y3} dp_l + p_{0y4} dp_l^2)$$

TMeasy

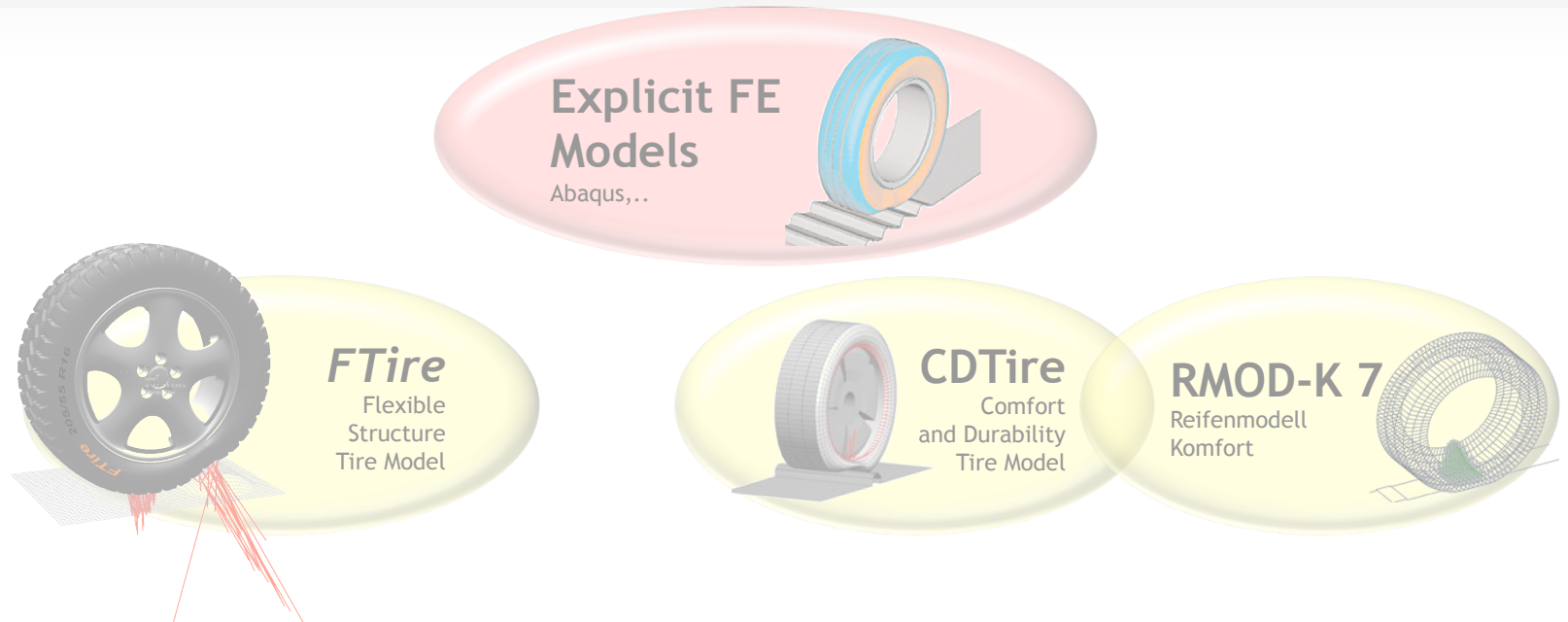
Tyre Model 'Easy-To-Use'





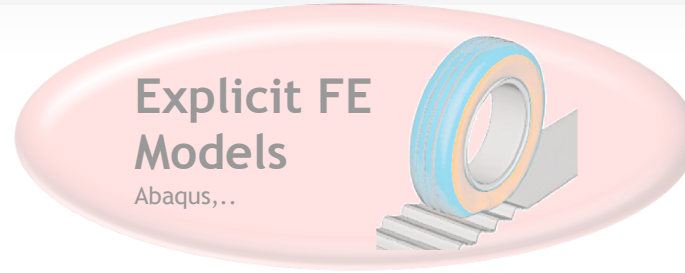
the **analytic** approach: ‘focus on **cause** rather than on effect’

- **physical**, **consistent**, and **comprehensive** description of relevant mechanics/thermodynamics/tribology
- model-inherent interaction effects between components and features; no need for extra modeling



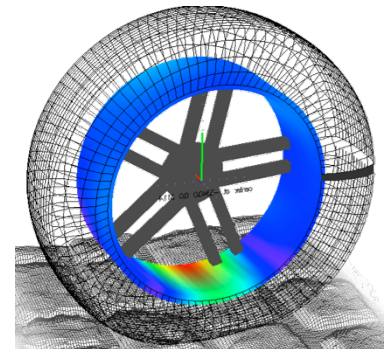
Tire model (in parts) is **teacher**:
even the developer can learn from the model's predicted
behavior in new operating points

'you get more insight than you have programmed'



discretization
abstractions
simplifications
negligances

but yet observing all relevant
physical principles





Why is *FTire* a teacher?

What can *FTire* teach us?

How does *FTire* teach?



A lot.

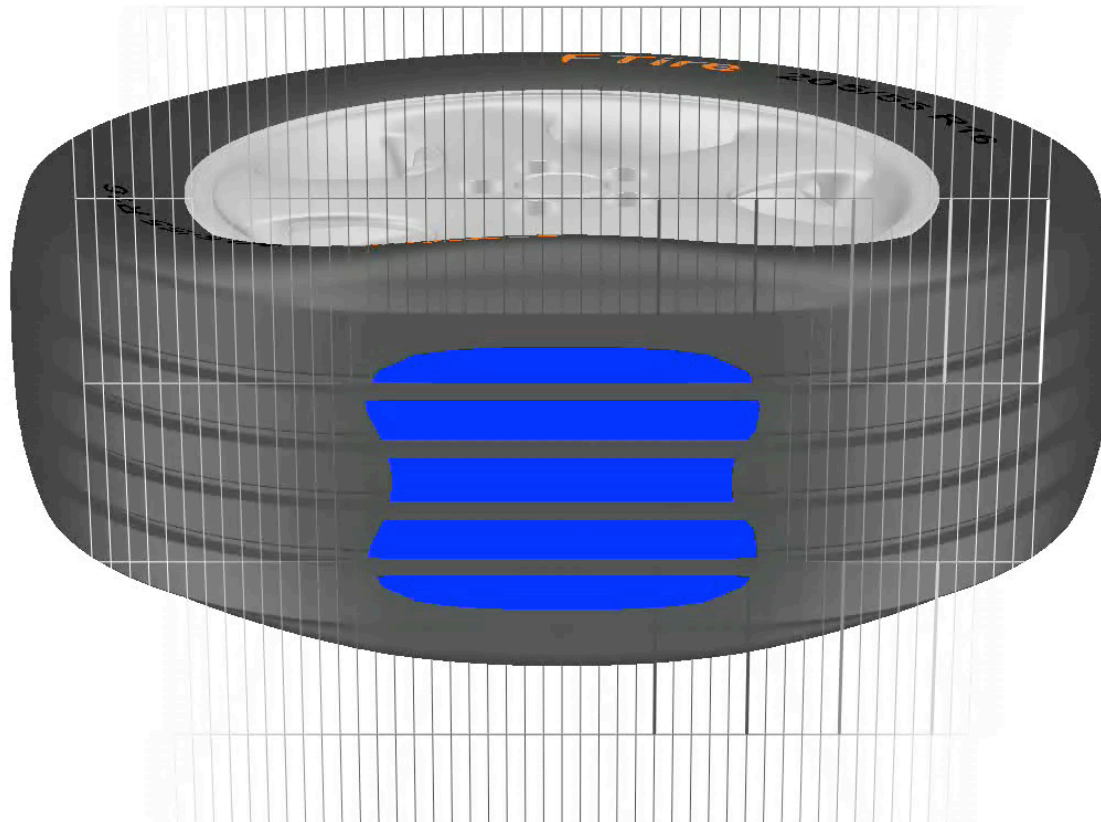
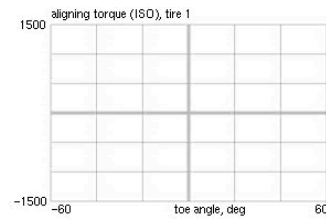
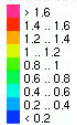
Some examples:

1. parking torque
2. handling on flat road
3. relaxation length
4. ‘attracting’ cleat
5. handling on rough road



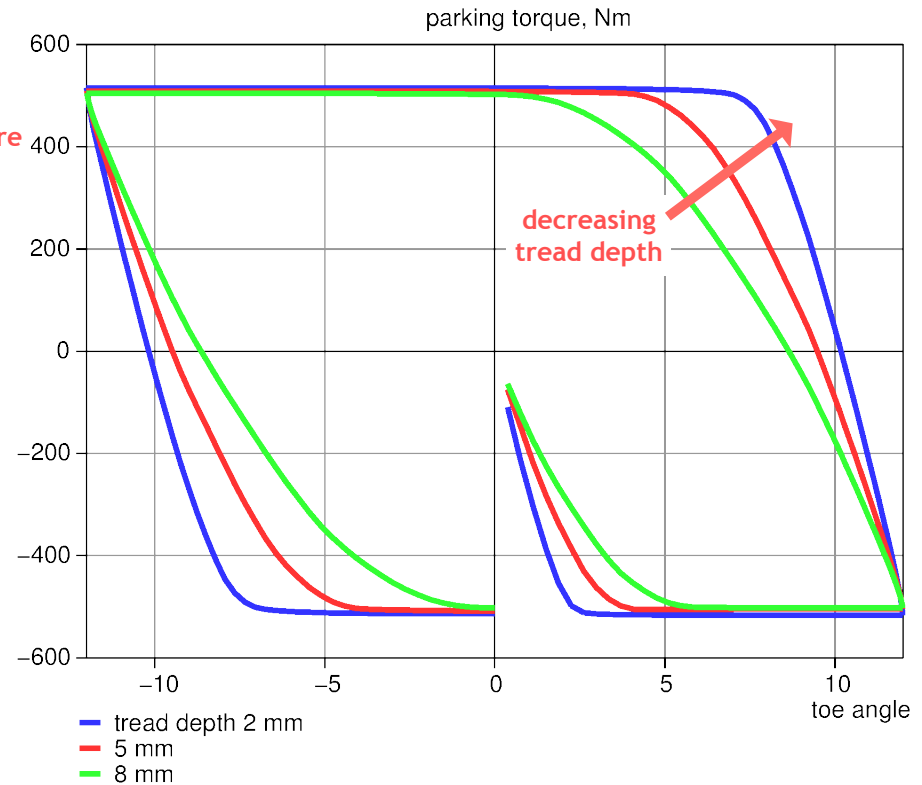
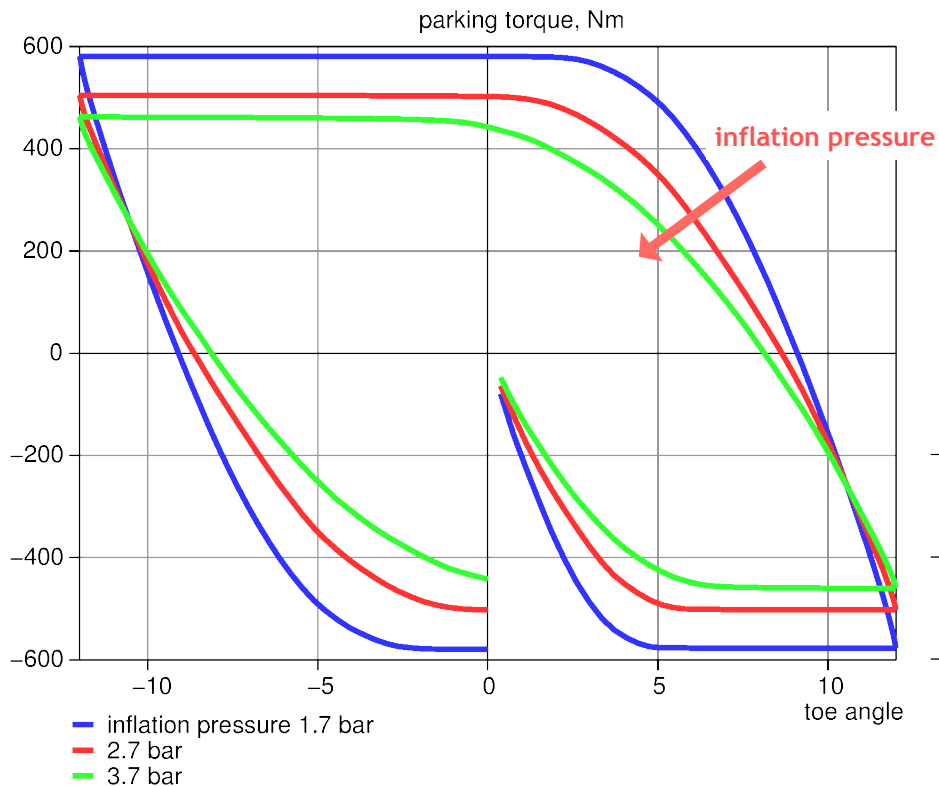
tire deformation and **stick-slip**
when parking at very high wheel load (10 kN)

lat. shear stress tire 1 [MPa]



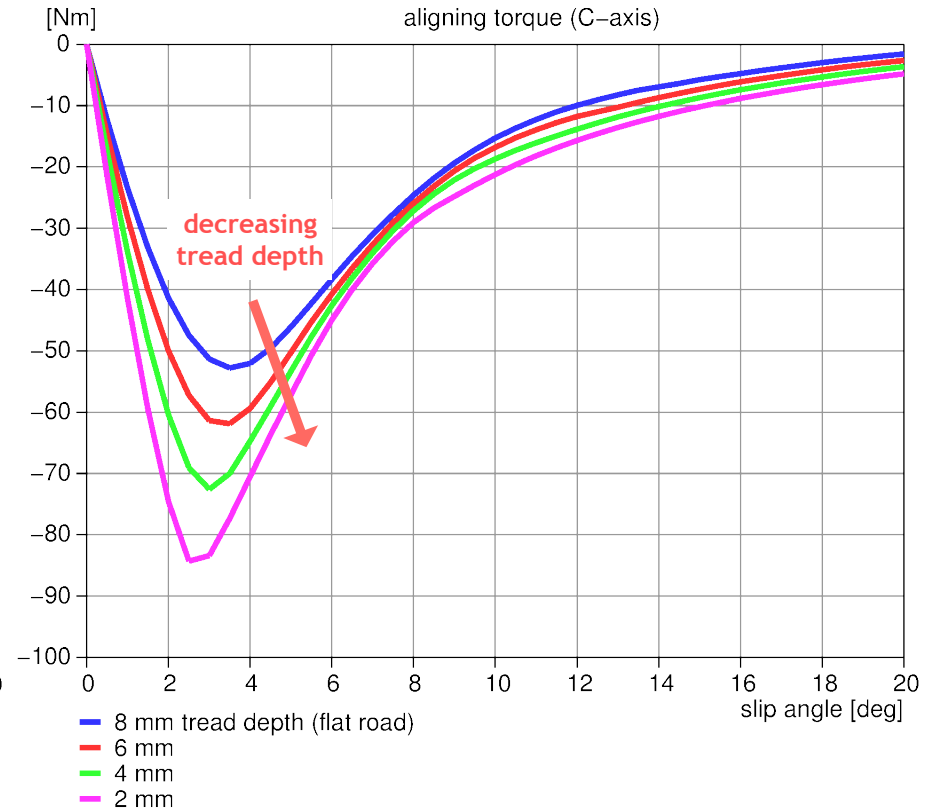
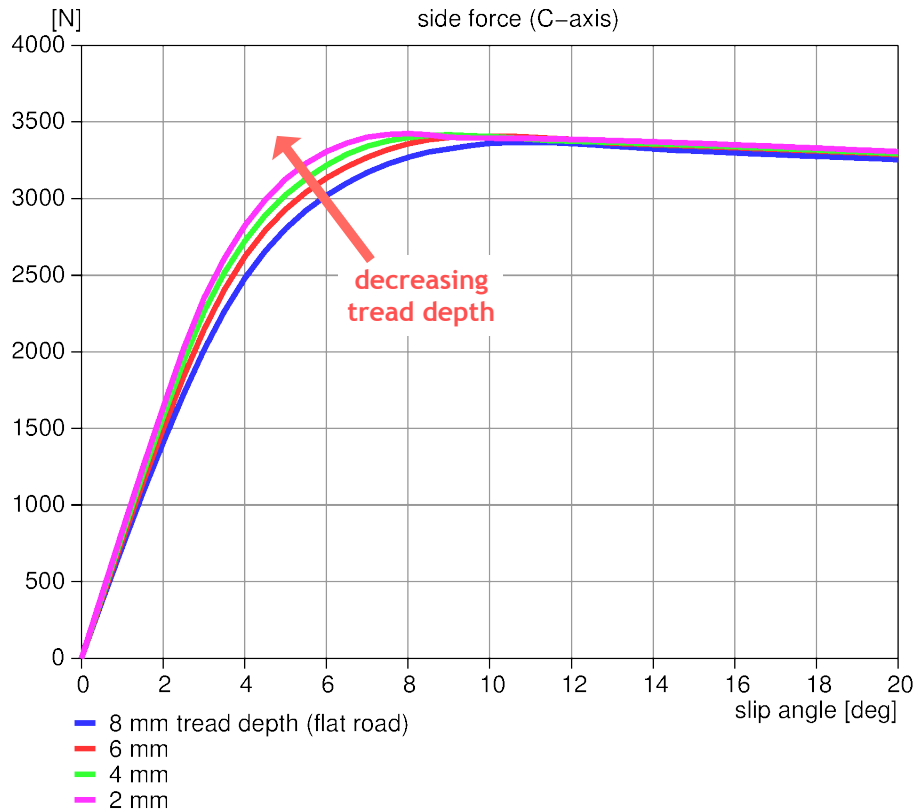


parking torque depending on **inflation pressure** and **tread depth**



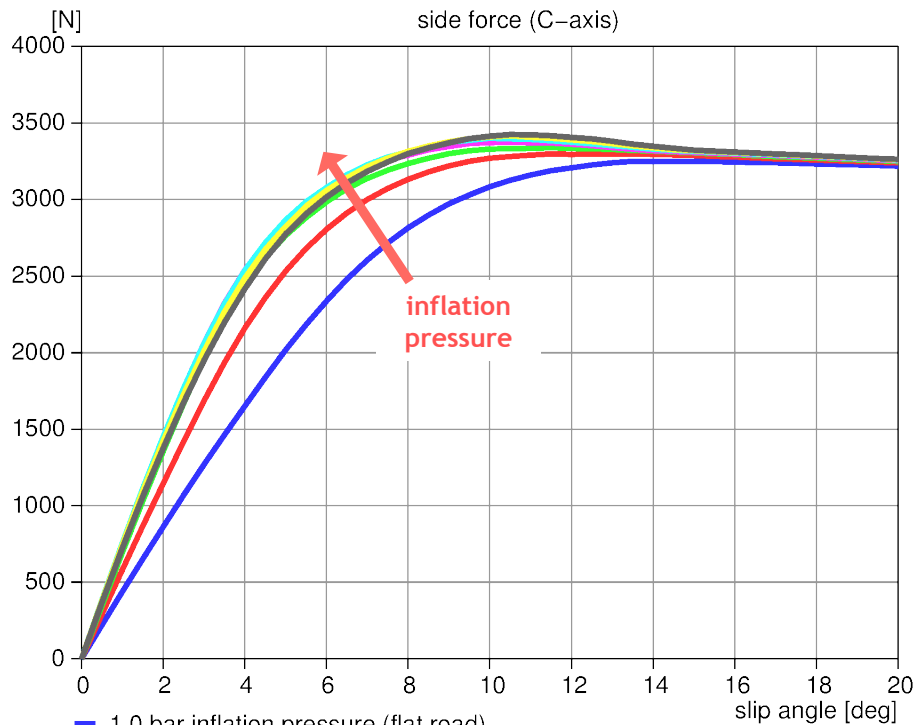


handling characteristics at different tread depths on flat road

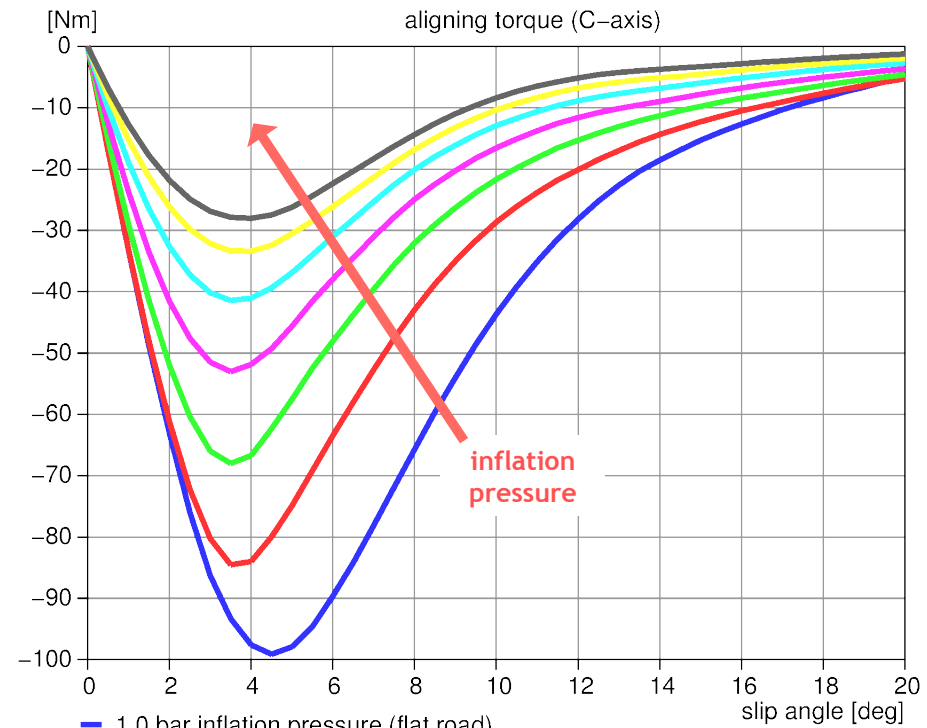




handling characteristics at different inflation pressures on flat road



- 1.0 bar inflation pressure (flat road)
- 1.5 bar
- 2.0 bar
- 2.5 bar
- 3.0 bar
- 3.5 bar
- 4.0 bar

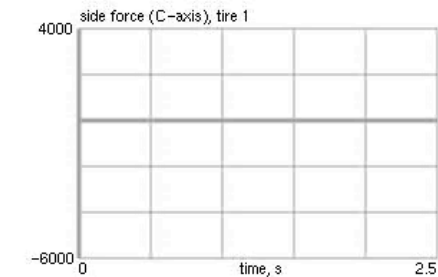
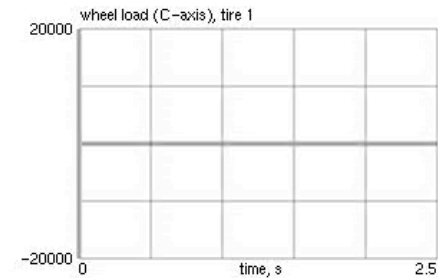
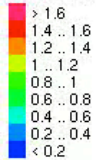


- 1.0 bar inflation pressure (flat road)
- 1.5 bar
- 2.0 bar
- 2.5 bar
- 3.0 bar
- 3.5 bar
- 4.0 bar



side force relaxation due to suspension/road induced **wheel load ramp up/down**
 $v = 20 \text{ km/h}$, slip angle 6 deg

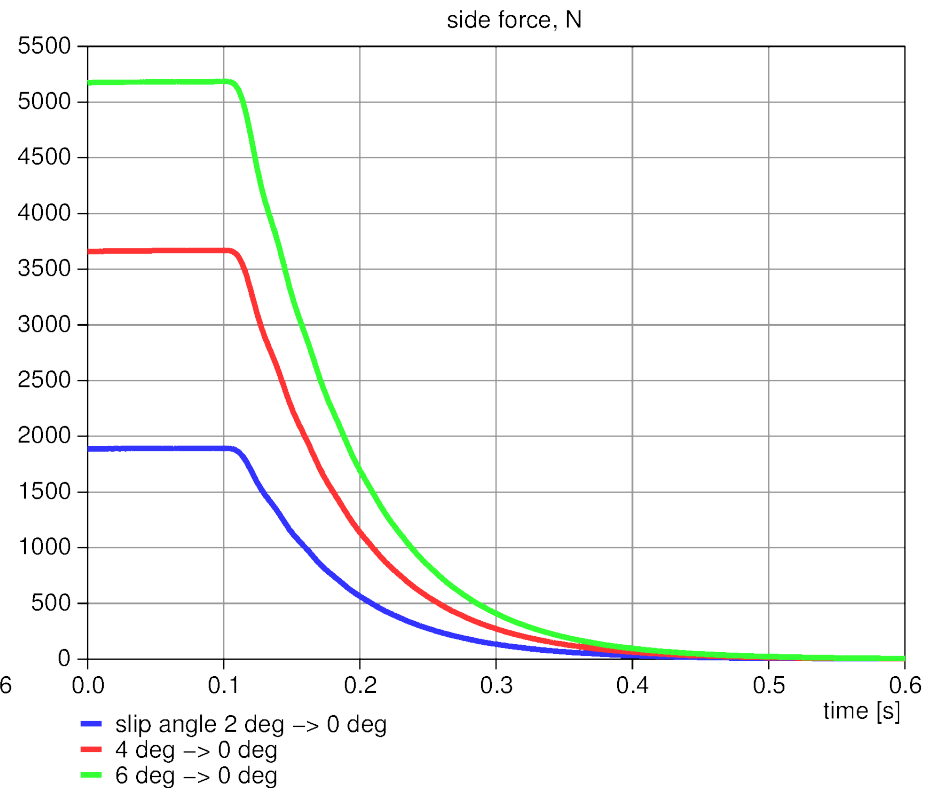
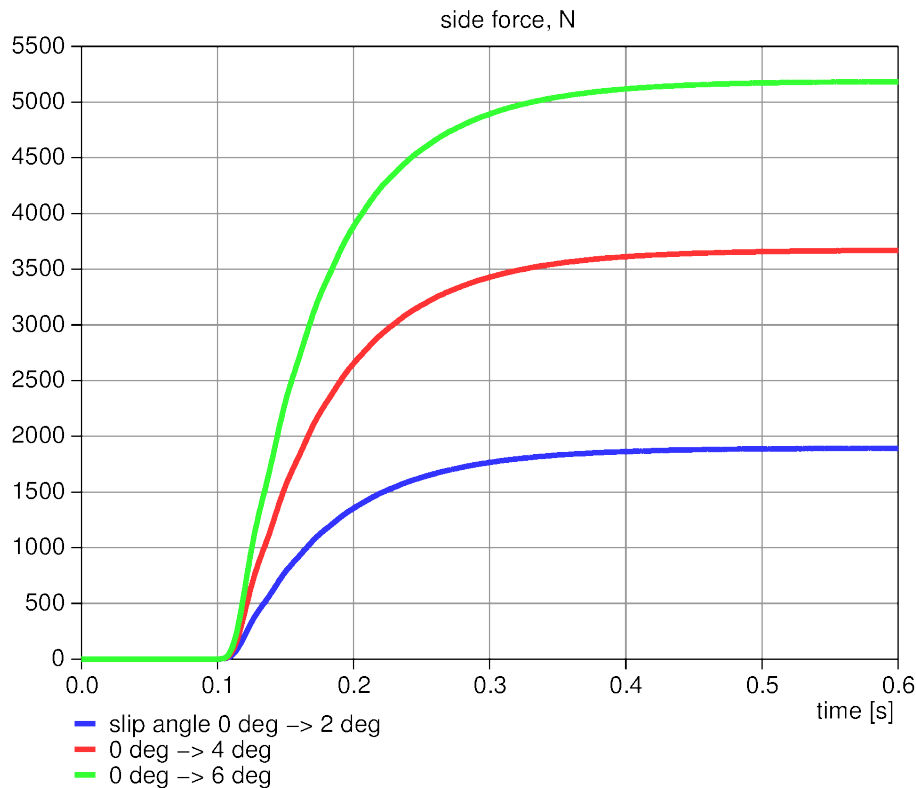
lat. shear stress tire 1 [MPa]



contact elements: force vectors
t = 0.0200s

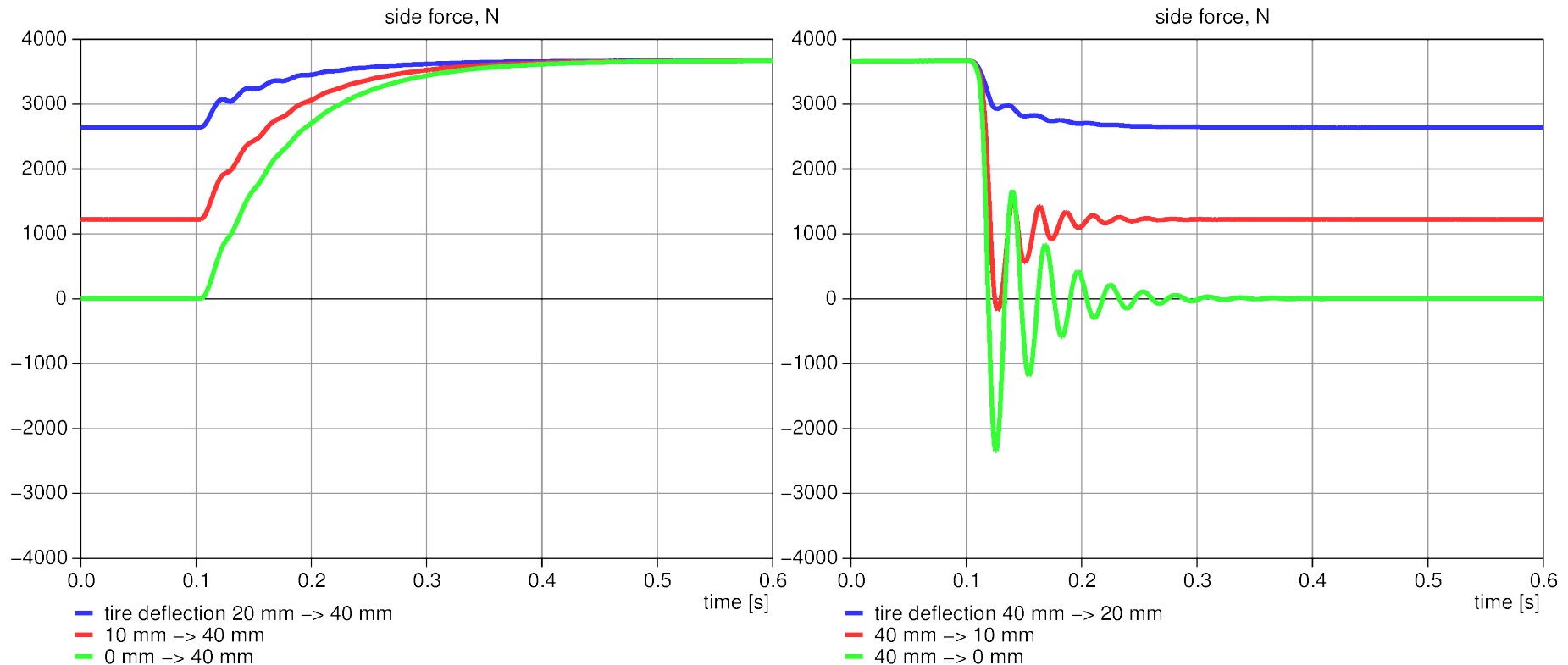


side force relaxation due to slip angle ramp up/down
 $v = 20 \text{ km/h}$, $F_z = 7.8 \text{ kN}$





side force relaxation due to wheel load ramp up/down
 $v = 20 \text{ km/h}$, slip angle 4 deg

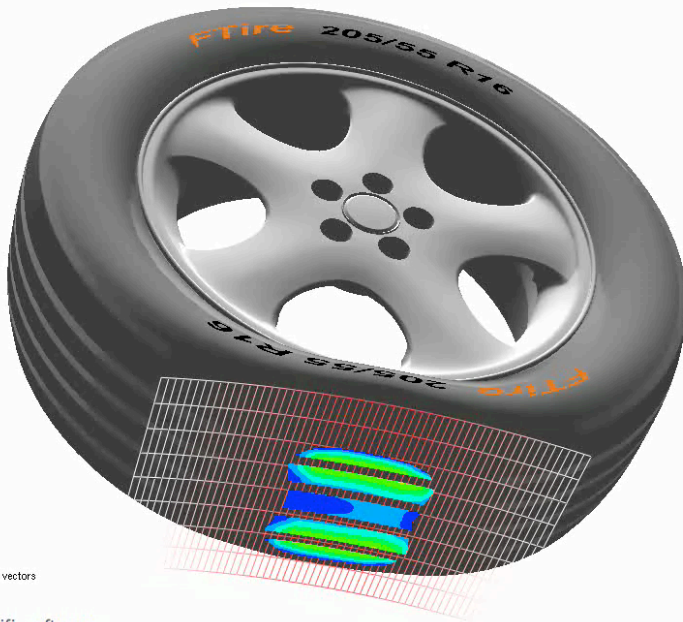




short period of **attracting** (positive) longitudinal force at first cleat contact

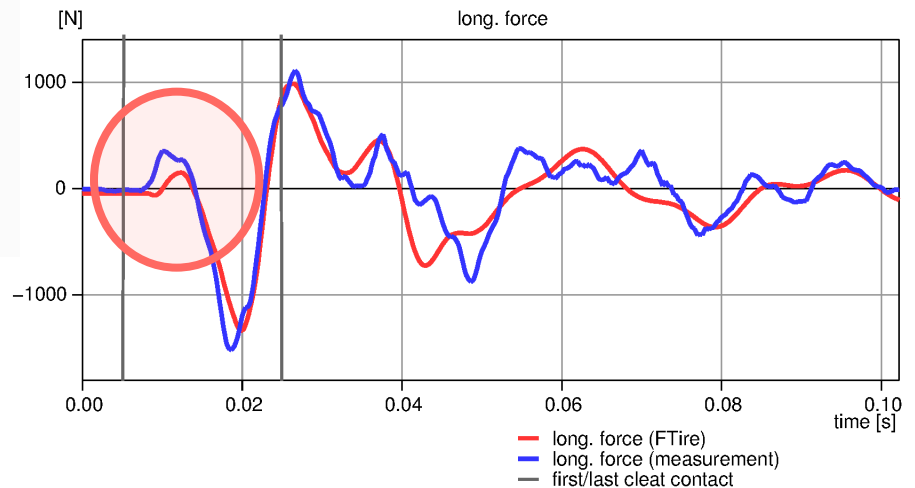
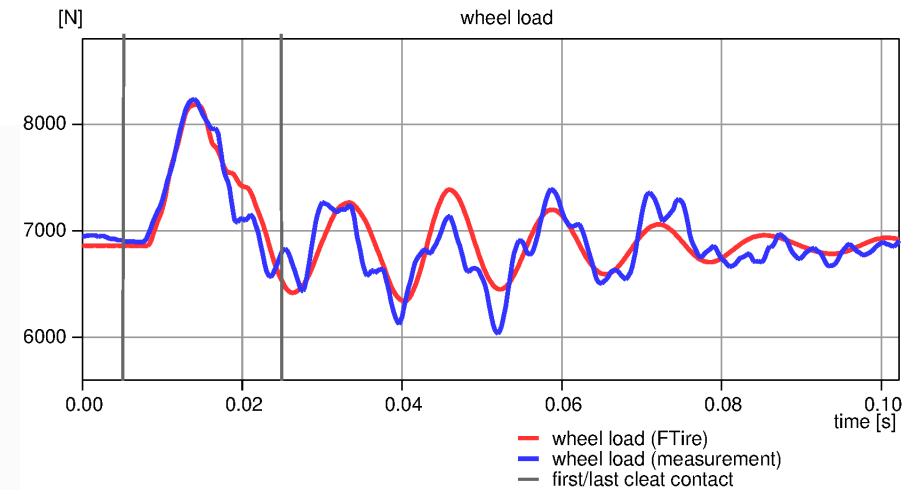
ground pressure tire 1 [MPa]

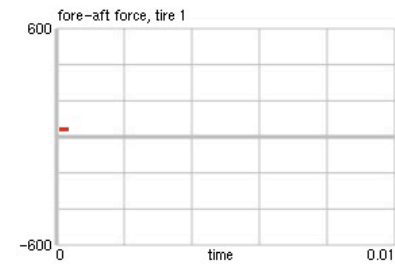
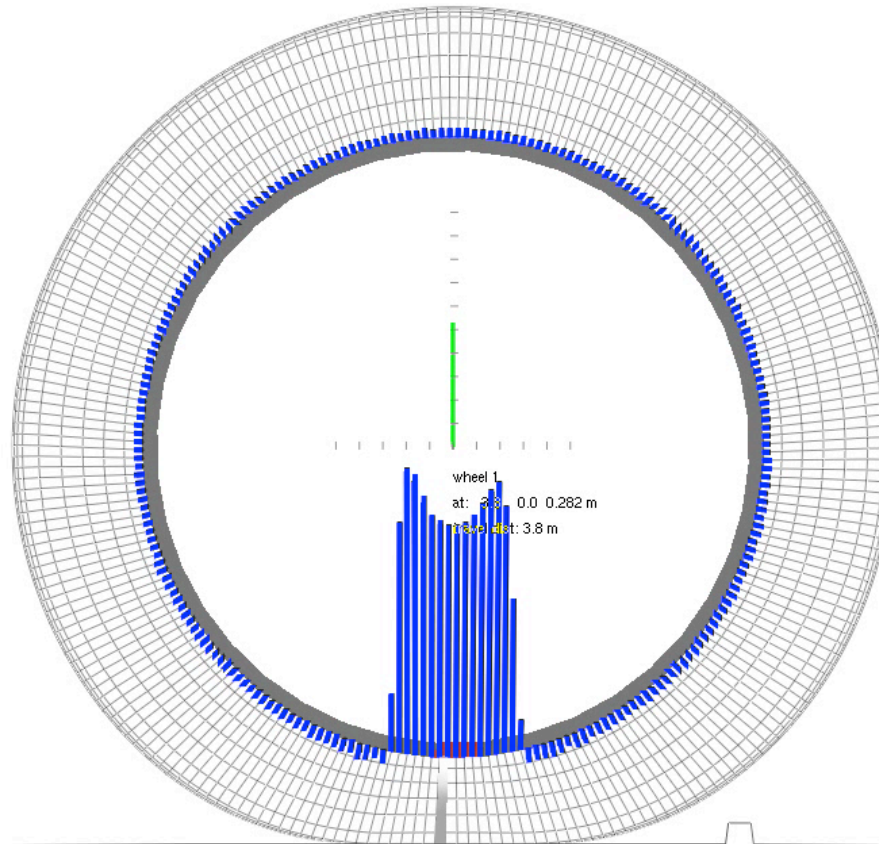
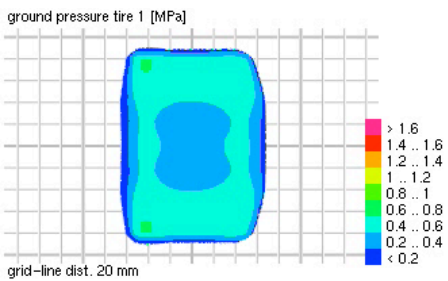
> 1.6
1.4 .. 1.6
1.2 .. 1.4
1 .. 1.2
0.8 .. 1
0.6 .. 0.8
0.4 .. 0.6
0.2 .. 0.4
< 0.2

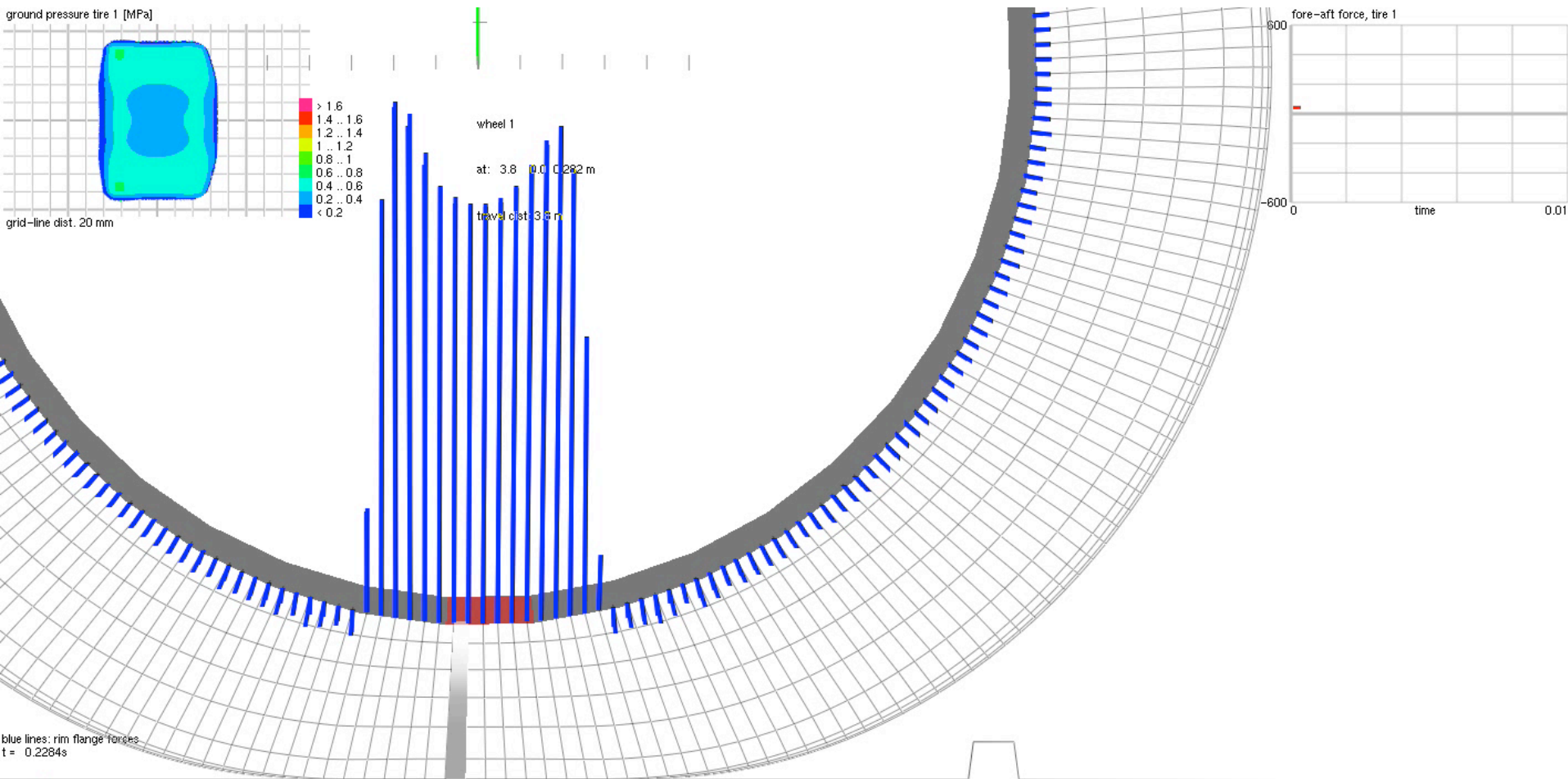


contact elements: force vectors
t = 0.0600s

cosin scientific software



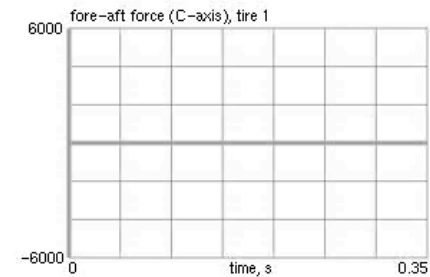
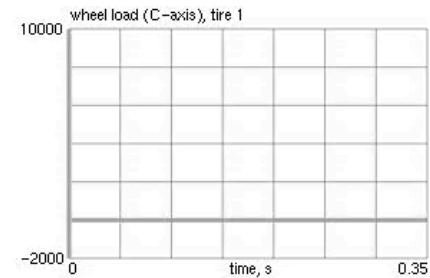
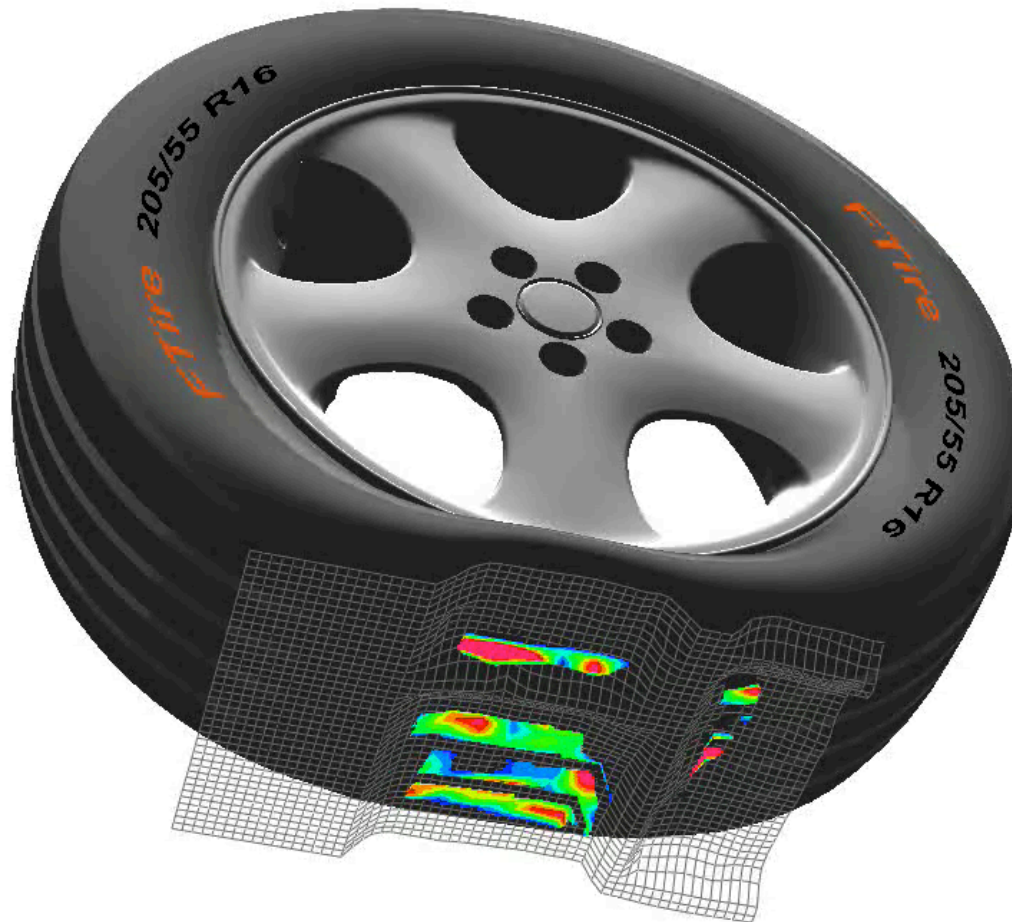
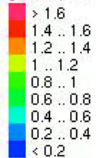






contact pressure distribution
passing Belgian block road at 50 km/h

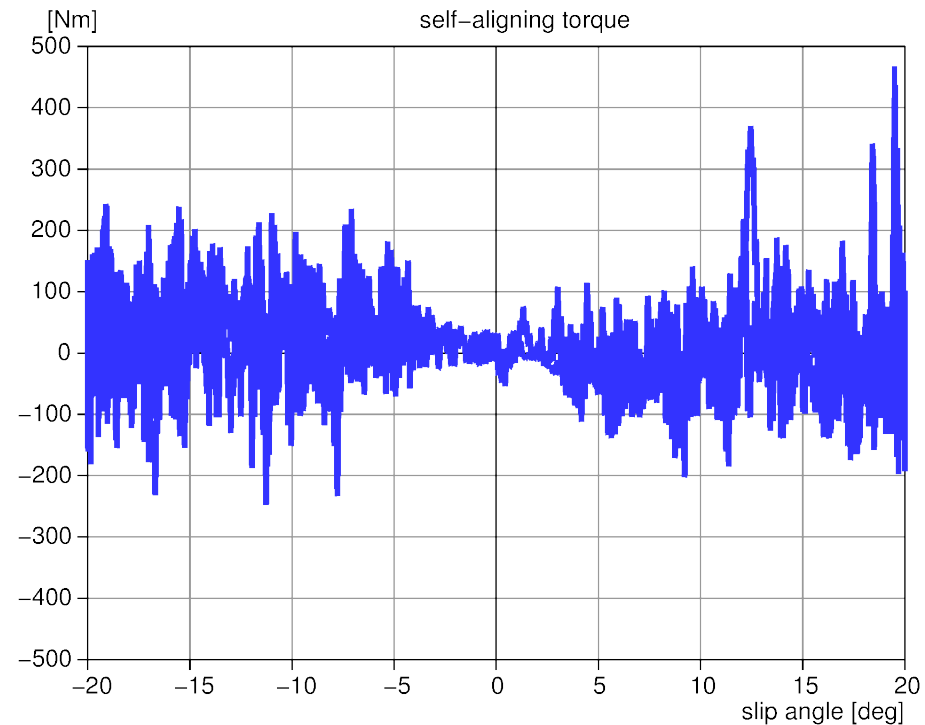
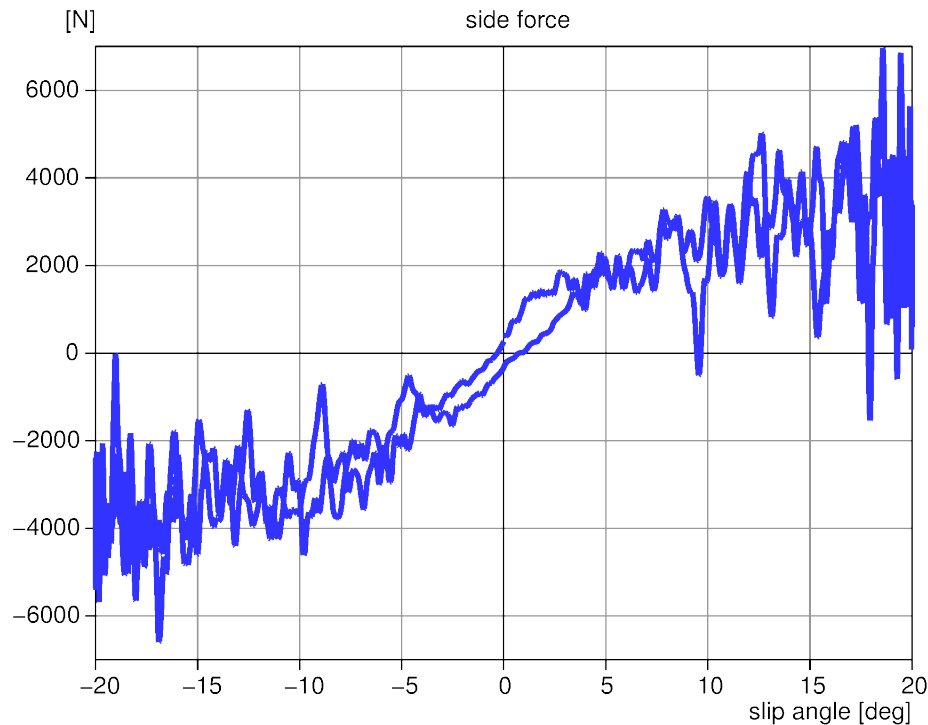
ground pressure tire 1 [MPa]



contact elements: force vectors
t = 0.0200s

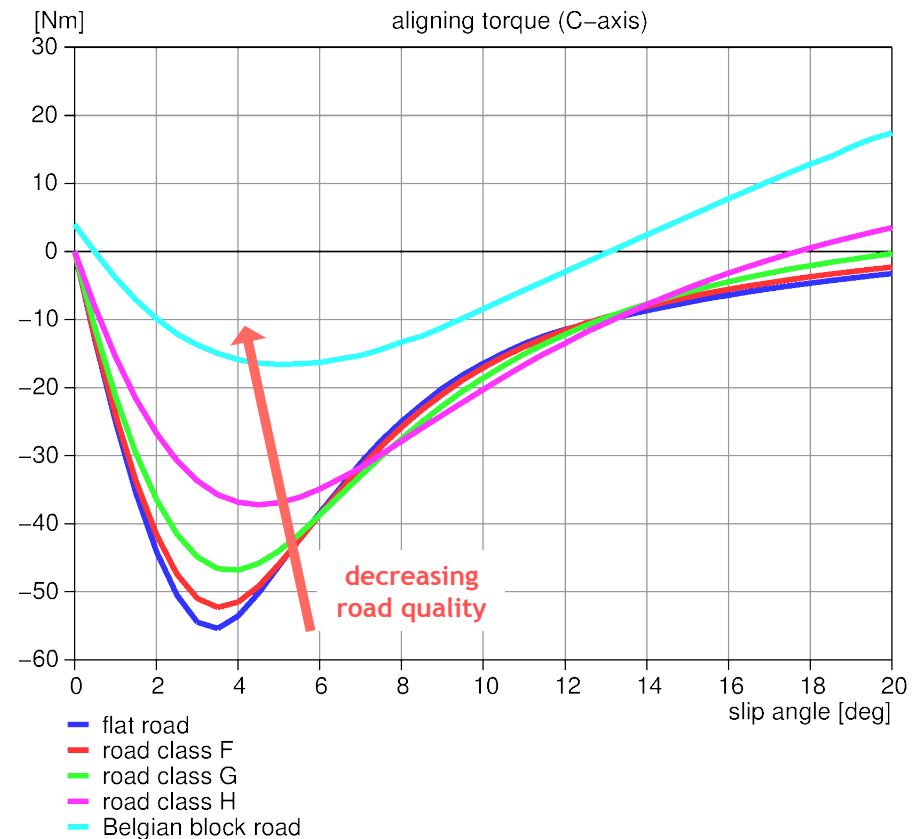
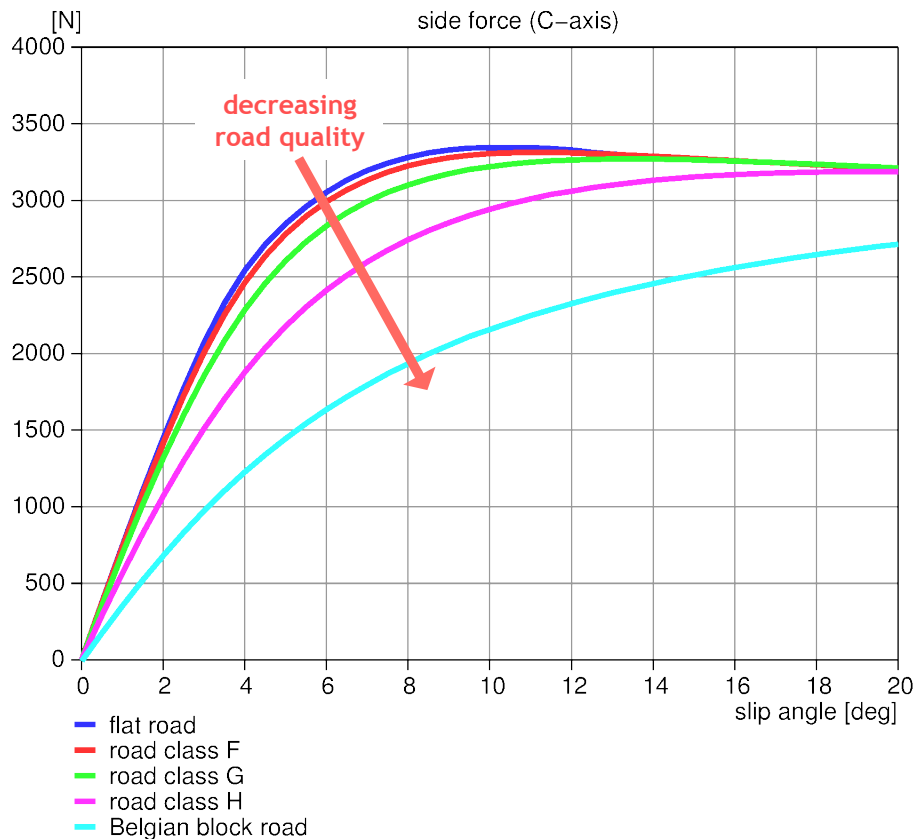


handling 'characteristics', unfiltered, on **Belgian block road**
 $v = 20$ km/h



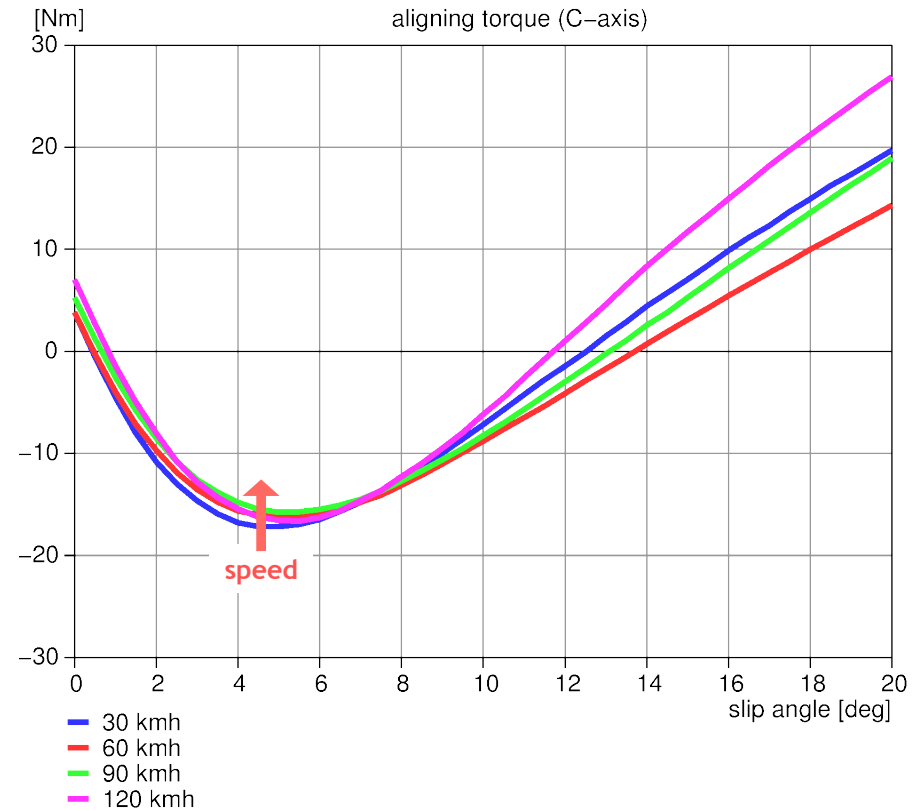
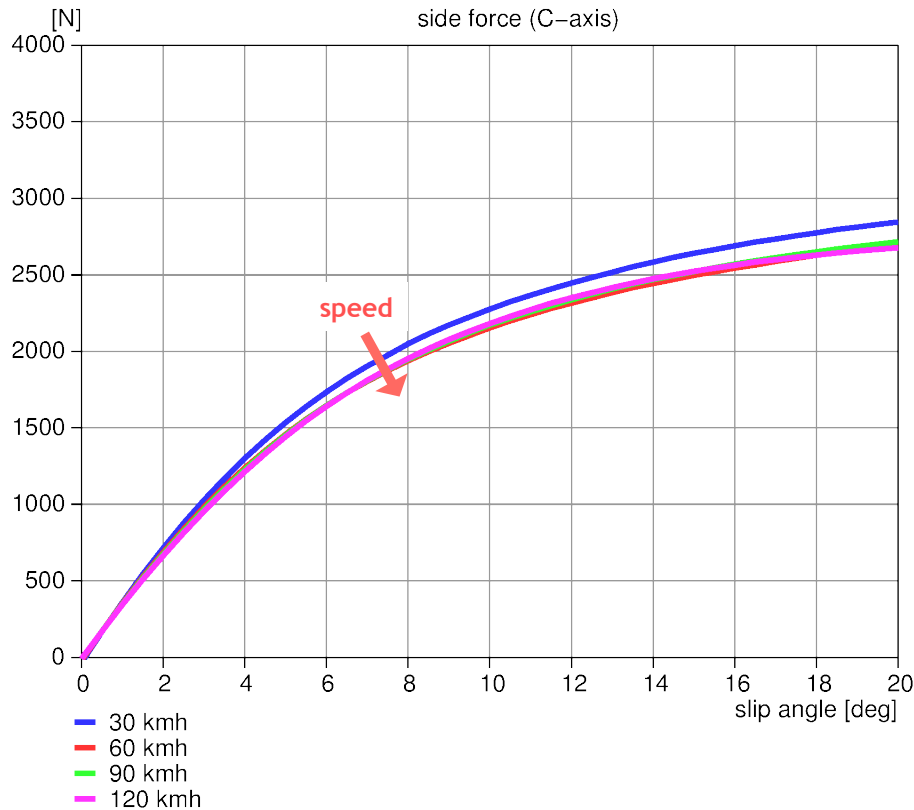


effective handling characteristics on different ISO road classes and on Belgian block



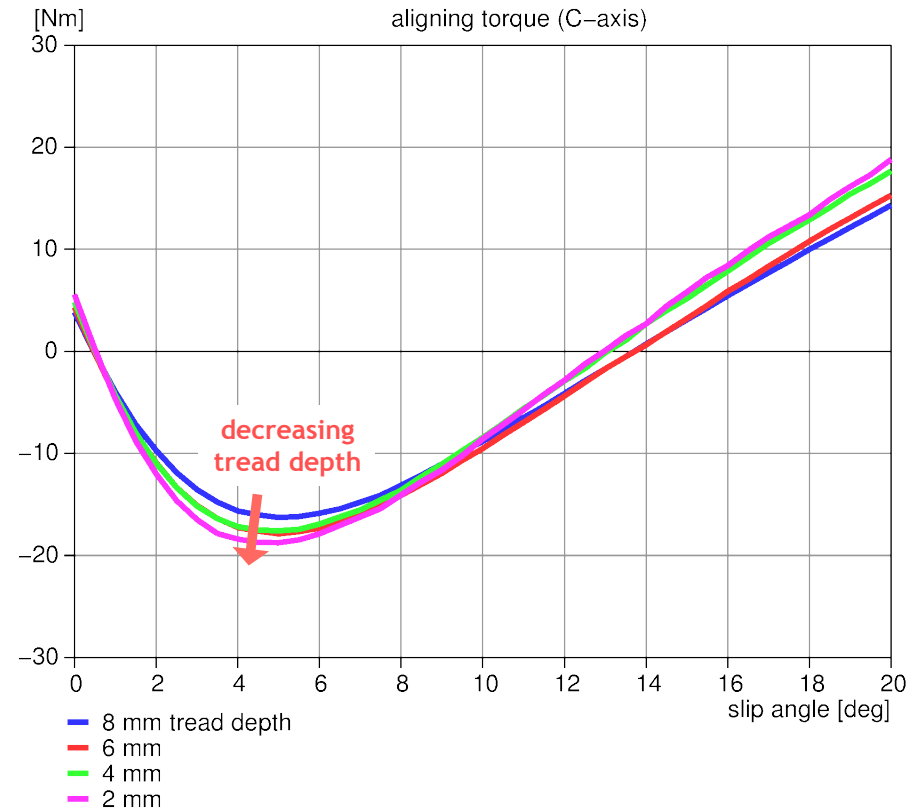
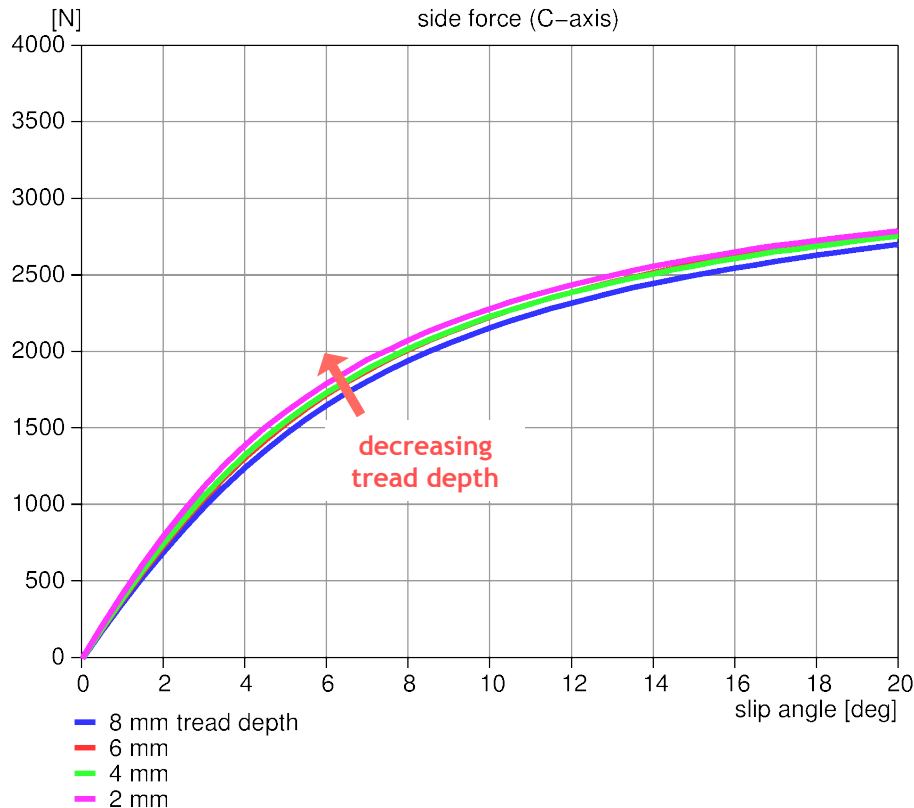


effective handling characteristics at different speeds on Belgian block





effective handling characteristics at different tread depths on Belgian block





Why is *FTire* a teacher?

What can *FTire* teach?

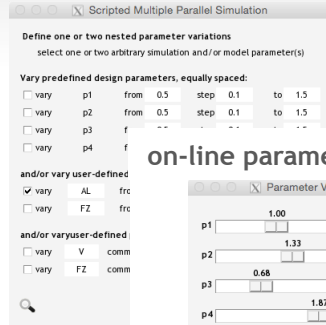
How does *FTire* teach?

cosin scientific software

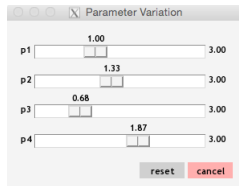
How does FTire teach? FTire Analysis Tools



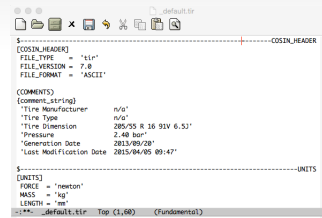
parameter variation loops



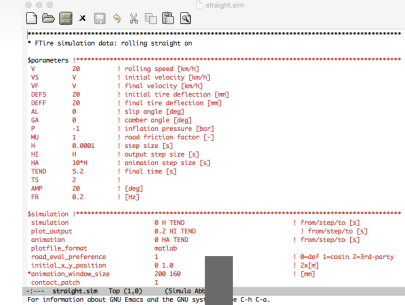
on-line parameter variation



parameterized tire data file



parameterized simulation script



cosin/tiretools

property fingerprint

interactive simulation

virtual test bench

static analysis (standing)

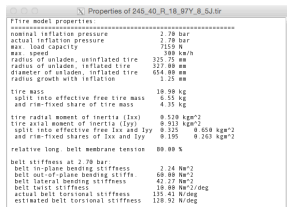
steady-state analysis (rolling)

modal analysis, unloaded

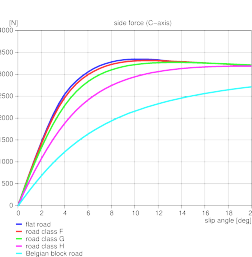
modal analysis, loaded

linearization

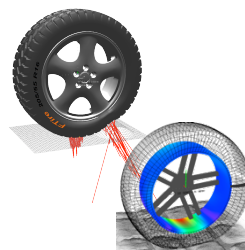
result list



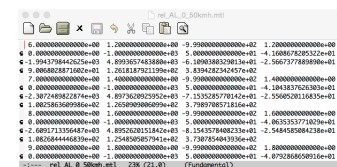
scripted plot generation



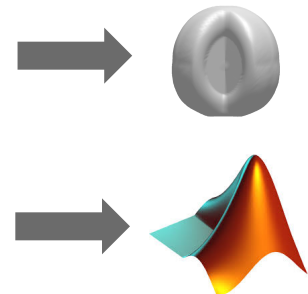
animations + movies



detailed tire state output files: contact forces, structure distortion, tread temperature, tire envelope...



result browser





..thank you for your attention!

Q & A

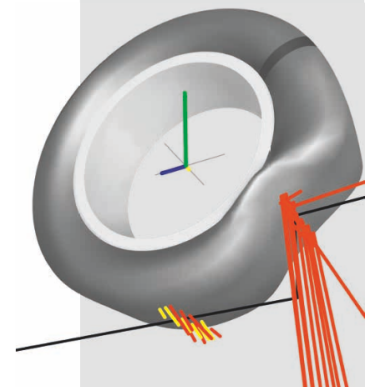
FTire demo versions, papers,
animations, documentation,
version updates, and more:

www.cosin.eu



3rd
FTire
User Meeting

14 – 15 September 2015
Aachen



www.fka.de/academy