Volkswagen Race Touareg

Motorsport

vertical dynamics of an offroad race car (MotionSolve)

(Altair MBD-conference USA)

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motorsport at Volkswagen



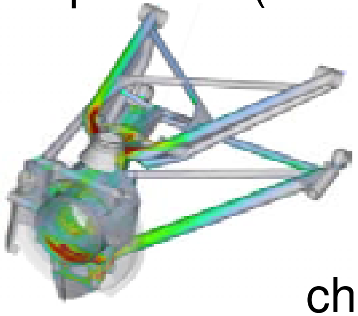
- VW-Motorsport GmbH (since 2004), 100% subsidiary of VWAG
- CEO: Kris Nissen
- 150 employees
- competing in rally raid, track racing and touring car championships
- rally raid:
  - marathon rally world cup
  - main event: Dakar Rally (Race Touareg)
  - success in Dakar 2009: double victory (over all)
1st victory of a diesel powered car
- Touring cars:
  - ADAC Volkswagen Polo cup in Germany, Polo cup in India
  - JettaTDI cup in USA, Scirocco cup in China, etc.
- Track racing:
  - "24h race" at Nürburgring (Scirocco)
  - success in GT24 2009: place 1+3 in class 2L-turbo (SP3T)
place 1+2 in class altern.fuel. (AT)
  - participation and engine supplier Formula 3 (EuroSeries, GB-F3, ATS cup D)

simulation at VW-M – example RaceTouareg

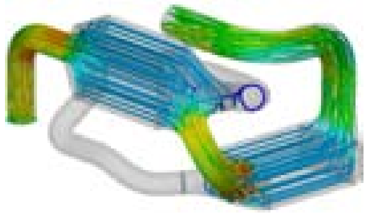
vehicle dynamics (MBD)

aerodynamics (CFD)

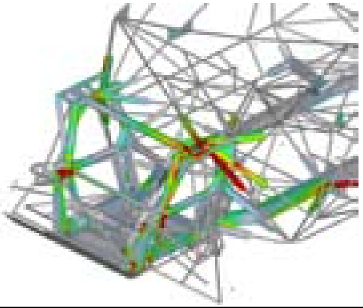
suspension (FEA)



intake / radiator (CFD)



chassis (FEA)



engine (FEA)

Why do we have problems to acquire representative loads?

production vehicle development:

- standard scenarios:
  - vehicle crash due to EuroNCAP: velocity v = compulsory
    barrier = compulsory
    post processing = standardized
    } regulations, laws based on empiric studies
  - comfort analysis (NVH: acoustic, vibration, static)
    1. BiW eigenfrequency > ##Hz
    steering wheel vibration > ##Hz
    } fictitious values „bottom-factor“
- test and validation phases
- risk: delayed start of production, recall campaign

motorsport:

- no standard scenarios:
  - comparison to preceding model
  - analysis of occurred damage
  } too late!
- no large-scale test series, we're driving in „prototypes“.
- risk: total failure, injury to persons

} we have to
- find reasonable and ample load assumptions
- make robust predictions

load identification – simplified scenarios

The real load situation (offroad) is very complex and barely reproducible.

Standard tests of production vehicles (e.g. VWs test area “Ehra”) are not applicable for this car.

⇒ own simplified test scenarios

RaceTouareg on artificial hill

Advantage of simplified tests:

- fewer parameters in the simulation (rigid ground, only vertical dynamics)
- reproducible
- small local test area useable

Important despite simplicity!
Example: *KickBack* as accident.

accident Dakar 2005

accident CER 2008

Volkswagen Race Touareg

MBD model

Motorsport

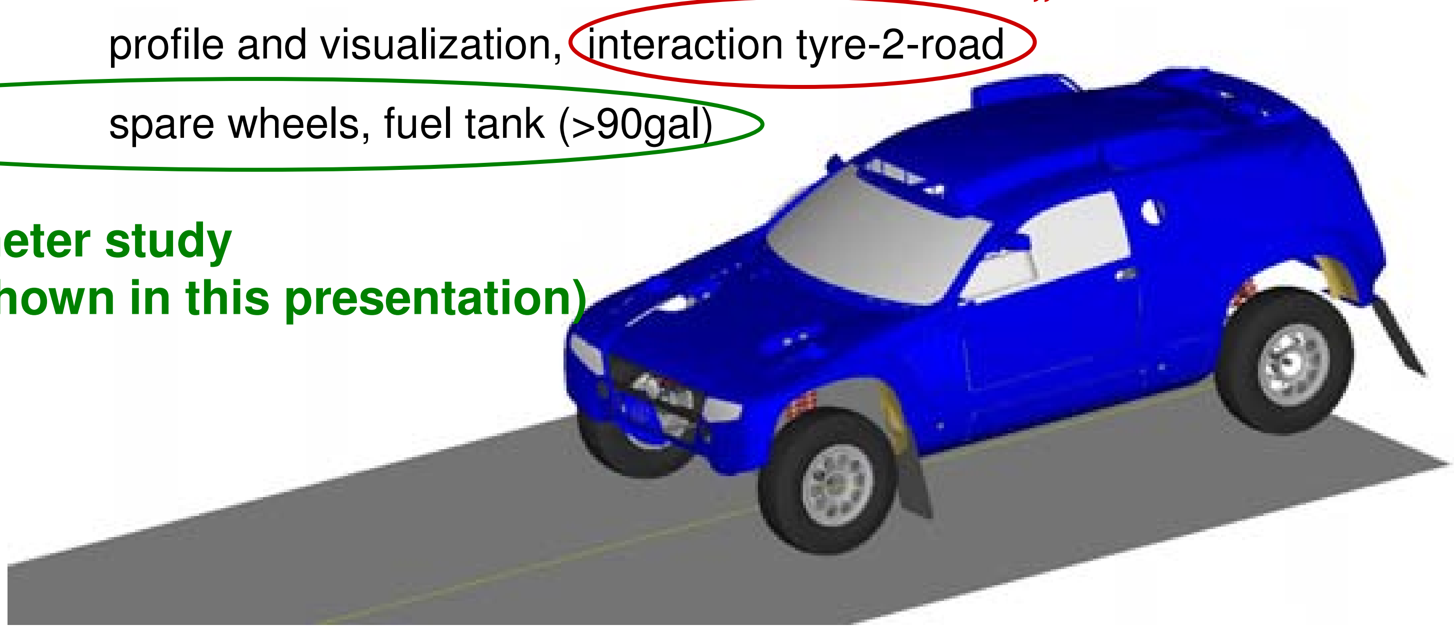
The MBD-model is based on submodels:

spring/damper

- front axle: *suspension FA, damper FA, spring FA, steering FA, power train FA*
- rear axle: *suspension RA, damper RA, spring RA, power train RA*
- chassis: rigid BiW with connection to ground
- road: profile and visualization, interaction tyre-2-road
- payload: spare wheels, fuel tank (>90gal)

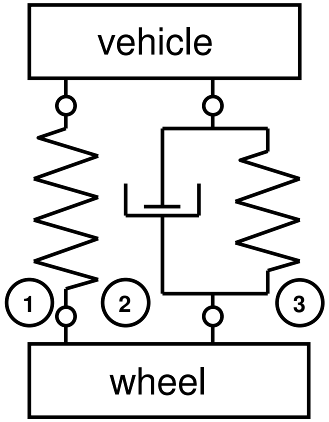
„tire model“

parameter study
(not shown in this presentation)

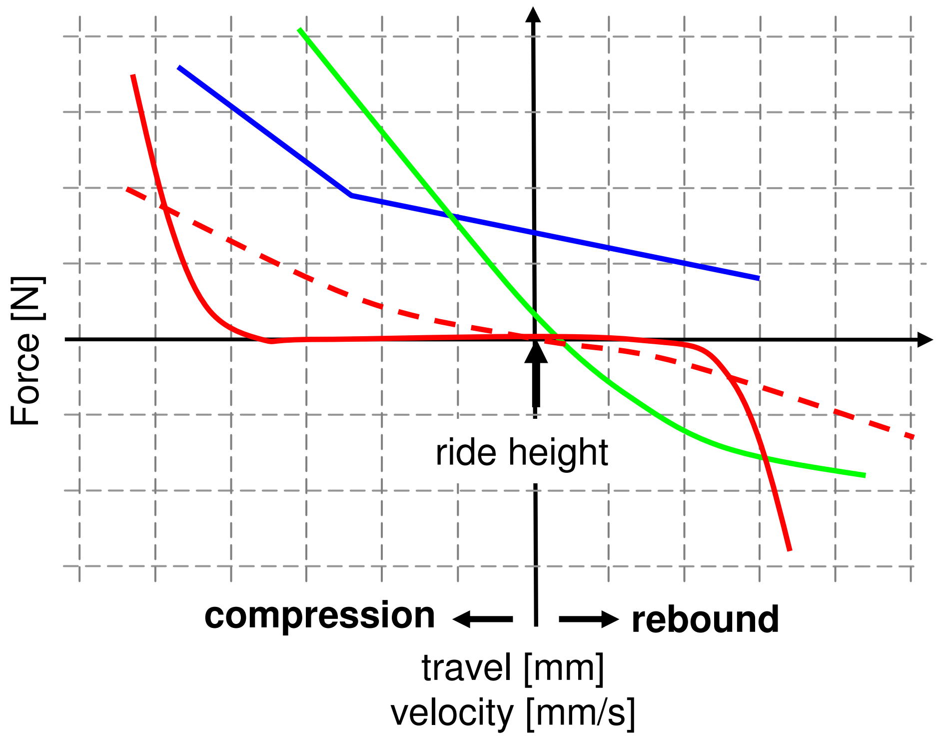


MBD model – spring/damper

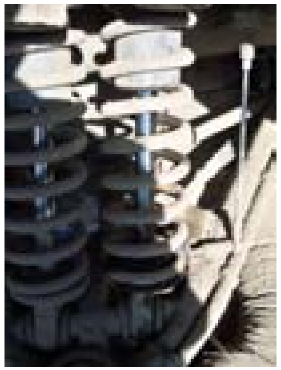
suspension in principle:



1. main a. helper spring
2. damper w. bump stop
3. gas pressure




suspension (clean)


suspension (dirty)

Volkswagen Race Touareg

MBD model – spring/damper

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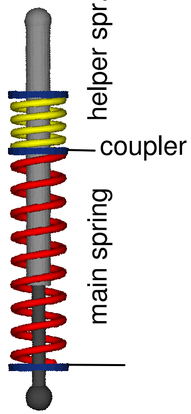
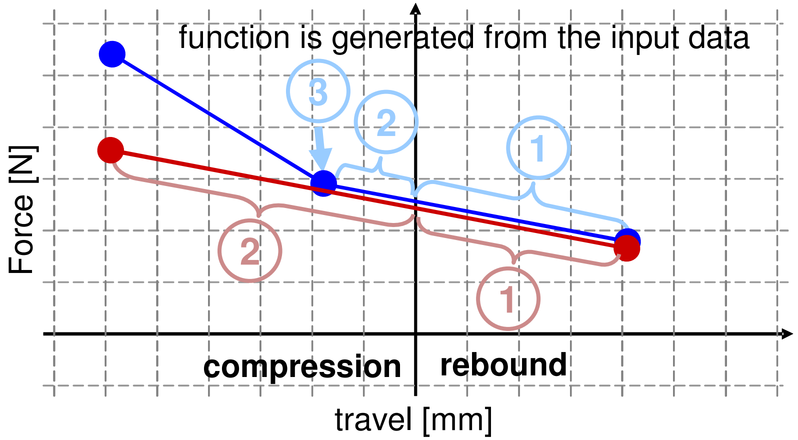
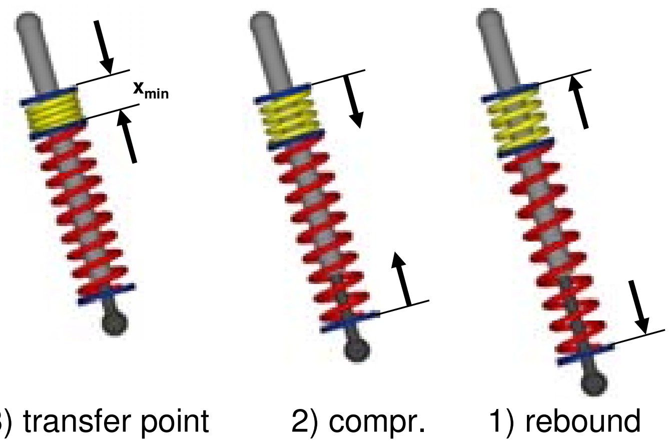
Generation of spring function by forms (datasets)

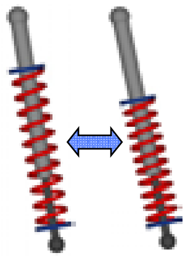
spring parameters	
stiffness main spring 1	49.60
stiffness helper spring 1	70.10
stiffness main spring 2	39.00
stiffness helper spring 2	0.00
free length main spring 1	324.00
free length helper spring 1	103.00
free length main spring 2	388.00
free length helper spring 2	0.00
block length main spring 1	141.00
block length helper spring 1	42.00
block length main spring 2	171.00
block length helper spring 2	0.00
preload length main spring 1	368.00
preload length helper spring 1	350.00
coupler height main spring 2	8.00
coupler height helper spring 2	0.00







<u>additional advantage:</u>
visual verification (spring length changes with input values)



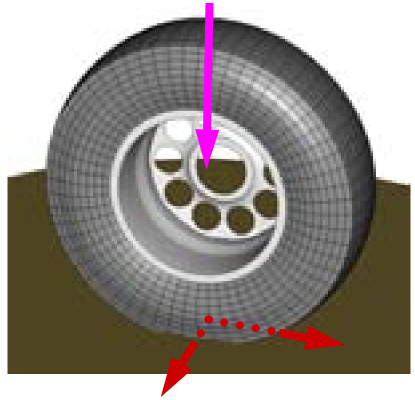
MBD model – “tire model”

All loads pass through the tire
⇒ tire model is very important in vehicle dynamics

Unfortunately ...

- MotionSolve9.0 has no tire model
- external tire models can’t be linked to MS9.0
- only very few tire data is available (deformable ground?)

⇒ tire properties must be approximated by MS-basic functions



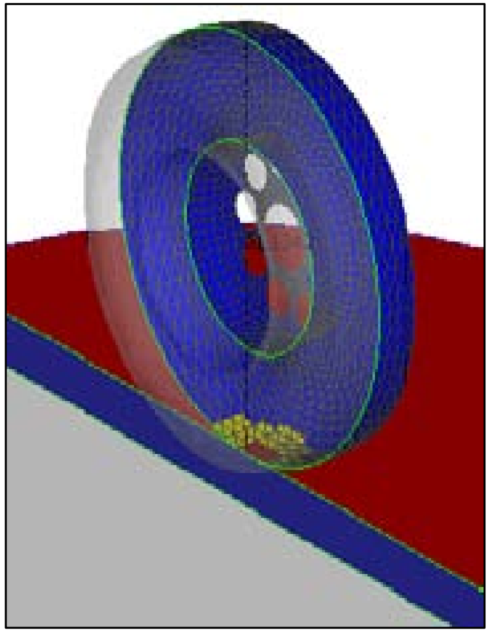
Which properties are important (in vertical dynamics) ?
How can they be modeled in MS/MV9.0 ?

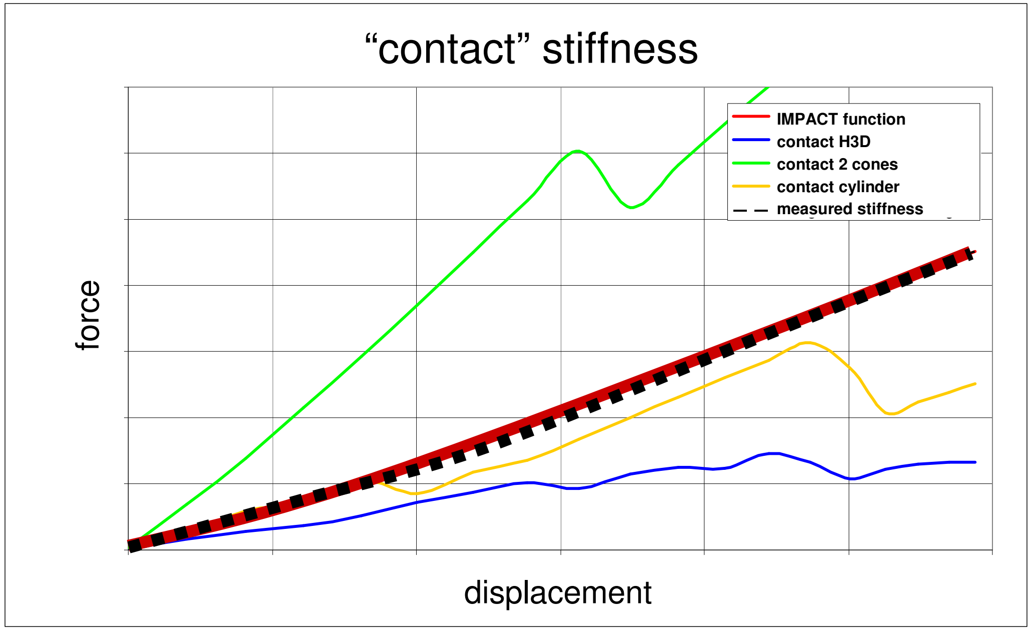
parameter	importance	known?
lateral stiffness	– –	–
radial stiffness	+ +	+
damping	+	–
friction	– –	–

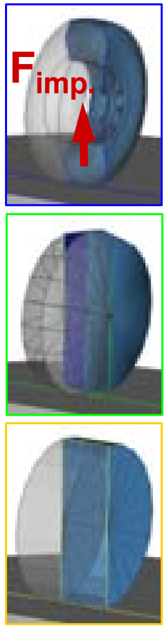
method	versatility	easy to use?
RigidBody contact (implicit or modeled)	contact form.	+
	impact form.	+
springs	variable	–
active force	variable	–

MBD model – “tire model”

static simulation of radial stiffness to verify different modeling techniques

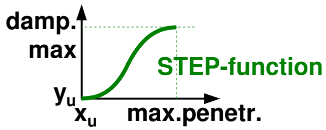






- rigid body contact produces unstable stiffness results
- only the active IMPACT-force reproduces the target stiffness well

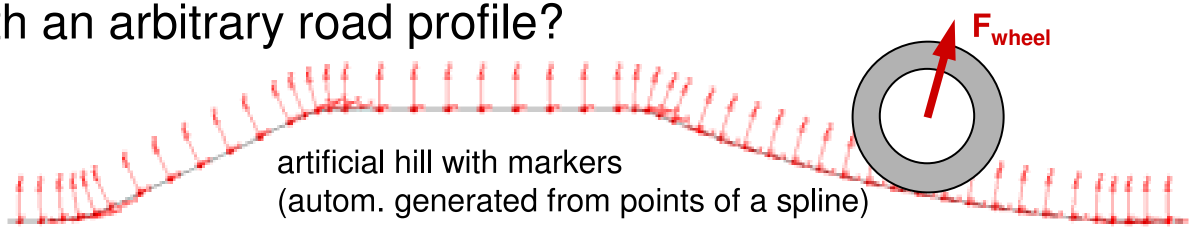
$$F_{impact} = k \times \Delta z^e - c \times \dot{z}$$



MBD model – “tire model”

- IMPACT-force shows good stiffness results between two markers.
- How to combine that with an arbitrary road profile?

⇒ lots of local markers !

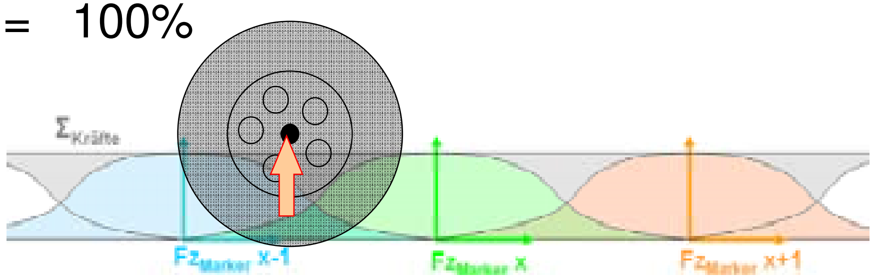


artificial hill with markers
(autom. generated from points of a spline)

The force on the wheel
is the total of all local forces.

$$F_{wheel} = F_0 + F_1 + \dots + F_{x-1} + F_{x-1} + F_{x-1} + \dots + F_{100}$$
$$= 0 + 0 + \dots + 70\% + 30\% + 0 + \dots + 0$$
$$= 100\%$$

With the implementation of
the STEP-function only the
markers near the wheel have
non-zero values.

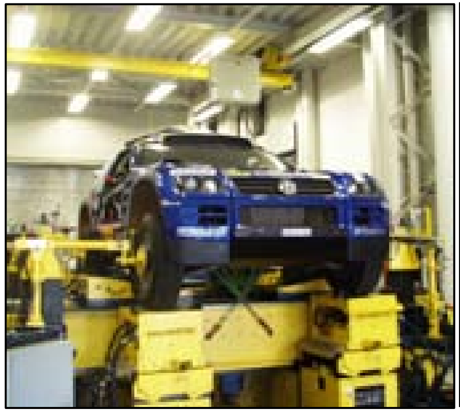


Advantage of this very simple tire model:

- easy to automate (only new spline needed)
- mathematical representation leads to fast and smooth results

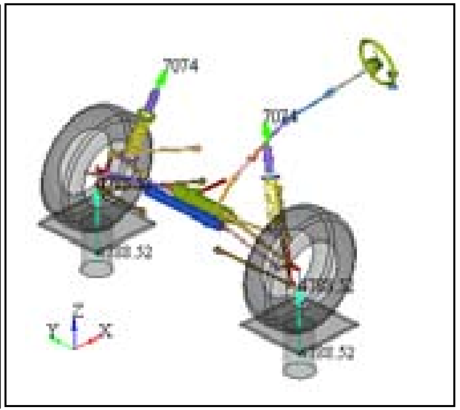
results – kinematic and compliance

test



k&c test bench @ VW-Wolfsburg

simulation



k&c simulation of a front axle

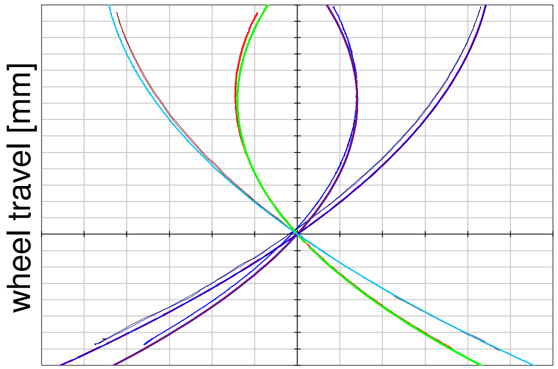
verification:

comparison of

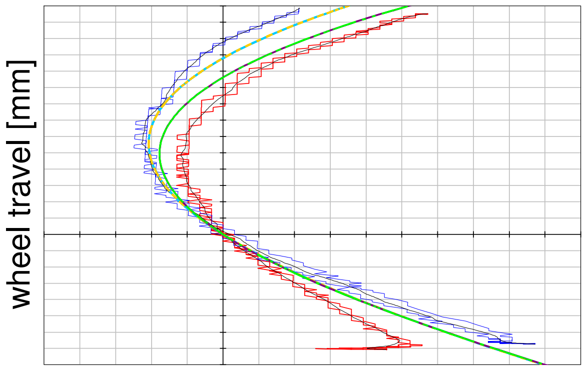
- k&c test (full vehicle) and
- k&c simulation of single axle

→ close match

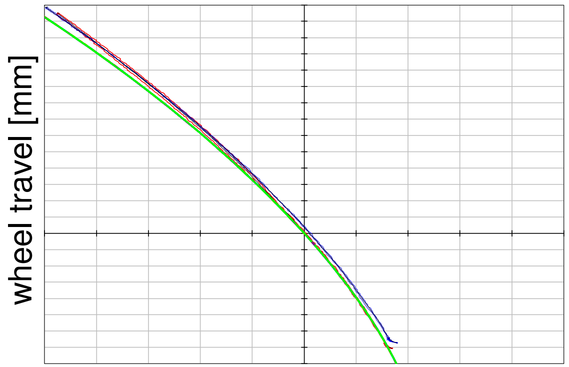
track width change



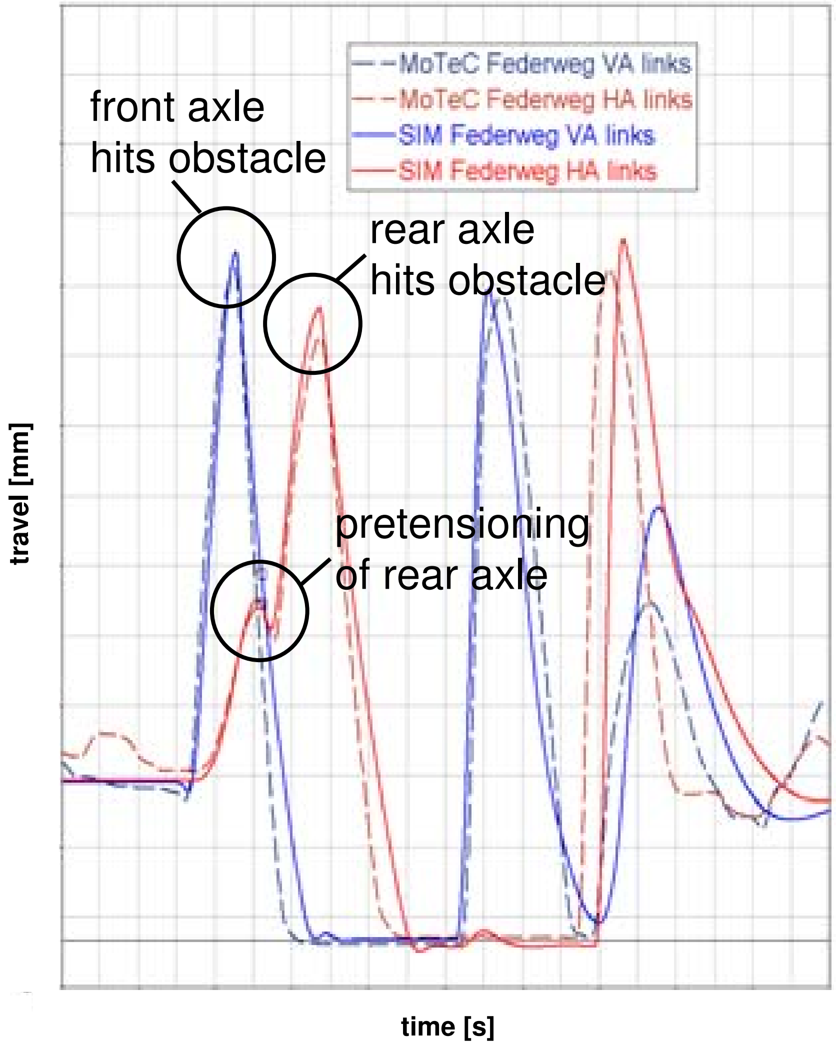
camber angle change



toe angle change



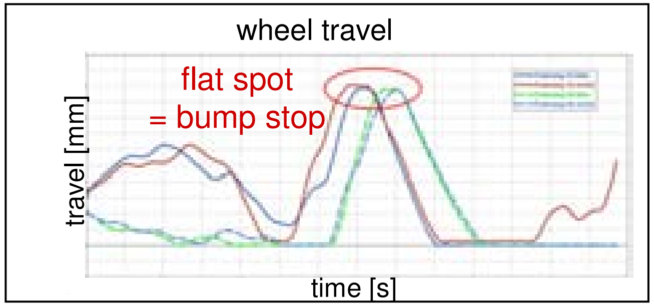
results – artificial hill



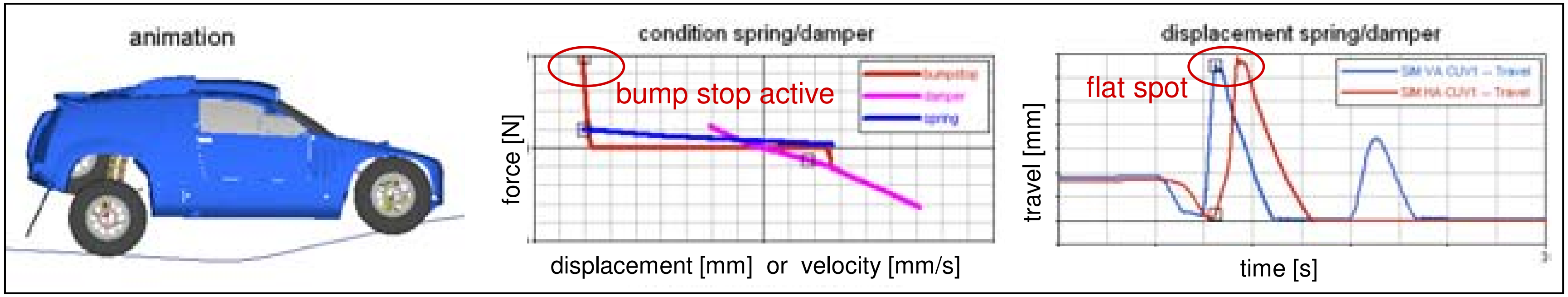
results – cuvette (natural depression)

in reality *KickBack* occurs in depressions (“cuvette”), when bump stop is active

- specific velocity
  too fast → energy in damper not in bump stop
- specific depth
  too shallow → energy in spring not in bump stop



test



simulation

Simulations of several sculptured cuvettes show promising flat spots in wheel travel, but car jumps too high, too long and too soon.

Reason is, that the real bump stop has both, elastic and damping properties ($F_{BS,test} = f(z, \dot{z})$) it absorbs energy.

The bump stop in the simulation is only stiffness ($F_{BS,sim} = f(z)$) and stores energy.

→ Bump stop characteristics are very important, but they are unfortunately not known.

summary and conclusion

the pilot project “vertical vehicle dynamics with MotionSolve” is based on a simplified scenario:

- simple car (no bushings ...)
- very simple tire model
- only vertical dynamics
- very few real data available
- almost no experience

with these premises all targets are met:

- model setup within HyperWorks (mainly MotionView, a bit HyperMesh)
- user-friendly data input with forms
- fast and stable simulations with MotionSolve
- close match of test and simulation data
- better understanding of effect of payload on *KickBack* (not shown)

⇨ **very successful project !**

next steps:

- integration of a more sophisticated tire model (partner product FTire?)
- transverse dynamics (tire, driver, power train, bump stop)
- flex bodies (all parts are available as FE-models [Optistruct])

thank you for your attention.