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Applications of SWIFT-Tyre: the next step in tyre modeling

TNO Automotive

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  - durability study
  - cornering uneven roads
  - aircraft landing gear shimmy

Relation MDI - TNO Automotive

Starting with ADAMS 12.0:

- **TNO Automotive will be responsible for the development of all ADAMS/Handling Tire models**

Agreement covers the tyre models:

- **Fiala, 521-Tire, UA-Tire, Pacejka '89 and '94**
- **ADAMS/Aircraft Tire**
- **MF-Tyre, MF-MCTyre and SWIFT-Tyre**

Activities: development, enhancements, solving bugs, second line support, documentation, training...

New in ADAMS 12.0...

MF-MCTyre: Magic Formula model for motorcycles:

- **valid for very large camber angles (up to 45-60 degrees)**
- **already in use for a number of years by three leading motorcycle manufacturers**
- **also suited for vehicle roll-over (!)**

MF-Dataset Libraries:

- **libraries with Magic Formula coefficients for car, motorcycle and light truck tyres**

SWIFT-Tyre...

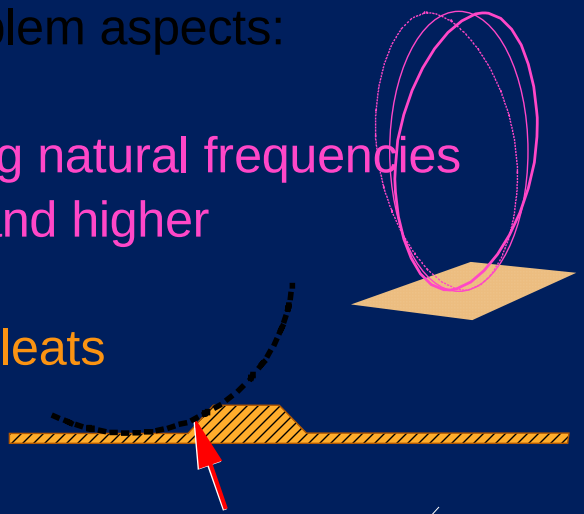
The SWIFT-Tyre model

SWIFT development

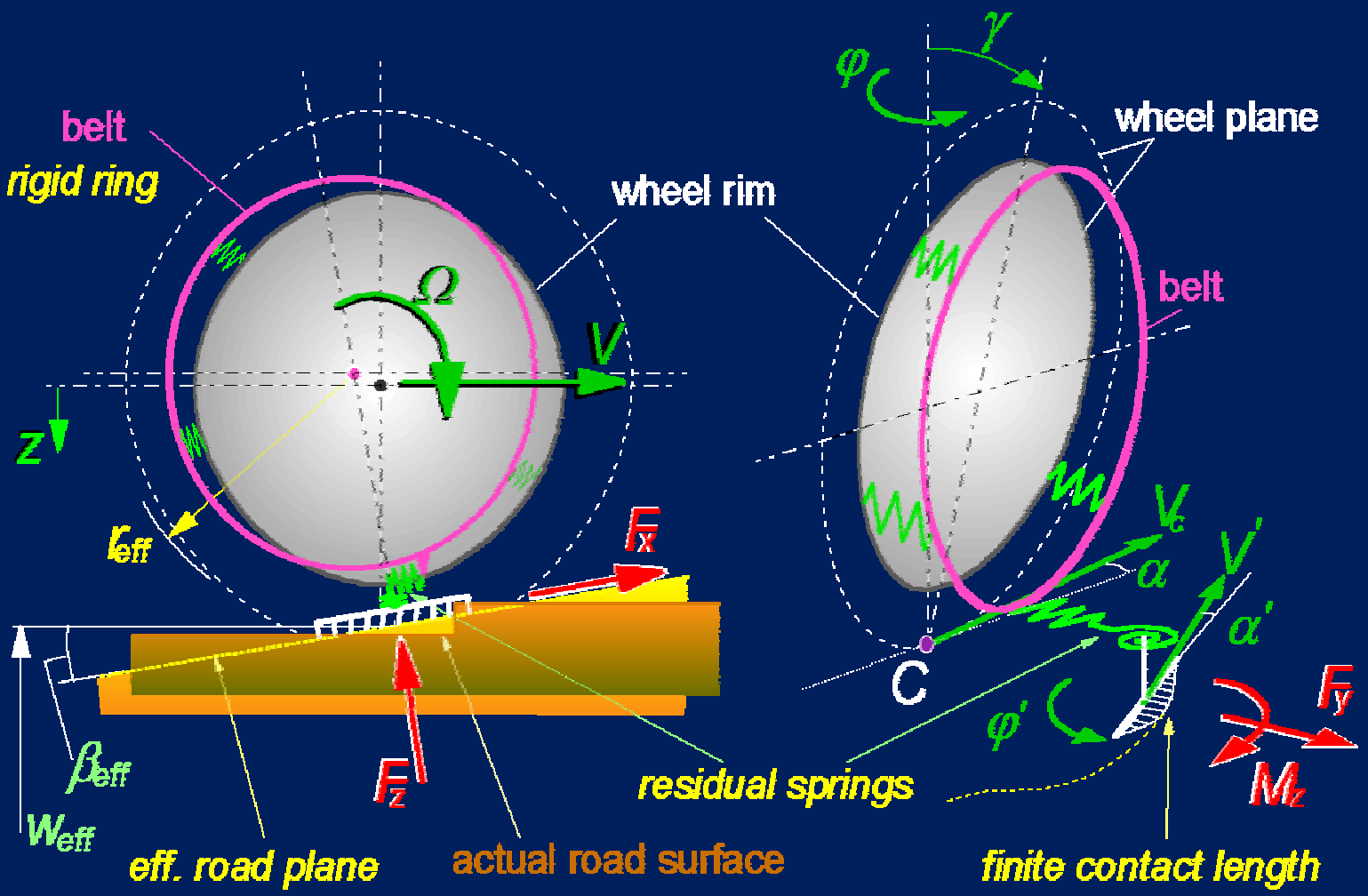
we have three main problem aspects:

- belt dynamics involving natural frequencies of ca. 30, 50, 70 Hz and higher
- road unevennesses: cleats
- short wavelength wheel oscillations

while retaining Magic Formula for steady state



Model lay-out



Data requirements

A SWIFT tyre property file contains information on:

- Magic Formula
- loaded radius and effective rolling radius
- contact length, enveloping properties
- relaxation lengths
- inertia of the rigid ring and residual mass
- stiffness and damping of the tyre

How to obtain this data?

Model validation

Many experiments:

- **drum:**

  -yaw oscillation

  -dynamic braking

  -loaded radius

  -high speed cleat testing

  -...

- **flat plank machine:**

  -contact length

  -enveloping properties

  -effective rolling radius

  -...

Important question...

Full measurement programme to determine all SWIFT parameters will be extensive and time consuming

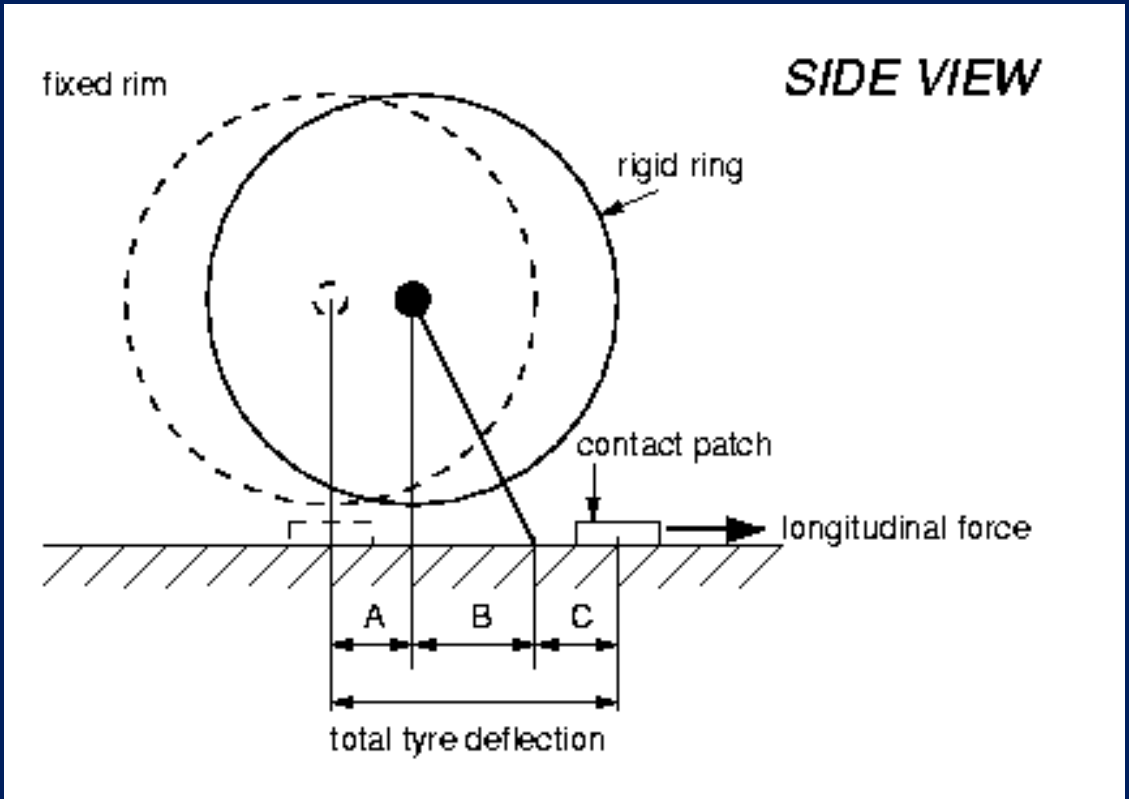
"Do we really have to do all this testing?"

Possible approaches:

- **limited test programme, depending on application**
- **use existing test data and/or model results (FEM) provided by the tyre manufacturer**
- **estimate coefficients based on previous tests, past experience**

Estimating parameters (1)

- **Longitudinal stiffness distribution**

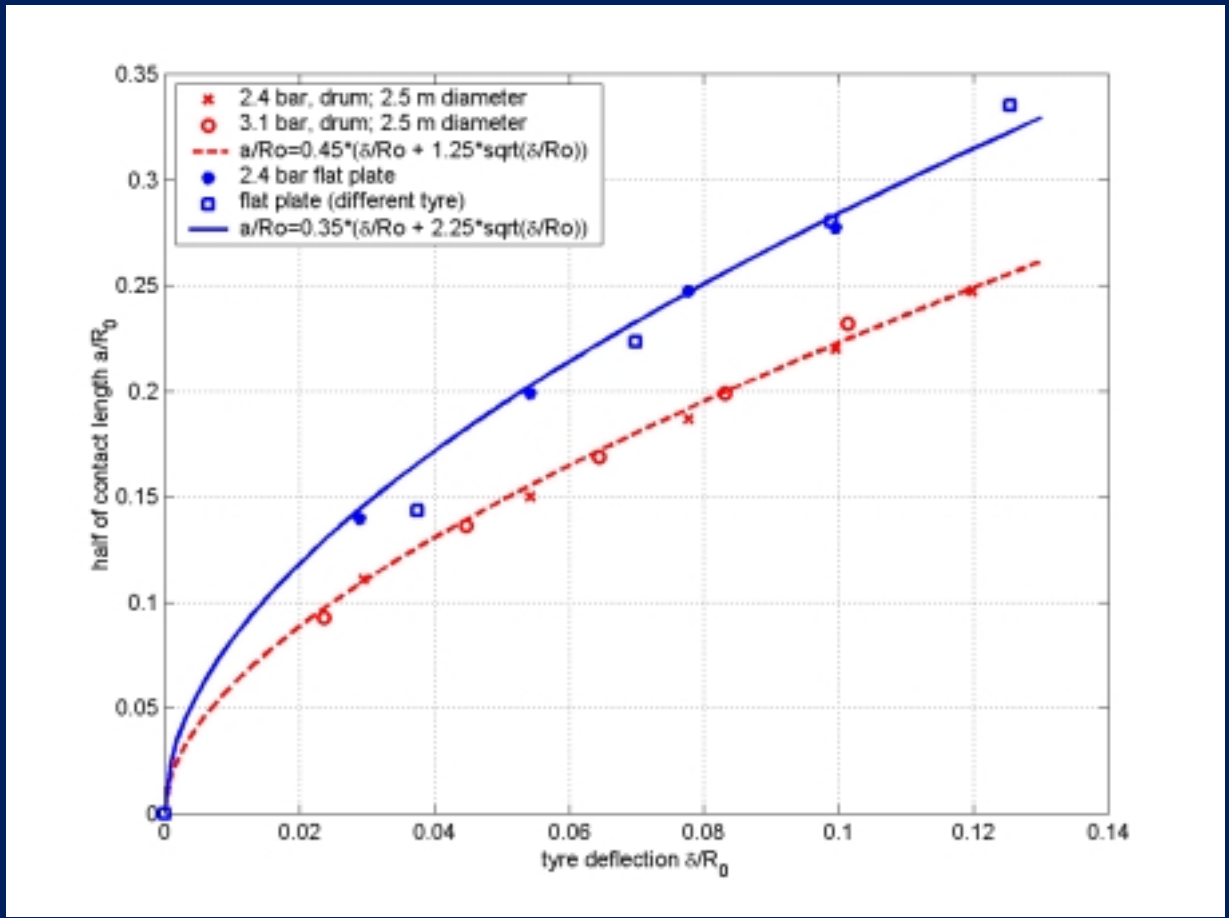


Experimental results for a number of different tyres indicate:

A:B:C = 3:6:1

Estimating parameters (2)

- Contact length



Based on geometrical considerations, literature, experience

Reducing overhead

Maximise commonality between MF-Tyre and SWIFT-Tyre

Examples:

- **MF-Tyre (ADAMS 12.0) will use the SWIFT loaded radius formula**
- **SWIFT-Tyre uses same Magic Formula as MF-Tyre**
- **rigid ring dynamics can be switched off**

Also:

- **tyre property files can be used across different simulation environments (e.g. MATLAB/Simulink)**

Some applications of SWIFT-Tyre...

- durability study
- cornering uneven roads
- aircraft landing gear shimmy

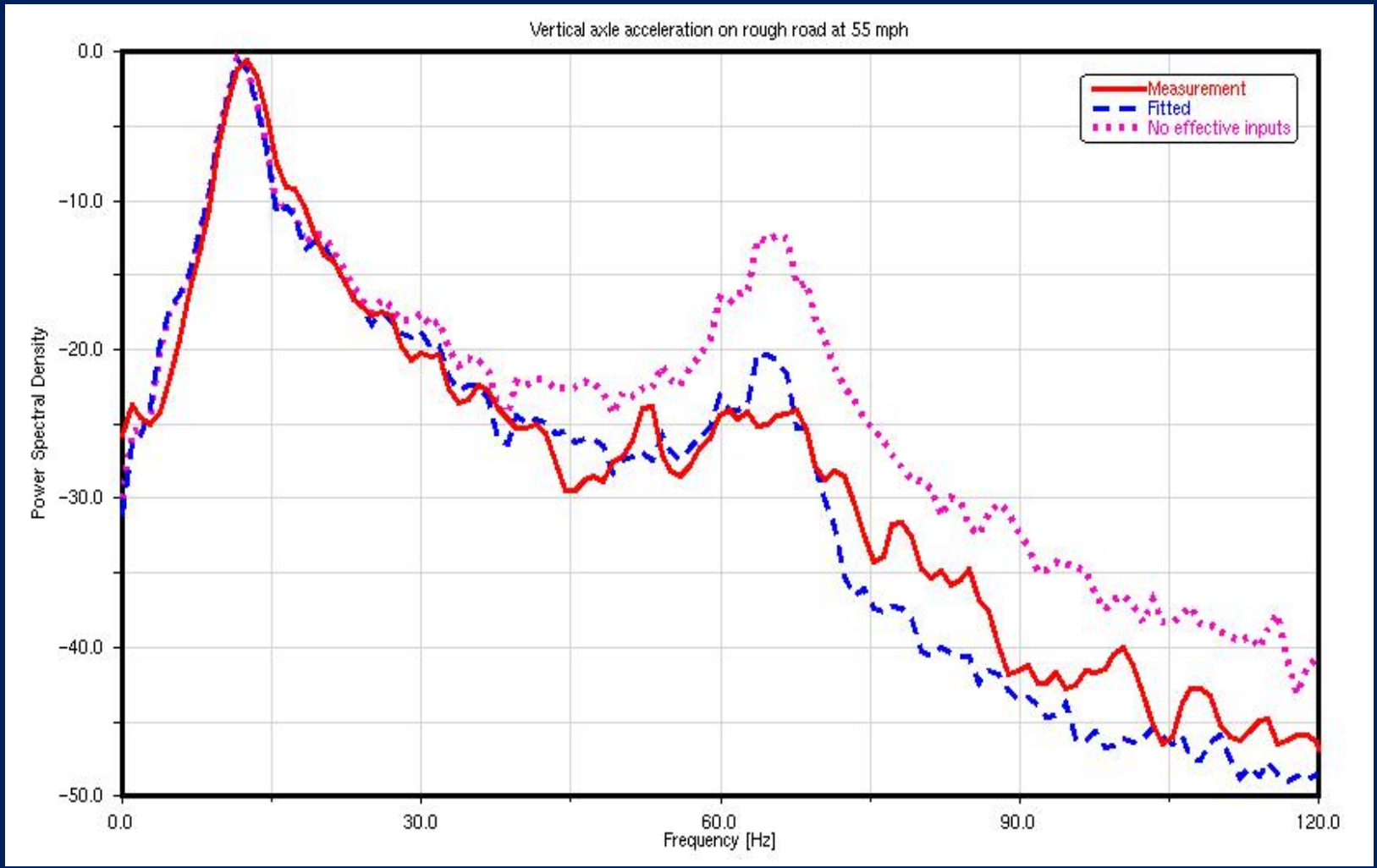
Durability study

Full vehicle model, driving over uneven road at 90 km/h

Comparison of vertical axle acceleration:

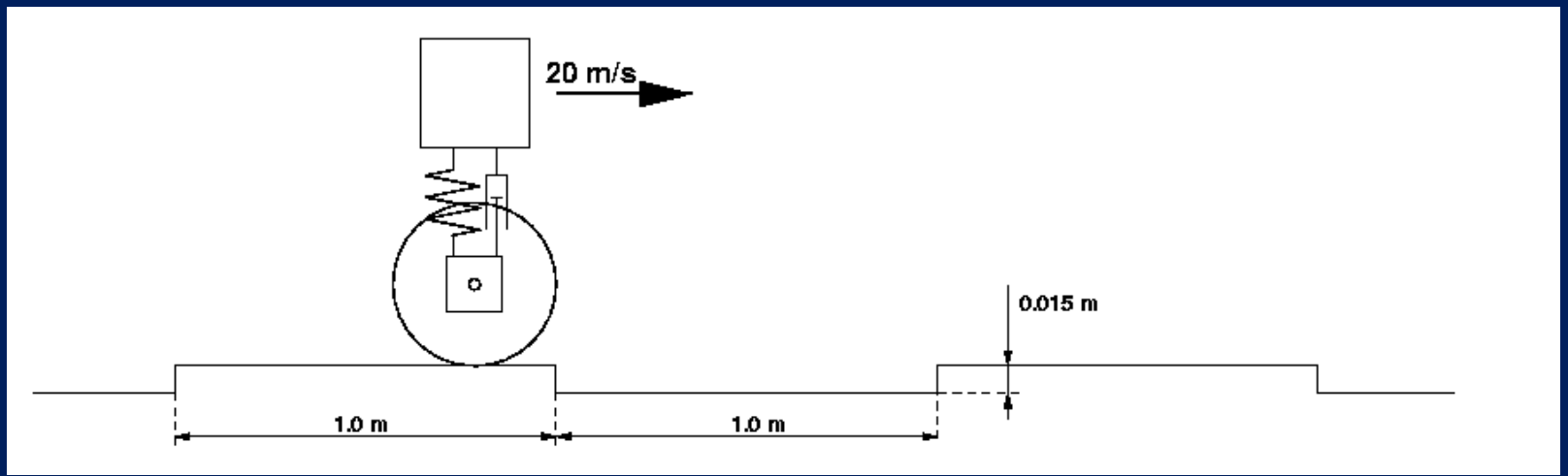
- **vehicle measurements**
- **full SWIFT-Tyre model**
- **SWIFT-Tyre without effective inputs**

- **vertical axle acceleration**

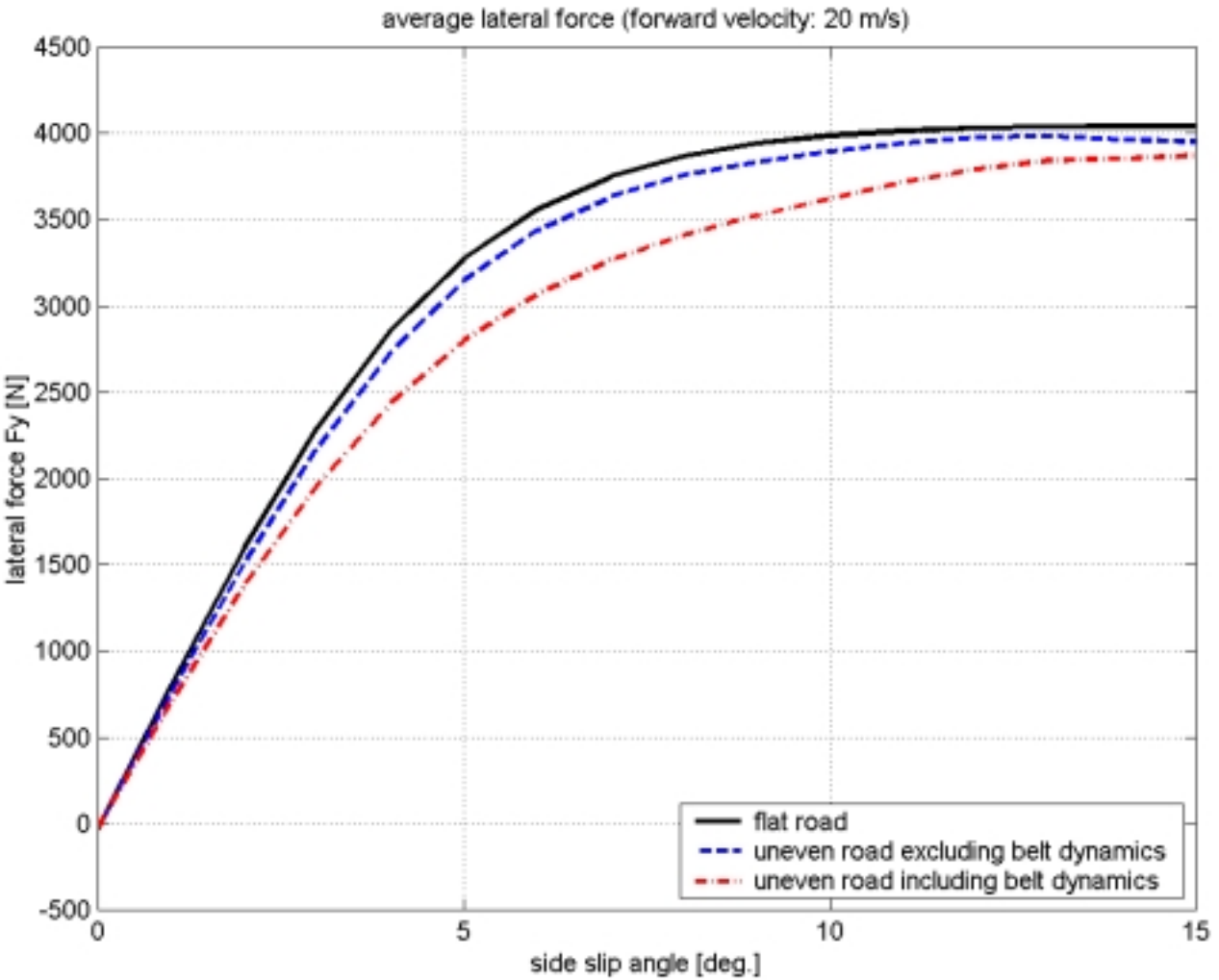


Cornering uneven roads

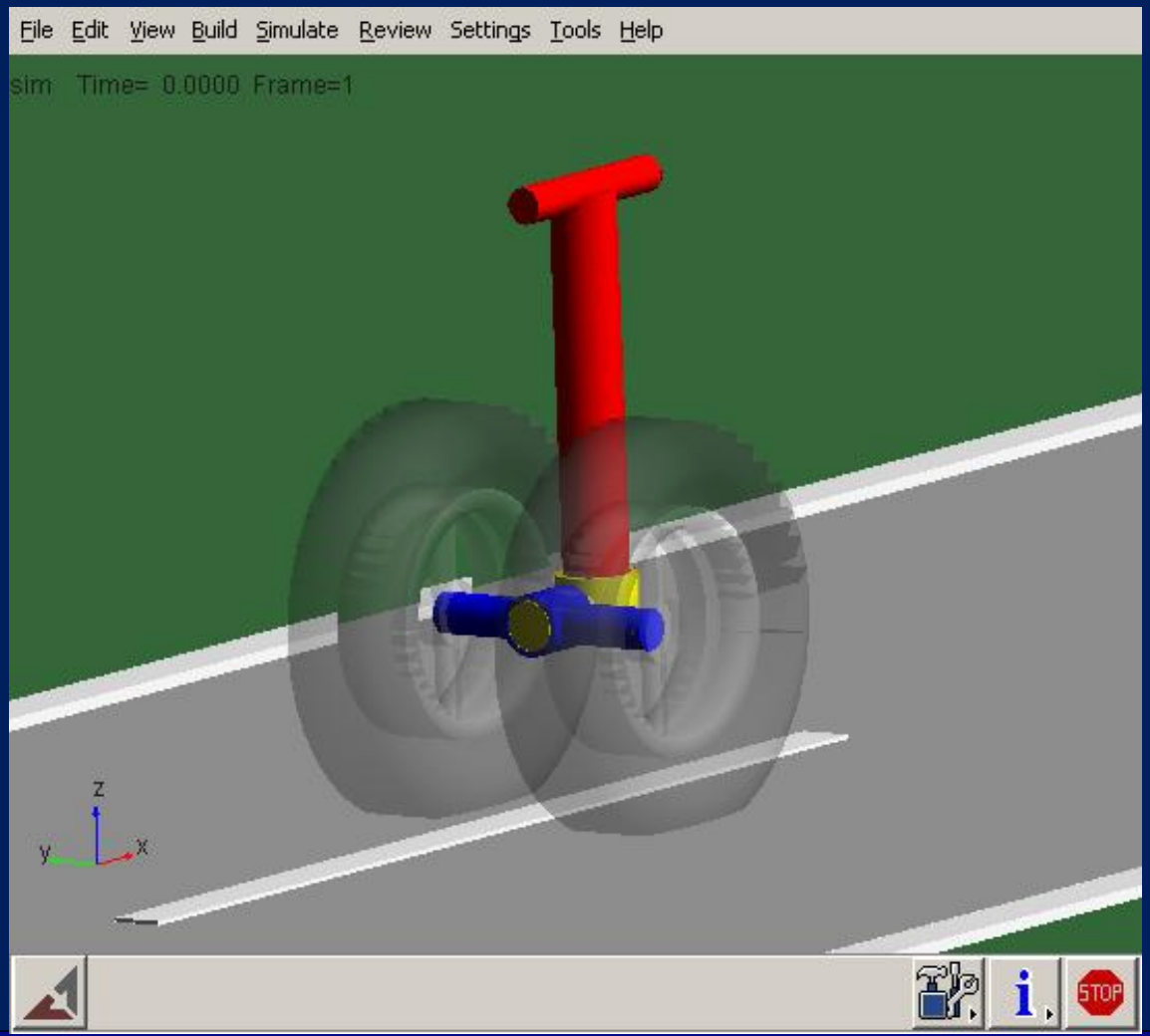
- quarter car model
- forward velocity: 72 km/h (20 m/s)
- road profile: base 1.0 m, height 0.015 m
- fixed steering angle, range: 0-15 degrees
- result: average lateral force



- **“effective” tyre characteristics**



Aircraft landing gear shimmy



simple, but representative landing gear model

Shimmy model

Simulation conditions:

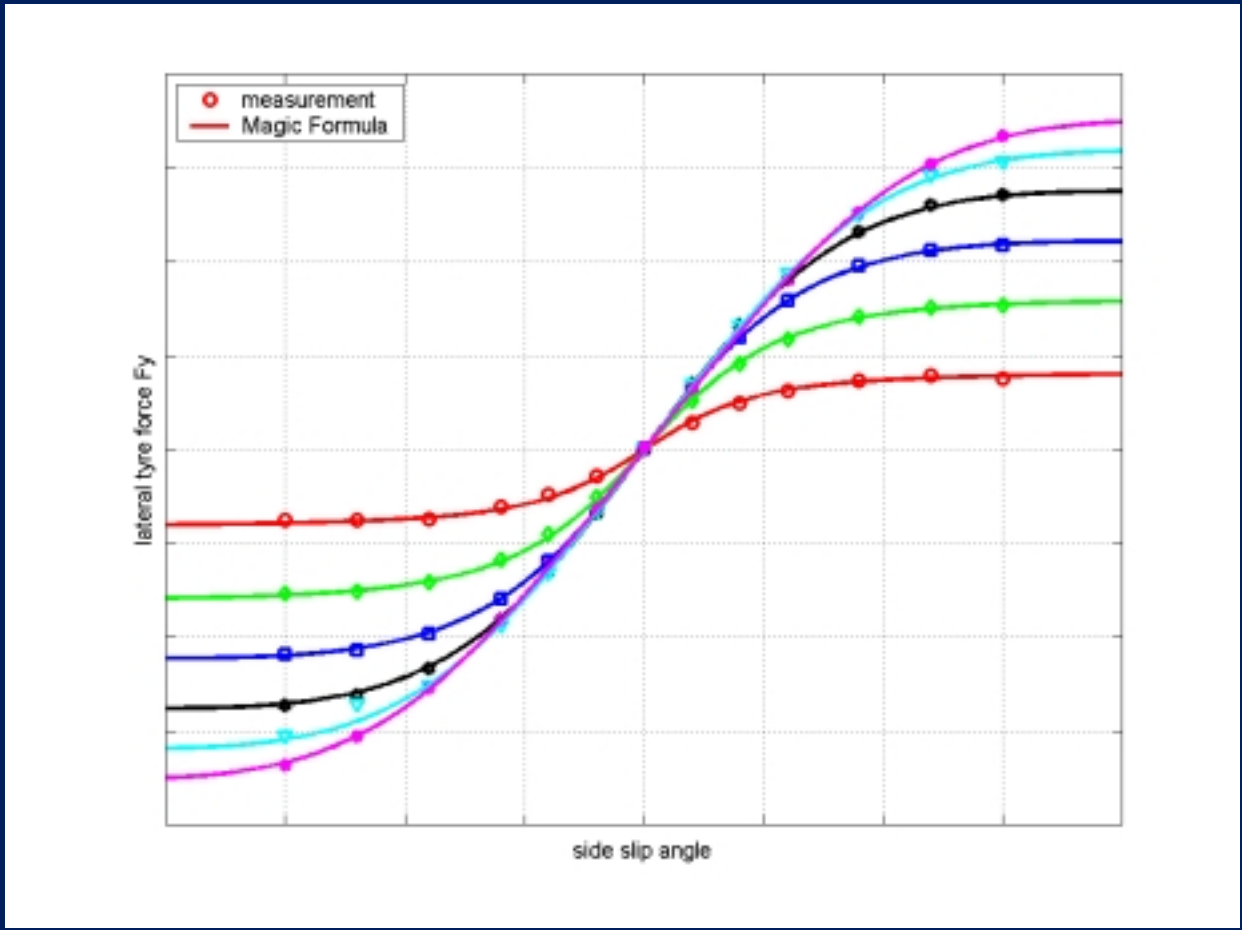
- **forward velocity 270 km/h (75 m/s)**
- **shimmy initiated by asymmetrical spin-up**

Advantages of SWIFT-Tyre over “classical” models:
(e.g. Von Schlippe, Smiley, etc.)

- **non-linear, includes combined slip**
- **relaxation length decreases as function of side slip**
- **gyroscopic behaviour of the tyre belt included**

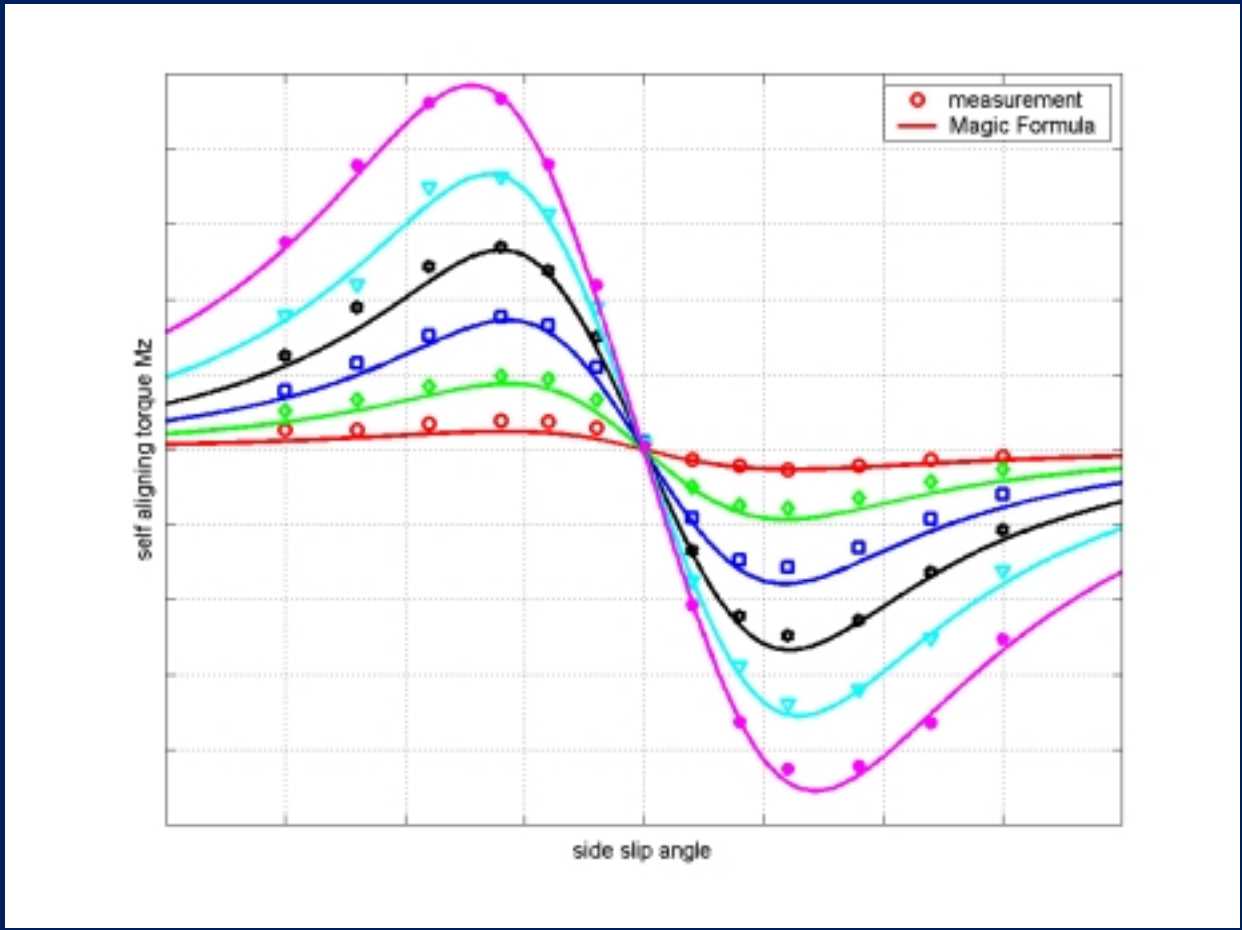
Steady state characteristics (1)

- **Magic Formula fit aircraft tyre: lateral force**



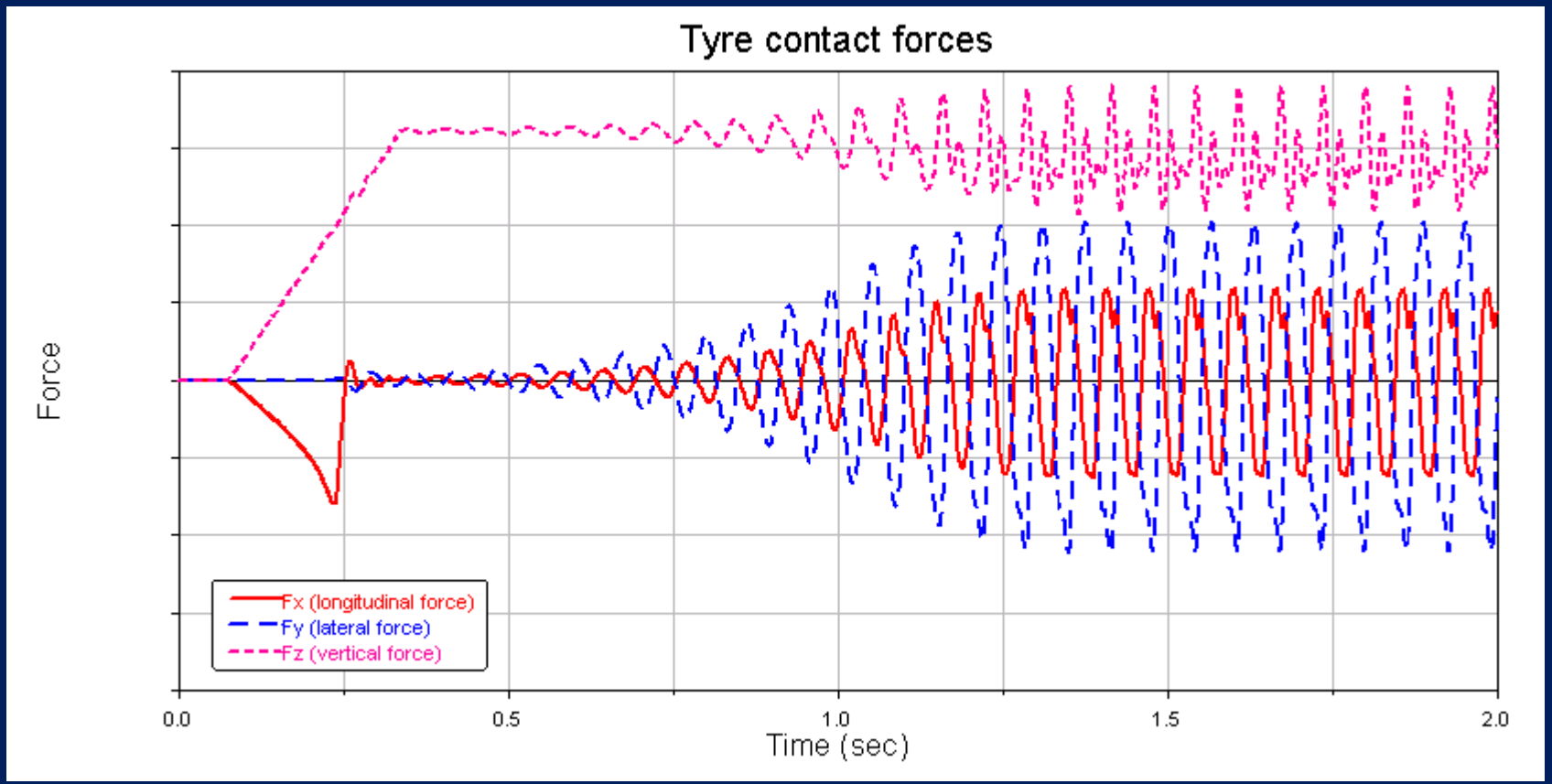
Steady state characteristics (2)

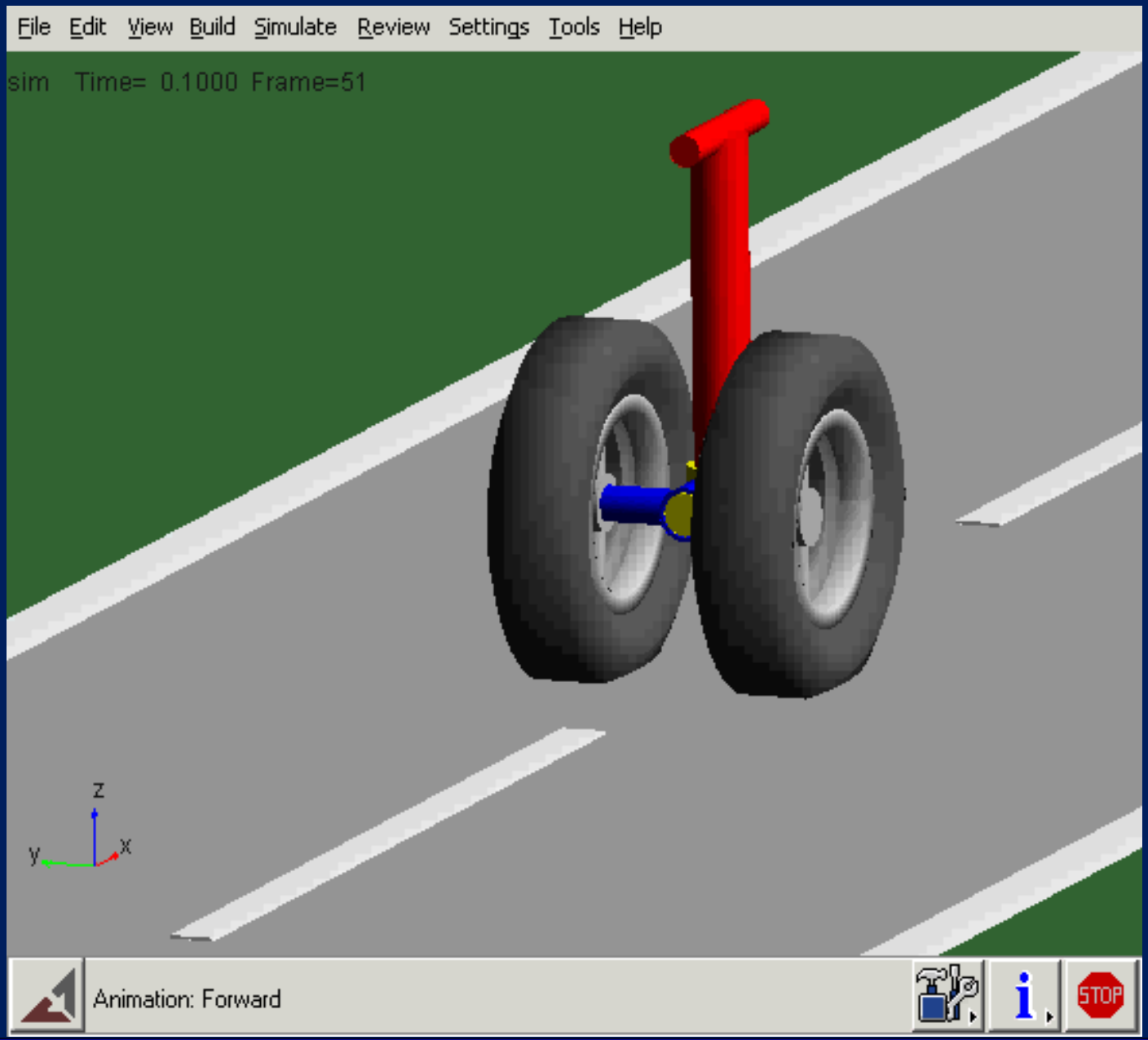
- **Magic Formula fit aircraft tyre: self-aligning moment**



Simulation results

- **unstable shimmy vibration: 15 Hz**

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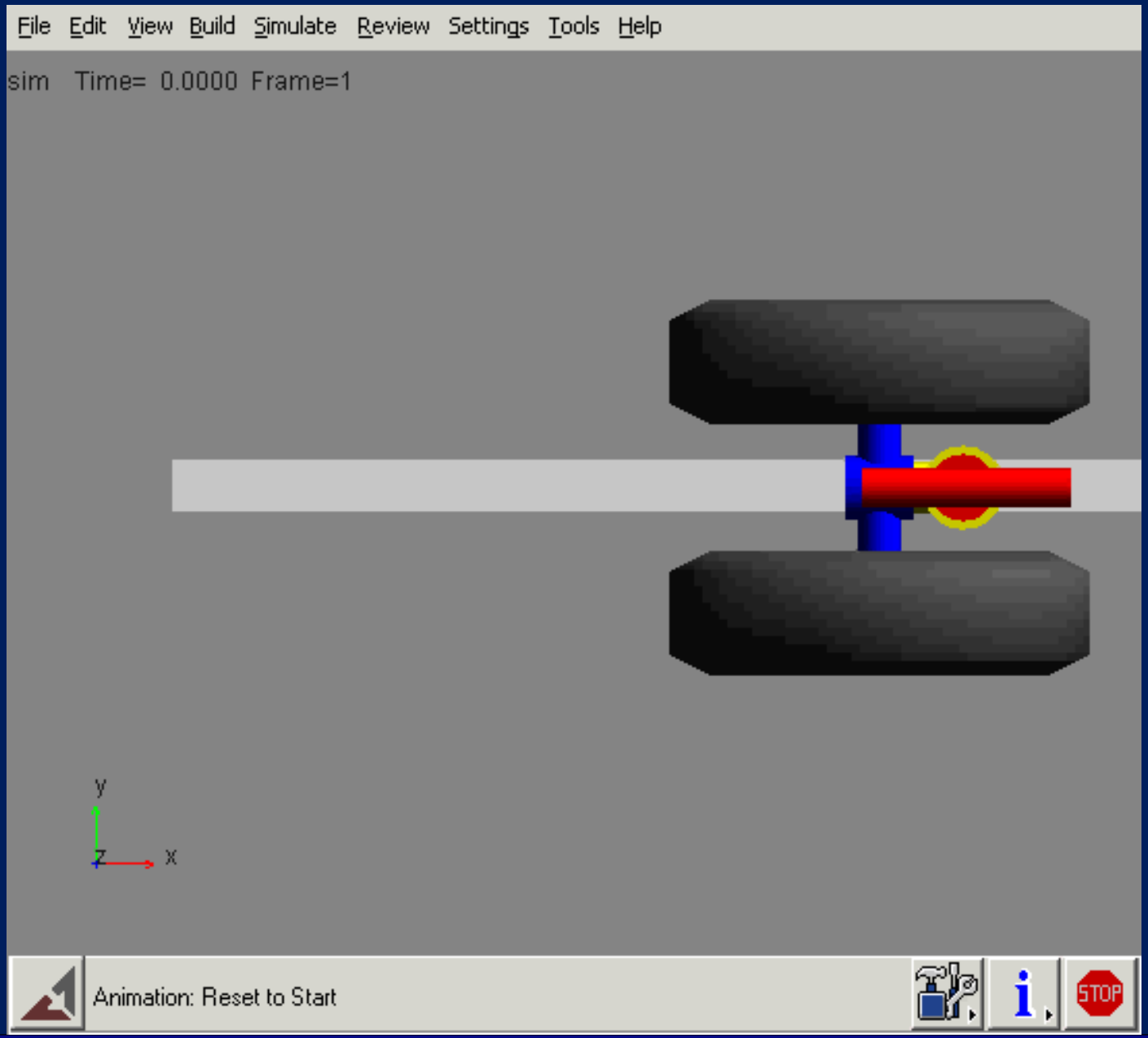
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Conclusions

TNO Automotive provides:

- state-of-the-art tyre modelling
- (tailor made) tyre testing
- processing of measurements, determination of tyre parameters (e.g. MF-Tool)
- tyre datasets from a library

SWIFT-Tyre is a versatile tyre model, which can be used for many applications!

Questions?

www.delft-tyre.com

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