SWIFT-Tyre: An accurate tyre model for ride and handling studies also at higher frequencies and short road wavelengths

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As is well known, Magic Formula tyre modelling (MF-Tyre is a part of ADAMS/Tire) allows an accurate and efficient description of tyre-road interaction forces required for any usual vehicle handling simulation. When it comes to modelling of tyre behaviour at higher frequencies and short road obstacles, which are important for vehicle ride assessment, advanced chassis control systems and chassis system vibrations, a more sophisticated approach is required.

In close co-operation with the Delft University of Technology and with involvement of nine automotive companies, TNO has developed the SWIFT (**S**hort **W**avelength **I**ntermediate **F**requency **T**yre) model, which is based upon a rigid ring type of tyre model. The SWIFT model is able to describe dynamic tyre behaviour for in-plane (longitudinal and vertical) and out-of-plane (lateral, camber and steering) motions up to about 60 Hz, and for road obstacles with short wavelength. For reasons of accuracy and calculation speed the SWIFT model has been programmed as a semi-empirical model which is derived using advanced physical models and dedicated high frequency tyre measurements to assess speed effects in tyre behaviour.

During the development of SWIFT much attention has been paid to validation of the model with advanced high frequency tyre testing. The extensive testing programme showed that tyre model parameter assessment by a modal analysis approach is certainly not sufficient for accurate tyre F&M modelling.

Similar to the MF-Tyre module, the SWIFT-Tyre has been linked to ADAMS using a Standard Tyre Interface and has been extensively validated with tyre measurements especially performed with high frequency excitations. In addition robustness, user friendly-ness and backward compatibility with MF-Tyre have been given high priority.

Typical applications of the SWIFT-Tyre module are:

- active chassis control system development,
- braking/driving behaviour during cornering on uneven roads,
- vehicle ride assessment using sharp and short road obstacles,
- suspension vibration analysis (i.e. steering oscillations)

In this presentation the SWIFT tyre model will be explained as well as a comparison between the model and the measurements will be shown. In addition, the use of the SWIFT tyre model in ADAMS simulation models will be illustrated for ABS braking, while cornering over uneven roads.

Delft-Tyre

SWIFT-Tyre

An accurate tyre model for ride and handling studies for high frequencies and short road wavelengths

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Delft-Tyre

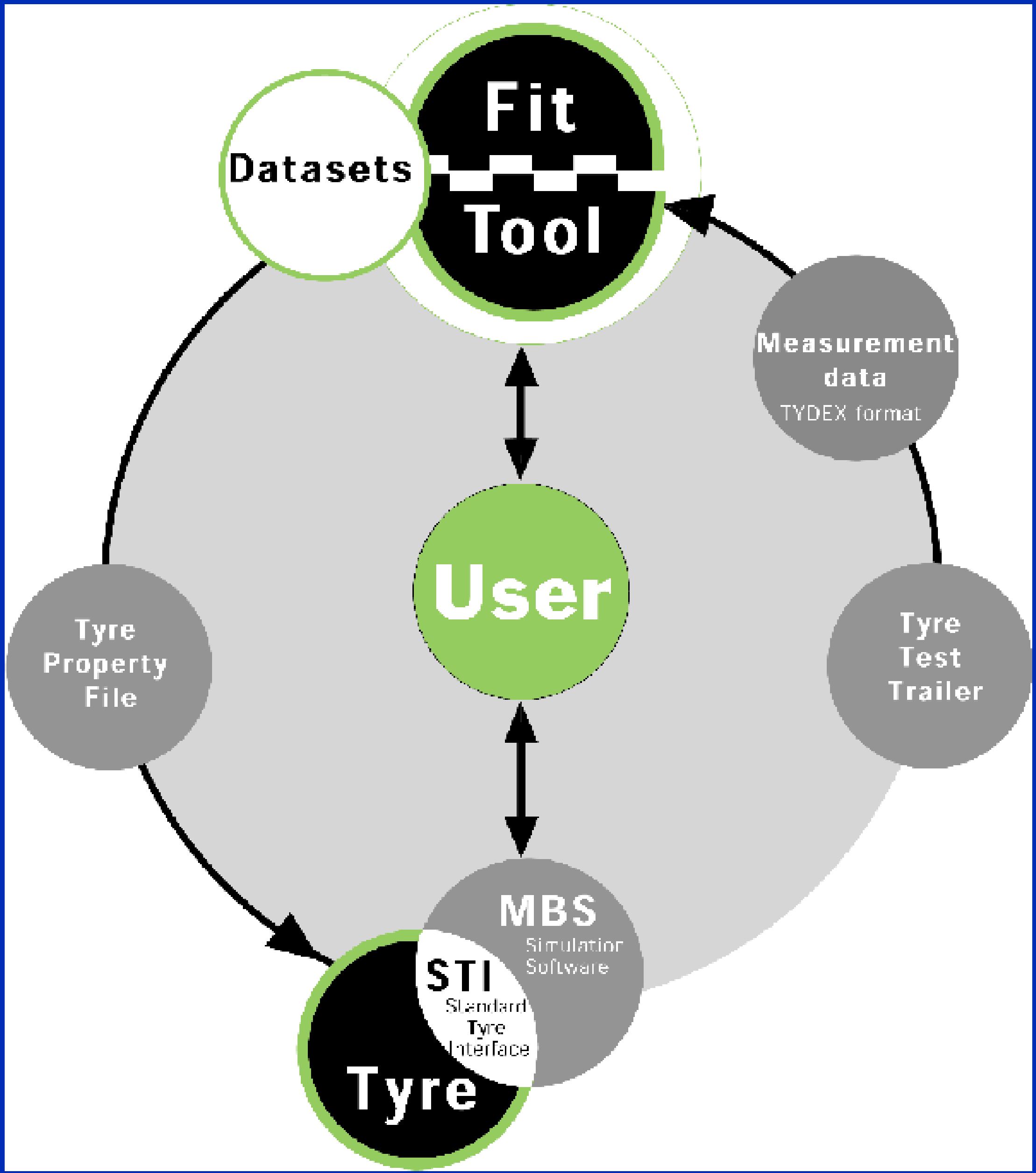
Content

- Current DELFT-TYRE modelling
- SWIFT-Tyre
  - the objectives
  - the model
  - experiments
  - validation
- SWIFT modelling in ADAMS
- Availability
- Concluding

Delft-Tyre

Design and analysis environment to support in optimization of the vehicle-tyre system

- MF-Tyre
- MF-MCTyre
- MF-Tool+
- MF-MCTool+



DELFT-TYRE

current models

MF-Tyre and MF-MCTyre:

Steady state and transient tyre modelling
for all basic vehicle handling studies up to 8 Hz

New version of MF-Tyre 5.2:

- vertical stiffness depends on slip angle and long. slip
- growth of tyre radius by rotational speed
- rolling resistance depends on speed
- improved combined cornering and braking/driving

Next step:
SWIFT-Tyre

Short Wavelength Intermediate Frequency Tyre

Objective:
A general pragmatic tyre model (3D) for the development of active chassis control systems and optimising vehicle ride properties

SWIFT-Tyre
applications

- Dynamic braking/driving (ABS/TCS)
- Vehicle Dynamic Control (VDC/ESP)
- Ride comfort & vibrations
- Suspension and steering system design: combined dynamic braking, cornering and ride
- 4 post rig ride testing
- ….
- All kinds of tyres

SWIFT-Tyre

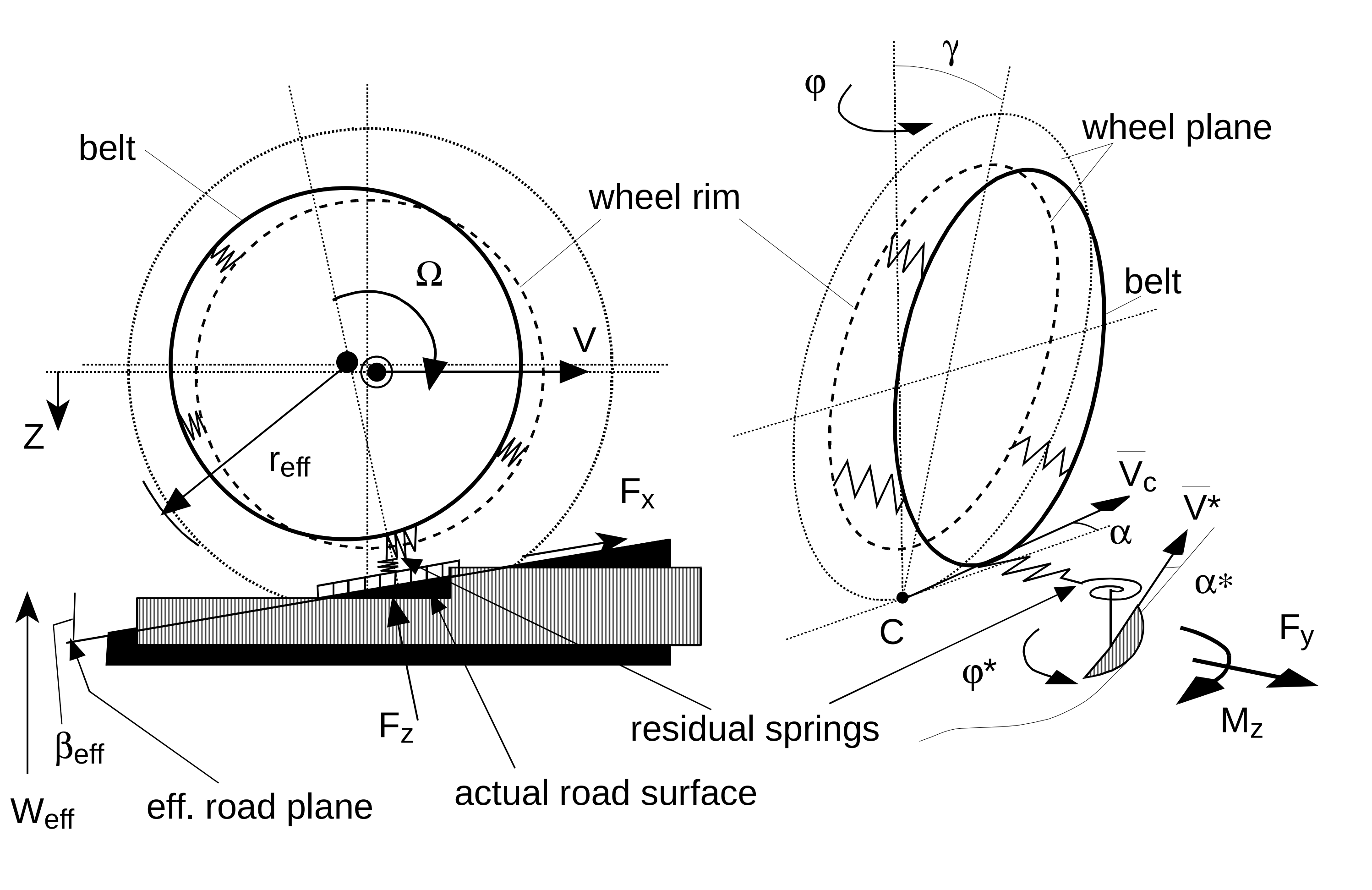
Model description

- Rigid Ring modelling for tyre belt vibrations up to 60 Hz
- Semi-emperical for optimal accuracy and calculation speed
- Elaborate contact model for short wavelength slip variations (wavelengths > 0.2 m)
- Effective inputs for discrete obstacles
- Magic Formula for slip force calculation
- Validation with realistic tyre test data

Delft-Tyre

SWIFT-Tyre

Model description



Delft-Tyre

SWIFT-Tyre

In- and out-of-plane

- Non-linear vertical force
- Load and speed dependent belt frequencies
- Tyre radius growth with speed
- Vertical force influenced by contact point displacement
- Slip dependent transient behaviour
- Eigenfrequencies of the tyre belt

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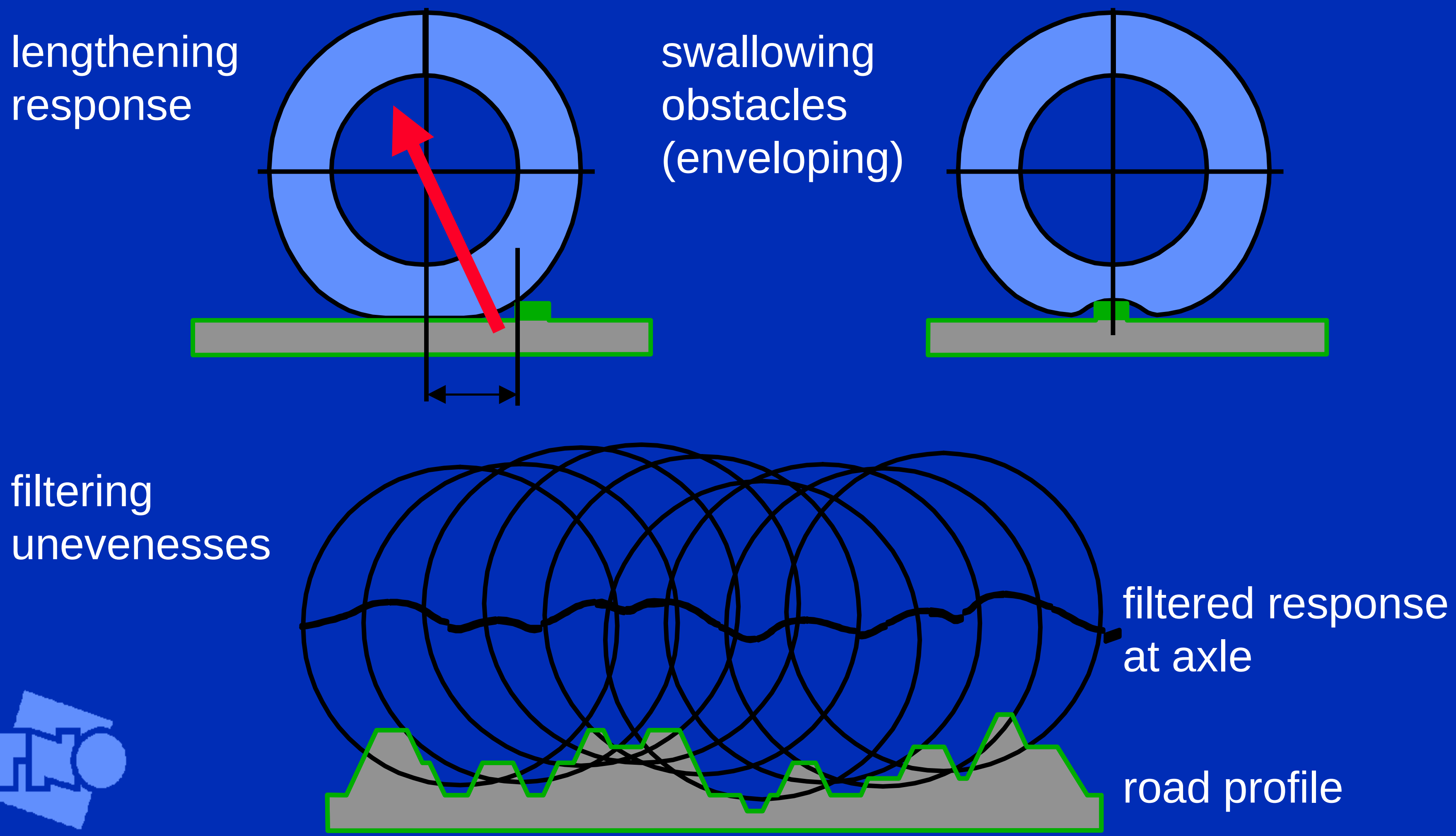
SWIFT-Tyre

Short obstacles

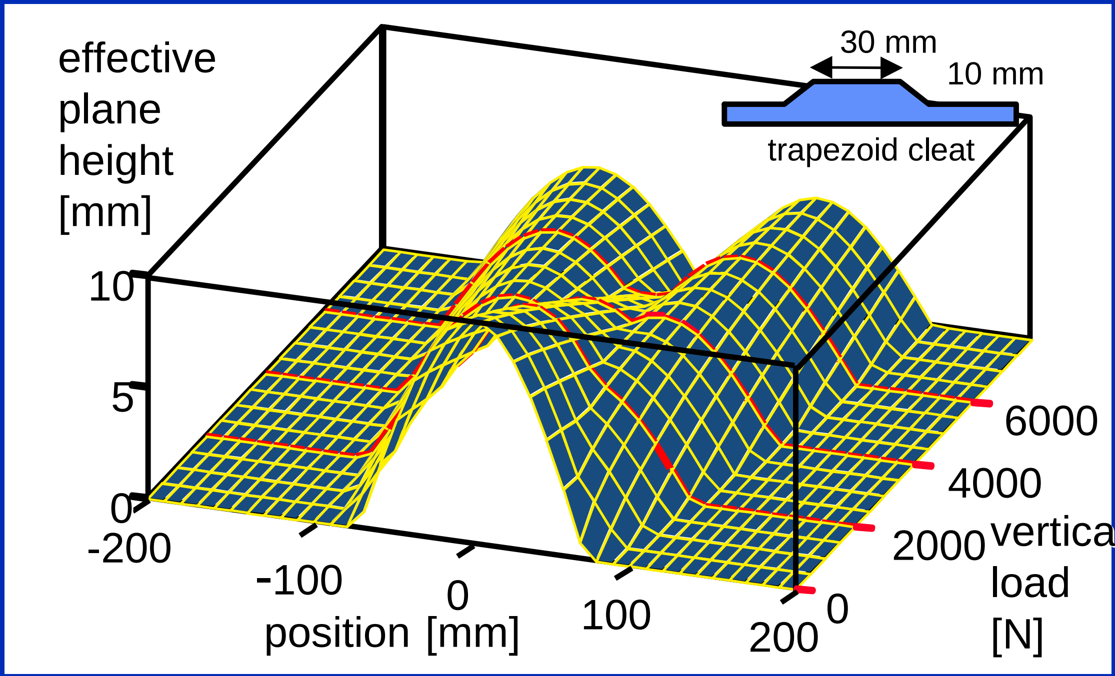


Delft-Tyre

SWIFT-Tyre
Short obstacles

Effective input approach:

- Road profile is transferred into effective inputs
  - Effective plane height
  - Effective plane angle
- Vertical and long. tyre forces
- Rolling radius variations



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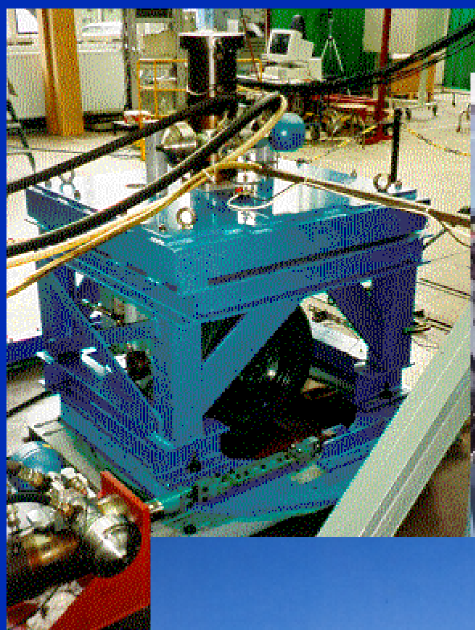
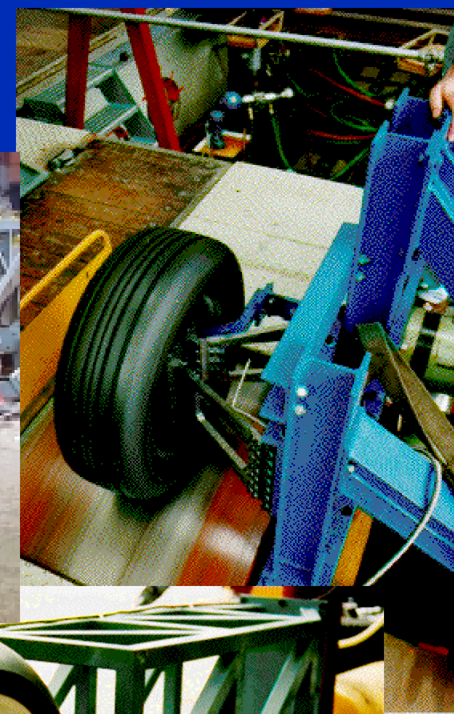
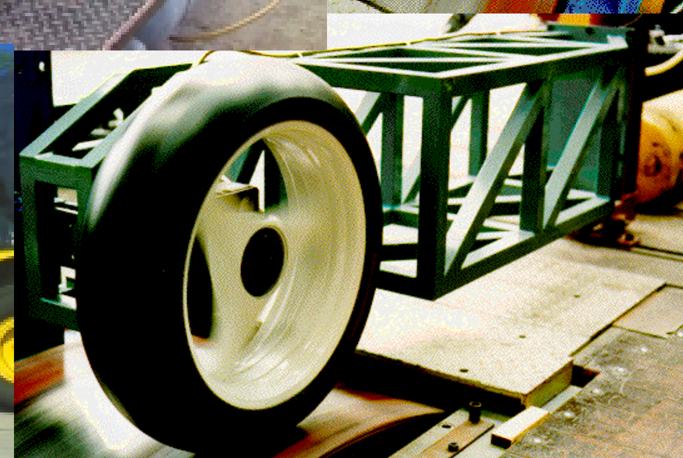
SWIFT-Tyre

Experiments & Validation







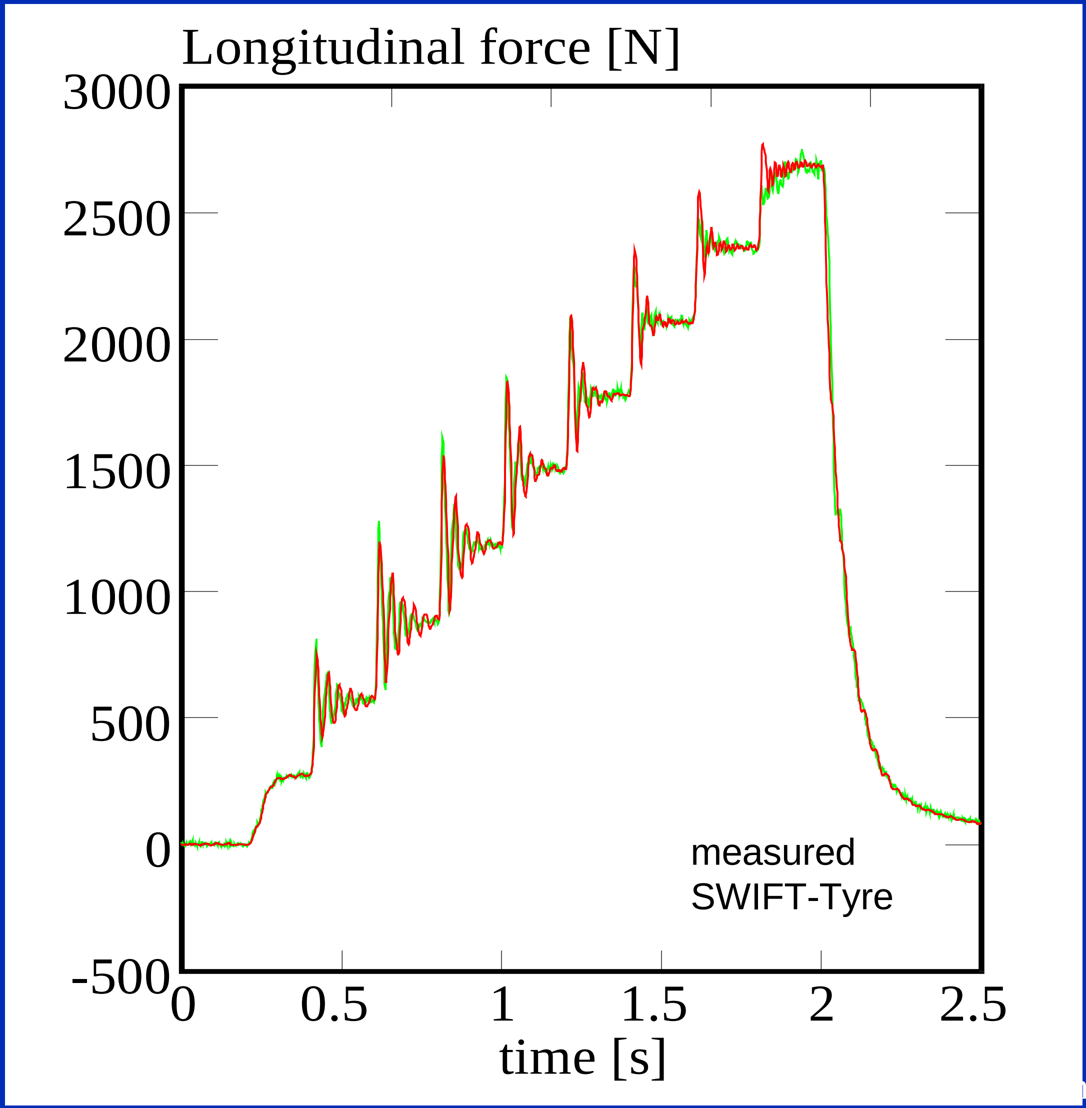
F&M testing

for SWIFT parameters

- Dynamic tyre testing for SWIFT parameters (at different loads and speeds)
  - dynamic braking
  - cleat testing
  - dynamic cornering
  - effective input tests
- Model analysis approach
  - Identified frequencies not representative for tyre behaviour under driving conditions
  - Not suitable to assess speed and load effects

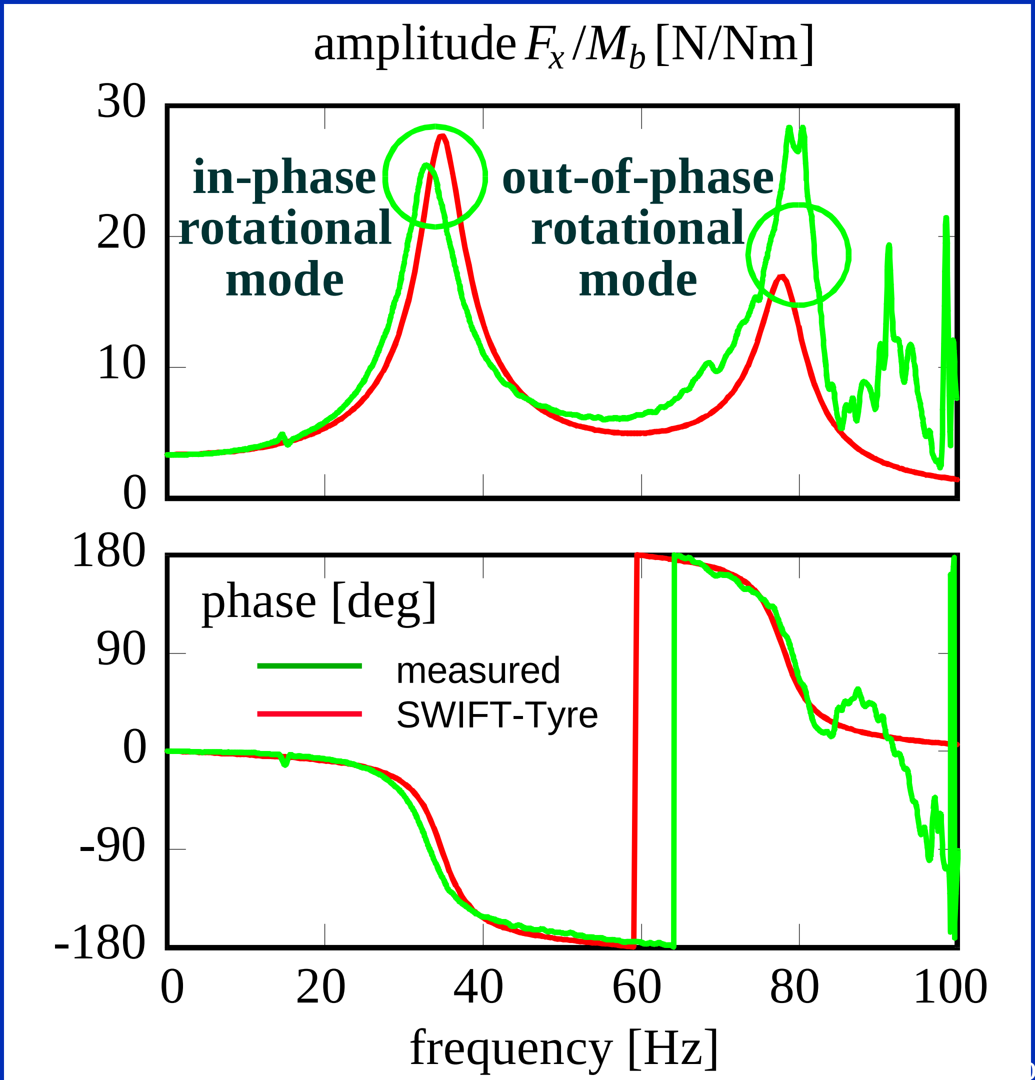
Validation

Step wise brake torque input



Validation

Step wise brake torque input



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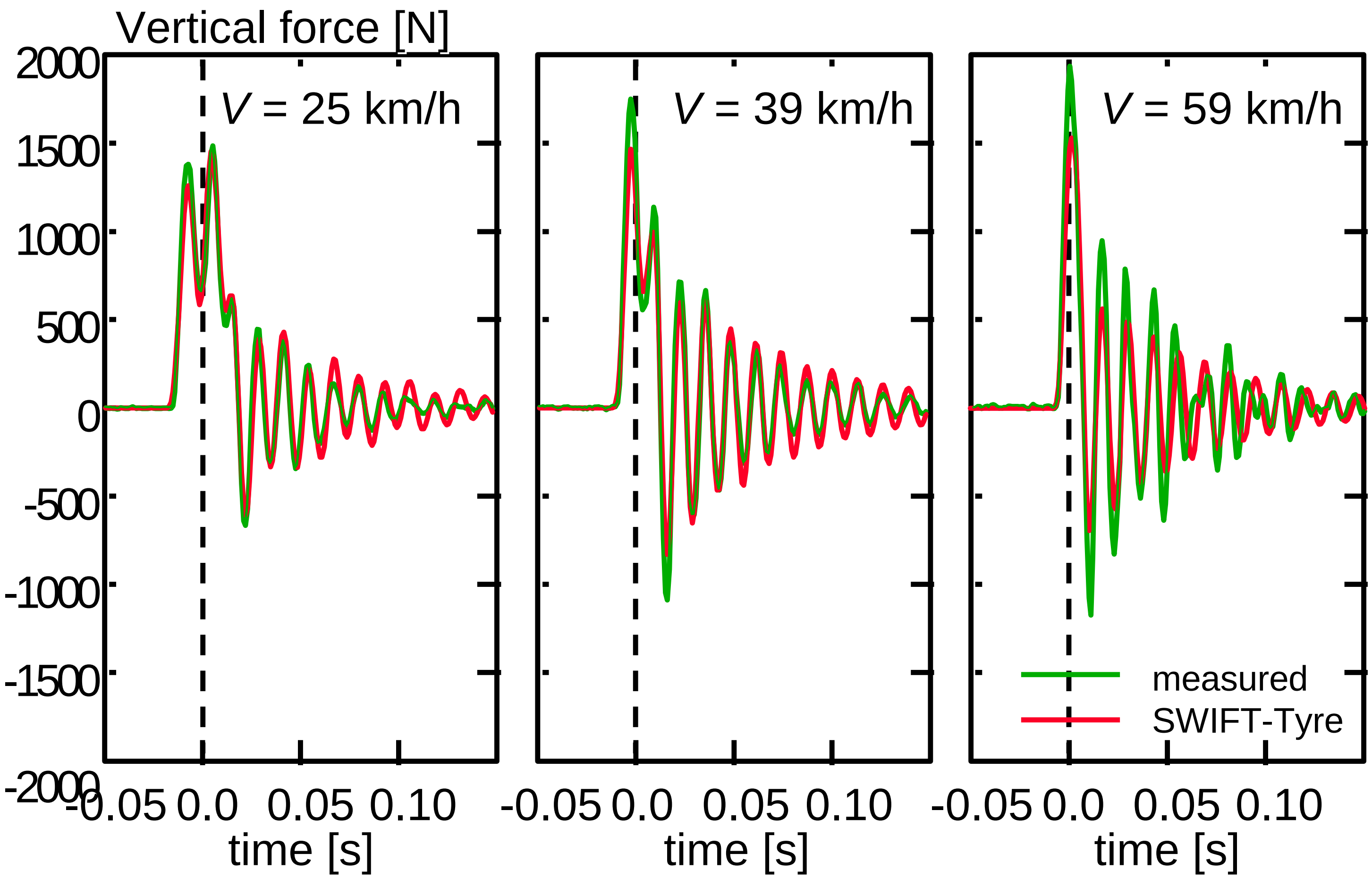
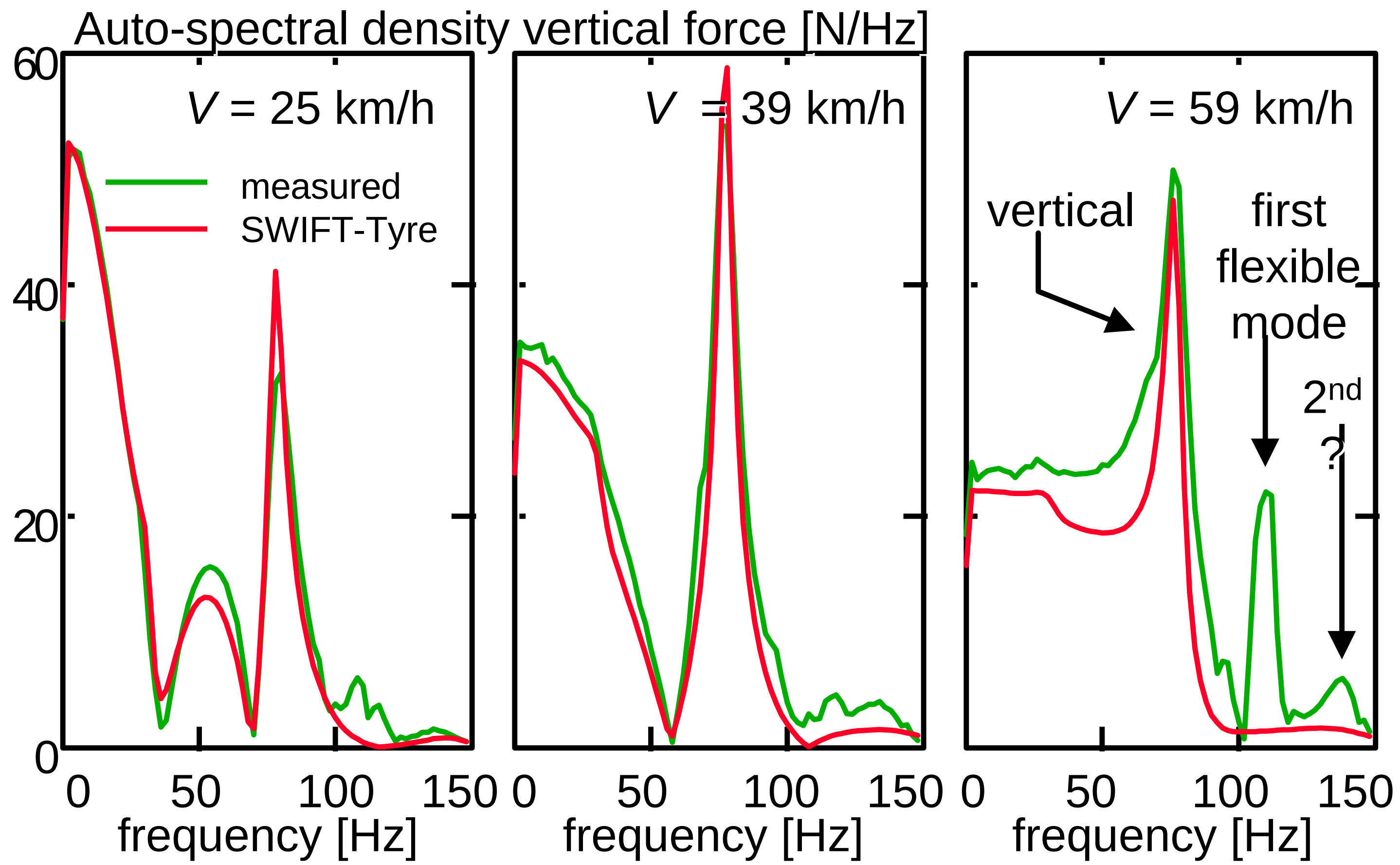
Validation

Vertical force when rolling over cleat



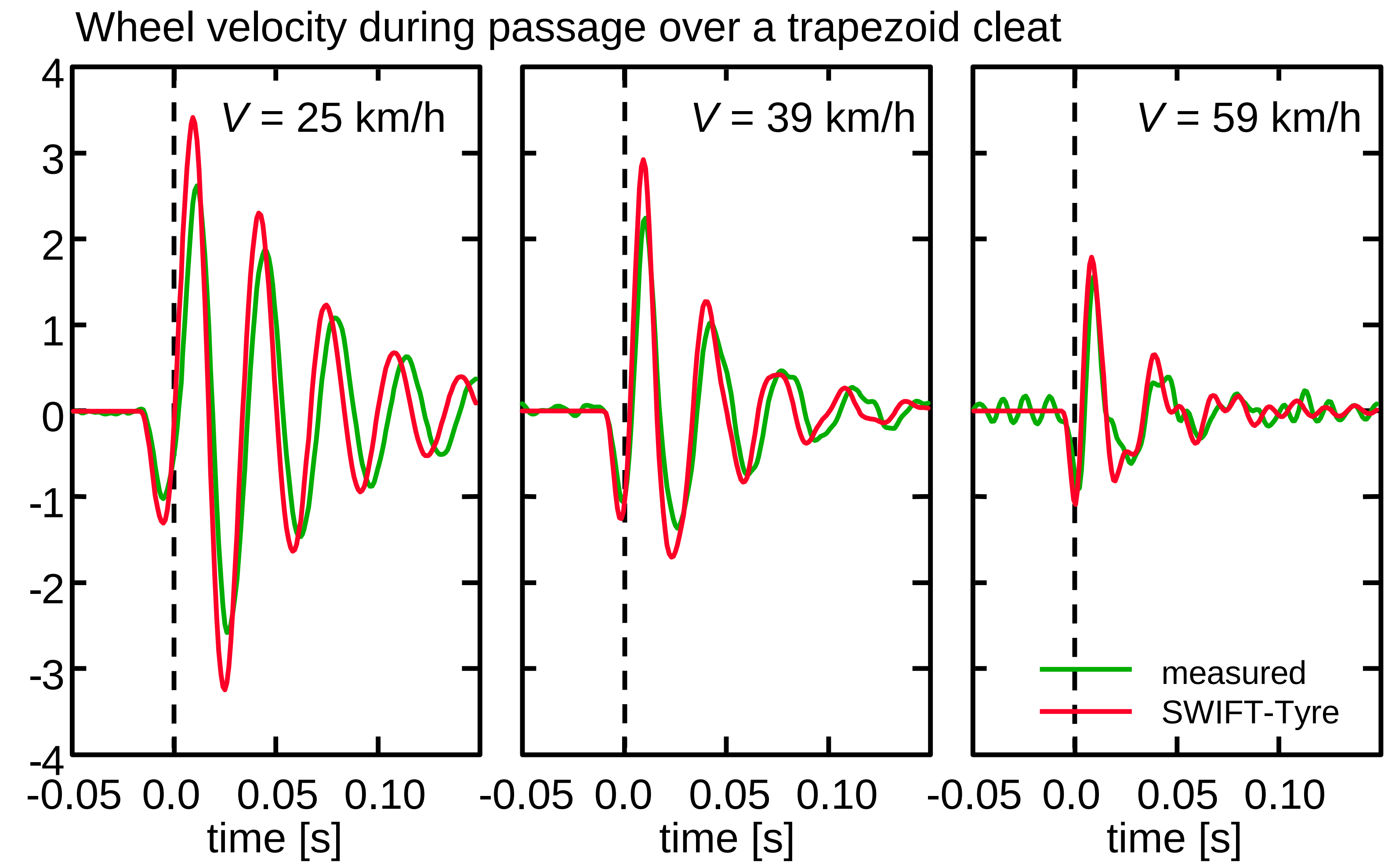
Validation

Vertical force when rolling over cleat



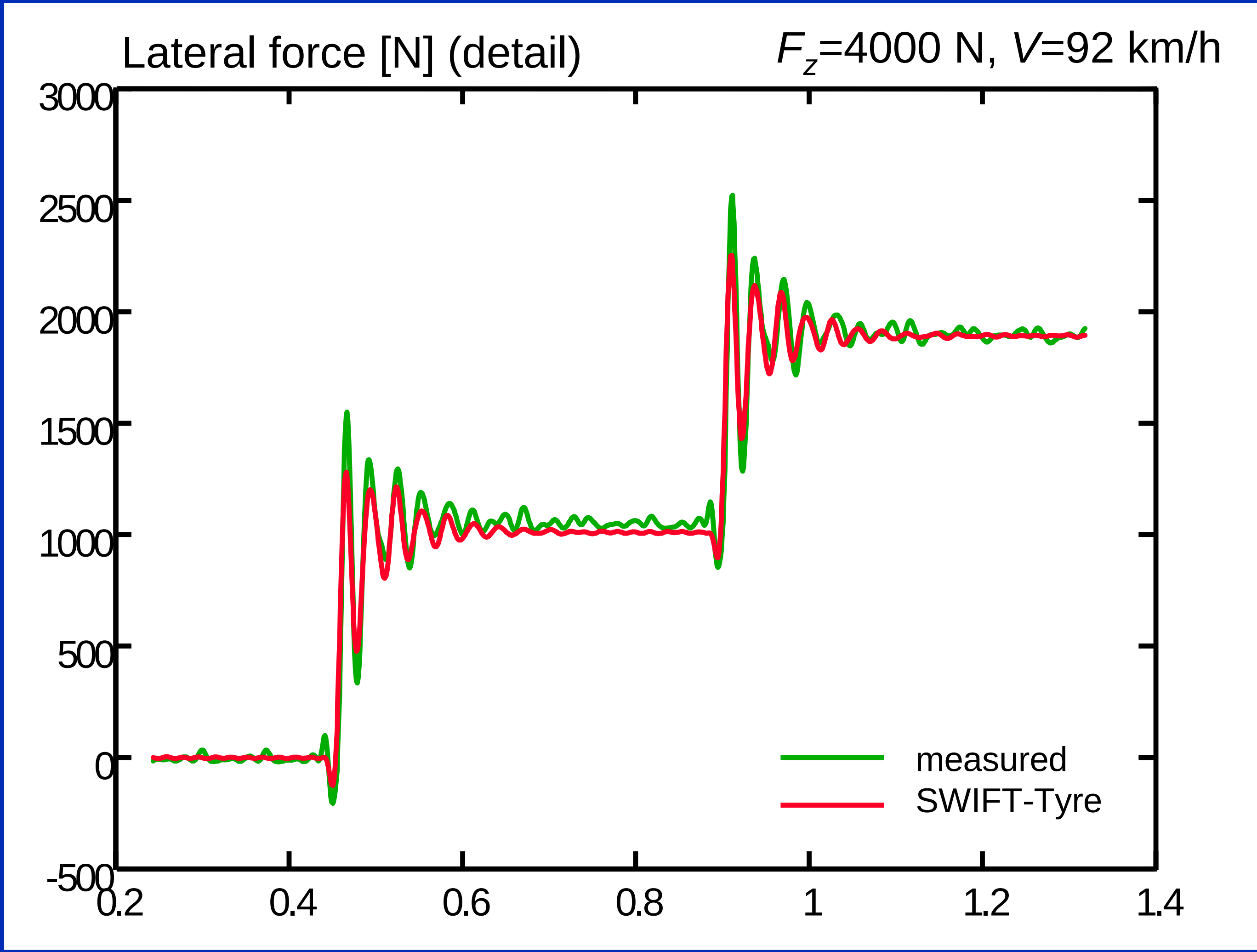
Validation

Long. force when rolling over cleat



Validation

Lateral force due to slip angle step

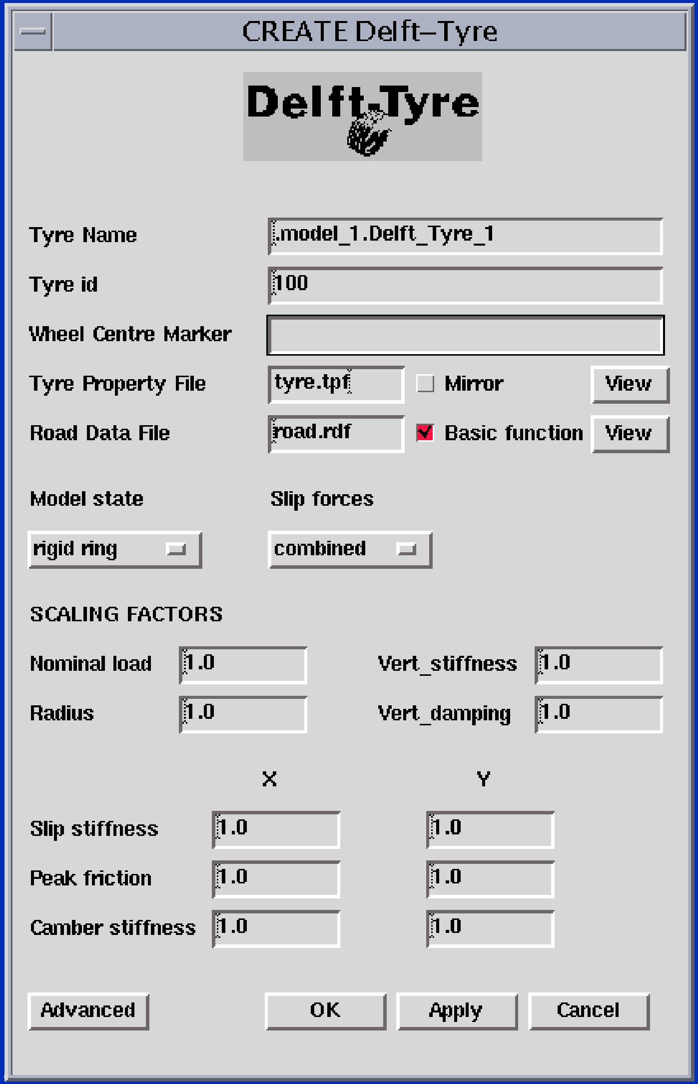


SWIFT in ADAMS

implementation

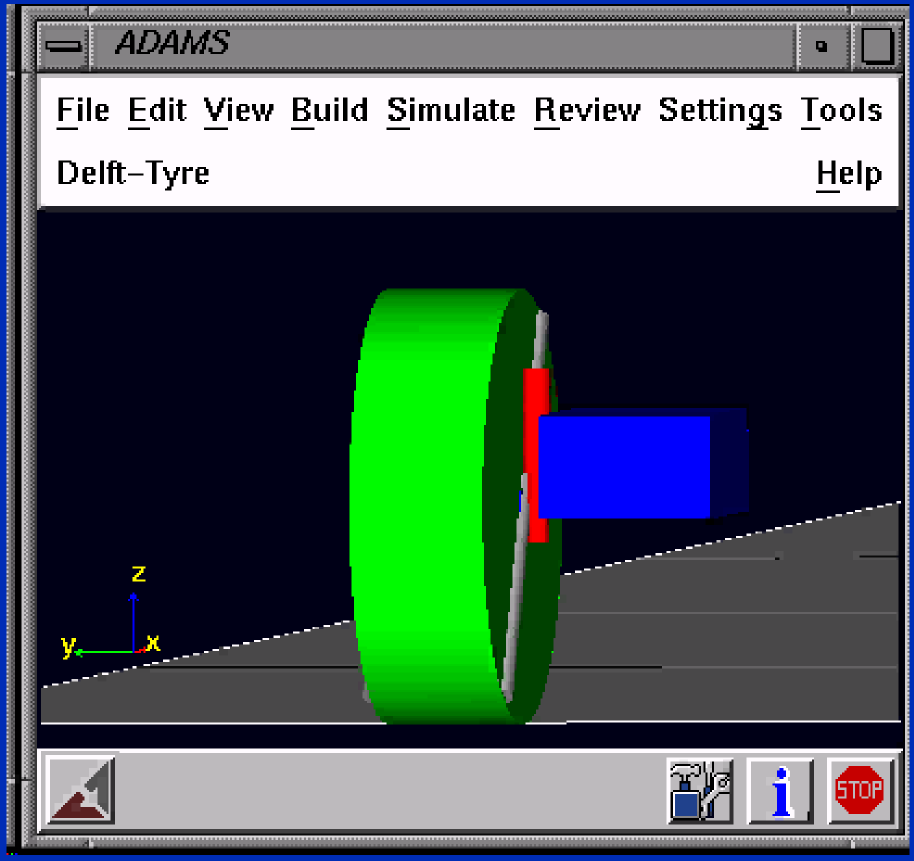
New Standard Tyre Interface:

- More than 2 states possible
- At least 2 x faster
  (benchmark with MF-Tyre)
- More flexible
- GUI allows change of tyre
  and road parameters



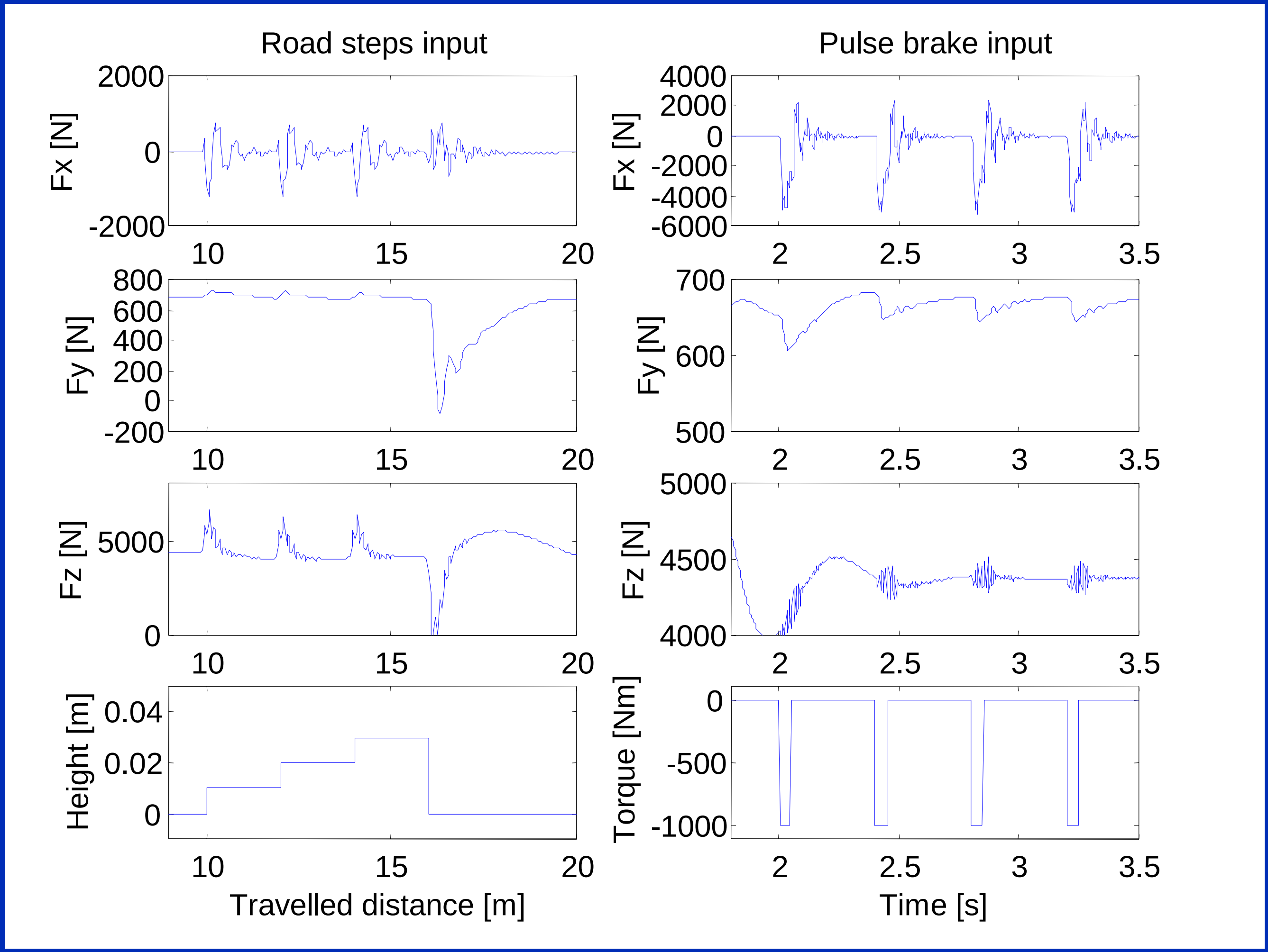
SWIFT in ADAMS
example

- Quarter vehicle model
- Tyre rolling over cleats with 6° slip angle
- ABS-pulse braking
- Vertical load variations during cornering
- Interaction between steering and braking forces



SWIFT in ADAMS

example



Delft-Tyre

ABS simulation

comparison of tyre models

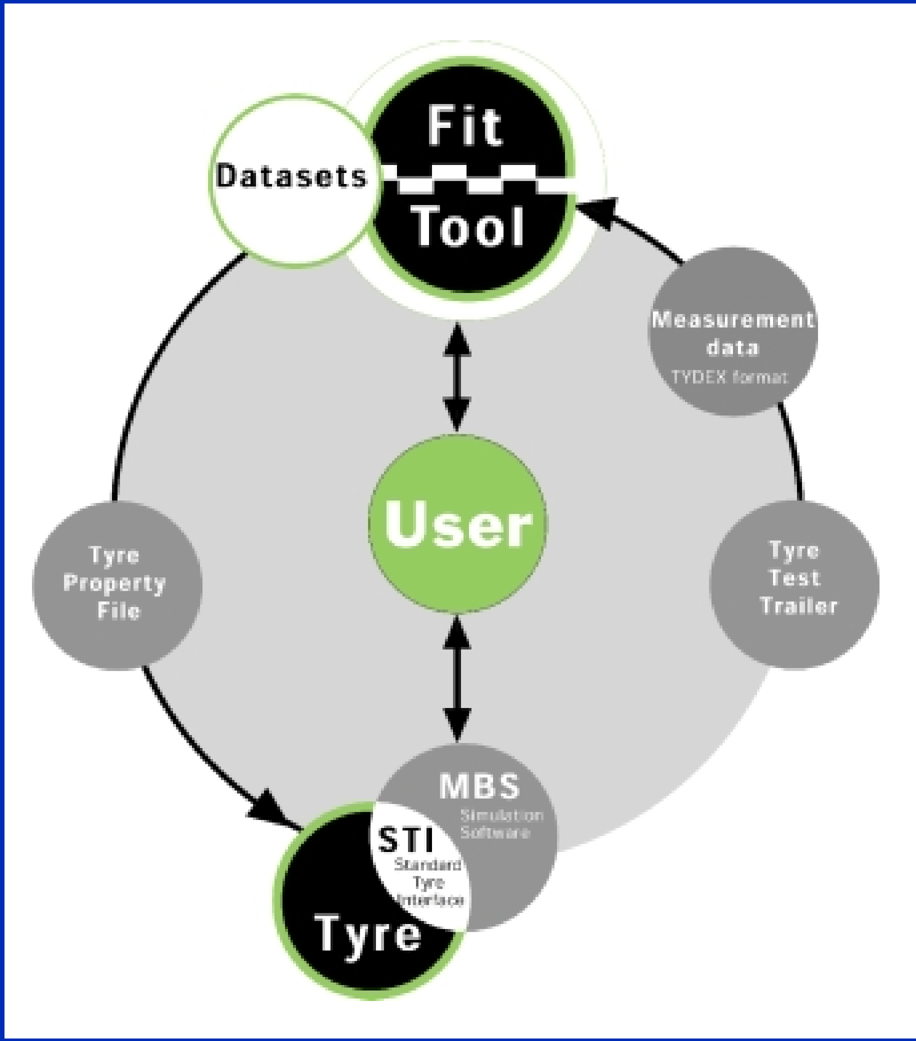
Availability

Now:

- SWIFT-Tyre
- SWIFT-Datasets

First half 2000:

- SWIFT-Tool
- SWIFT-Fit



Concluding...

- SWIFT is next step in DELFT-TYRE modelling
- robust, fast and accurate tyre modelling for ride and advanced chassis control applications
- validated with advanced dynamic tyre testing
- parameter assessment under realistic driving conditions
- allows ‘state of the art’ tyre modelling by any ADAMS user