

*Jan van Oosten*

# **SWIFT-Tyre in SIMPACK: for comfort, ride, durability and chassis control analysis**

**TNO Automotive**



# Contents

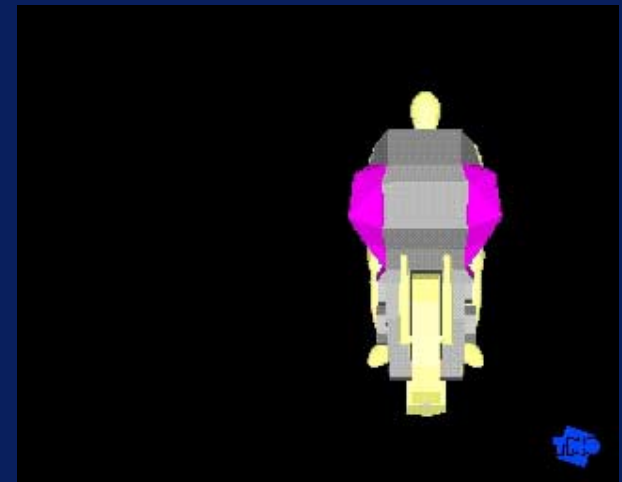
- INTEC - TNO co-operation
- From Magic Formula modelling to comfort, ride, chassis control and durability
- SWIFT-Tyre concept and validation with test data
- Application examples
- SWIFT parameter sets
- SWIFT-Tyre in SIMPACK
- Concluding

# INTEC - TNO co-operation

INTEC is reseller of DELFT-TYRE models

Current available models in SIMPACK:

- **MF-Tyre**
  - Standard MF model for all basic handling simulations
  - $\pm 10$  deg camber
  - up to 8 Hz
  - long road wavelength undulations ( $> 1.5$  m)
- **MF-MCTyre**
  - similar to MF-Tyre
  - all basic motorcycle handling simulations
  - up to 60 deg camber
  - applicable for vehicle roll-over



# From handling to ride, chassis control,..

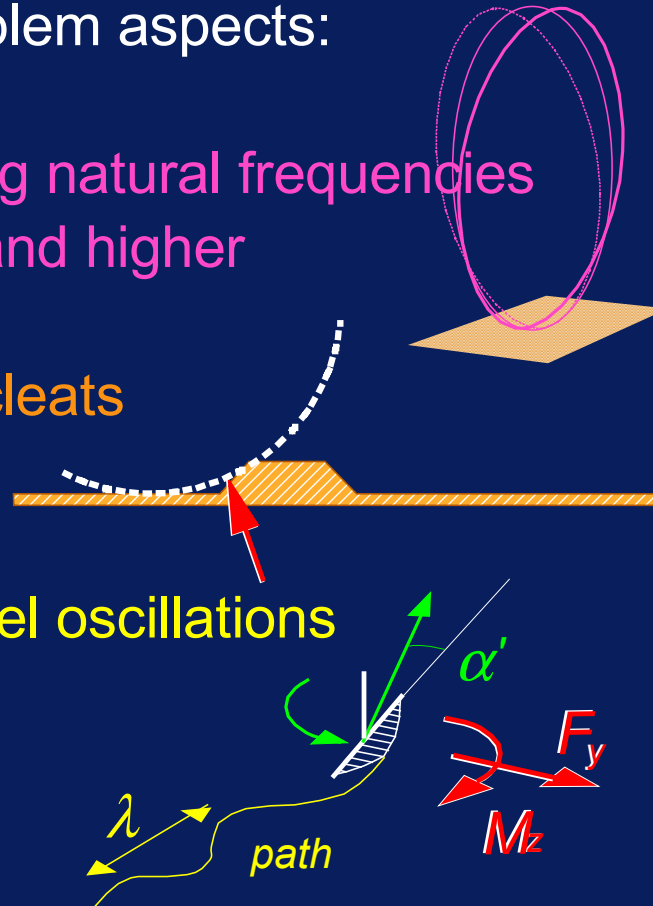
Extending to higher frequencies and shorter obstacles

we have three main problem aspects:

- belt dynamics involving natural frequencies of ca. 30, 50, 70 Hz and higher

- road unevennesses: cleats

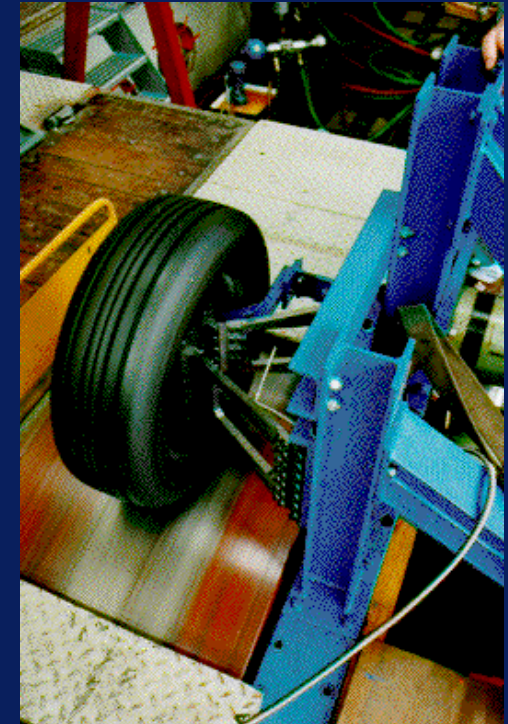
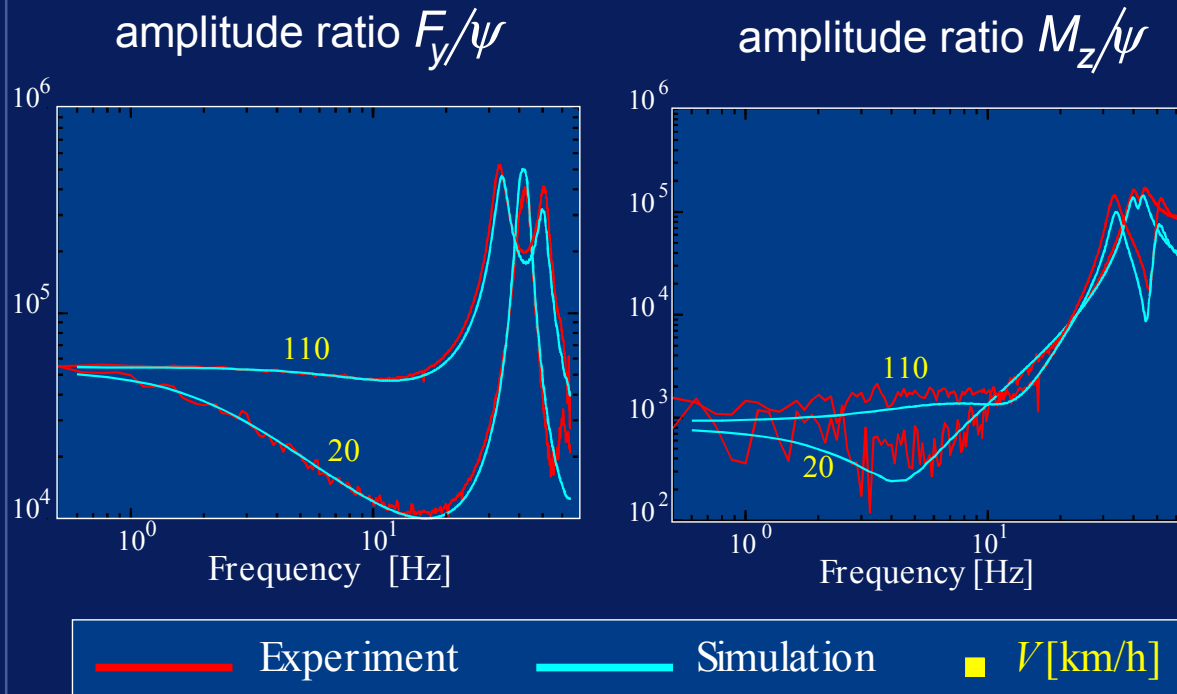
- short wavelength wheel oscillations





# Tyre belt natural frequencies

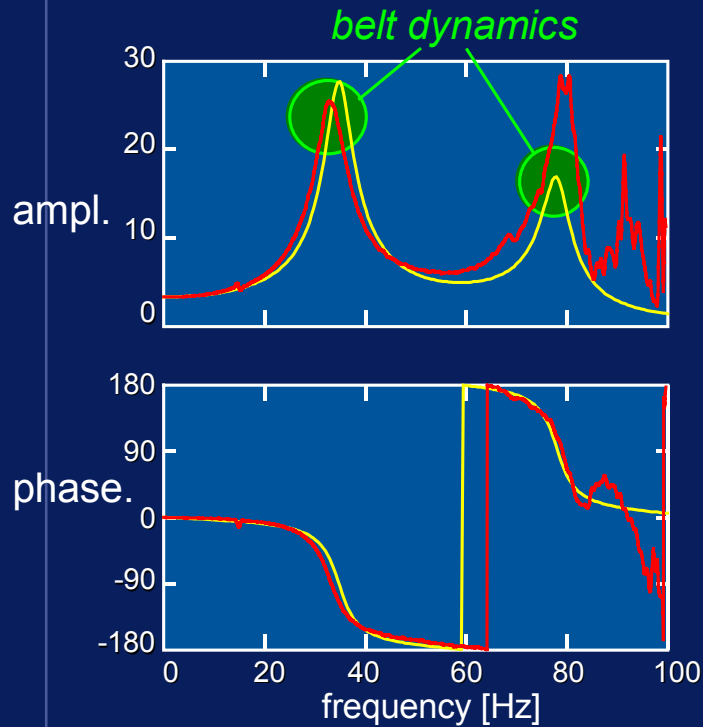
Lateral: Yaw oscillation test



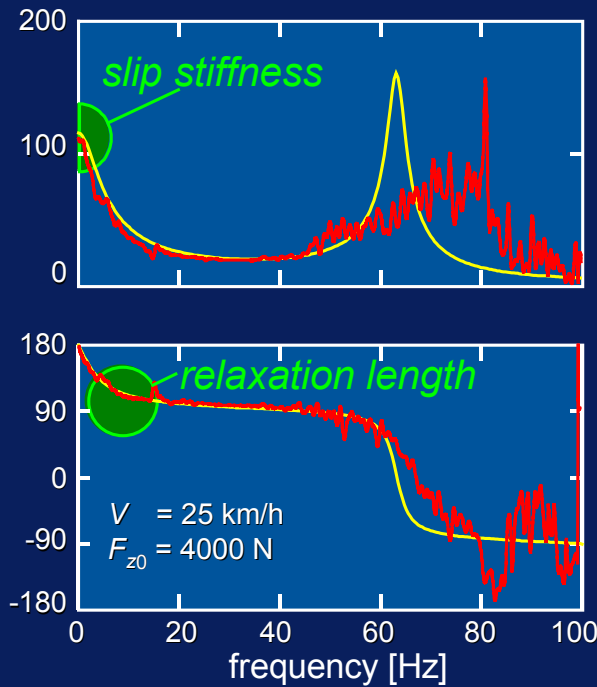
# Tyre belt natural frequencies

Rotational: Dynamic braking test

longitudinal force to brake torque



longitudinal force to wheel slip

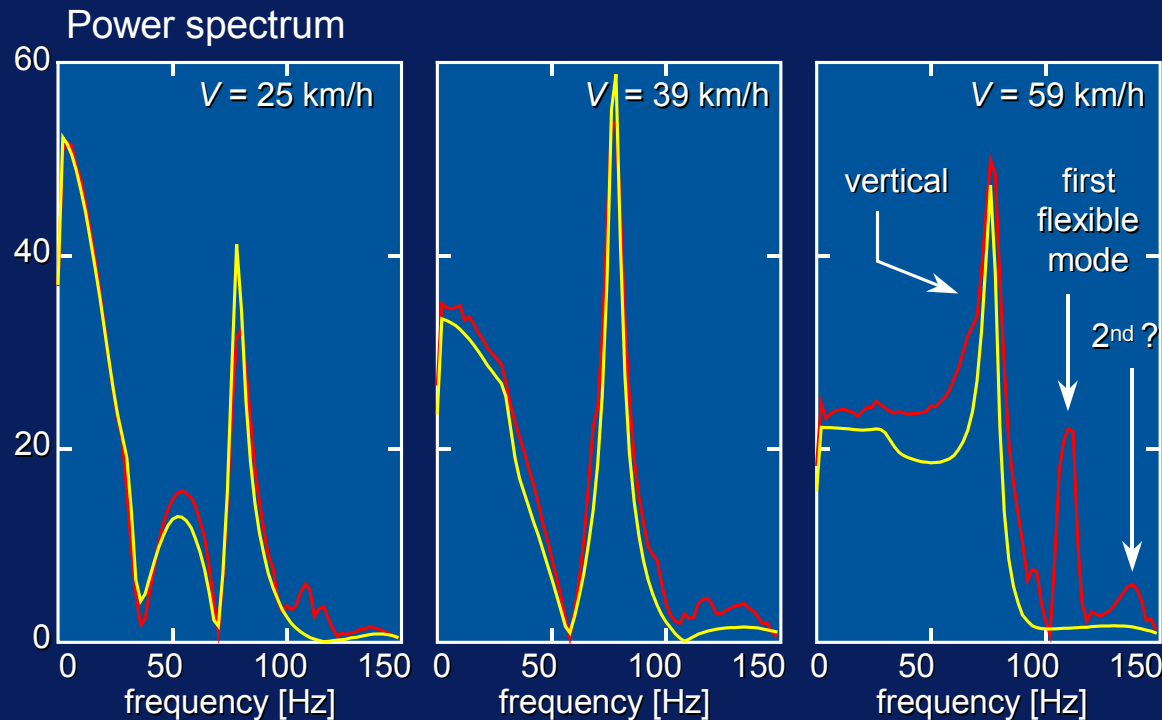


— measurement — simulation

# Tyre belt natural frequencies

Vertical: Cleat excitation

Vertical force  
free rolling



— measurement — simulation

# Tyre enveloping

Rolling over cleats

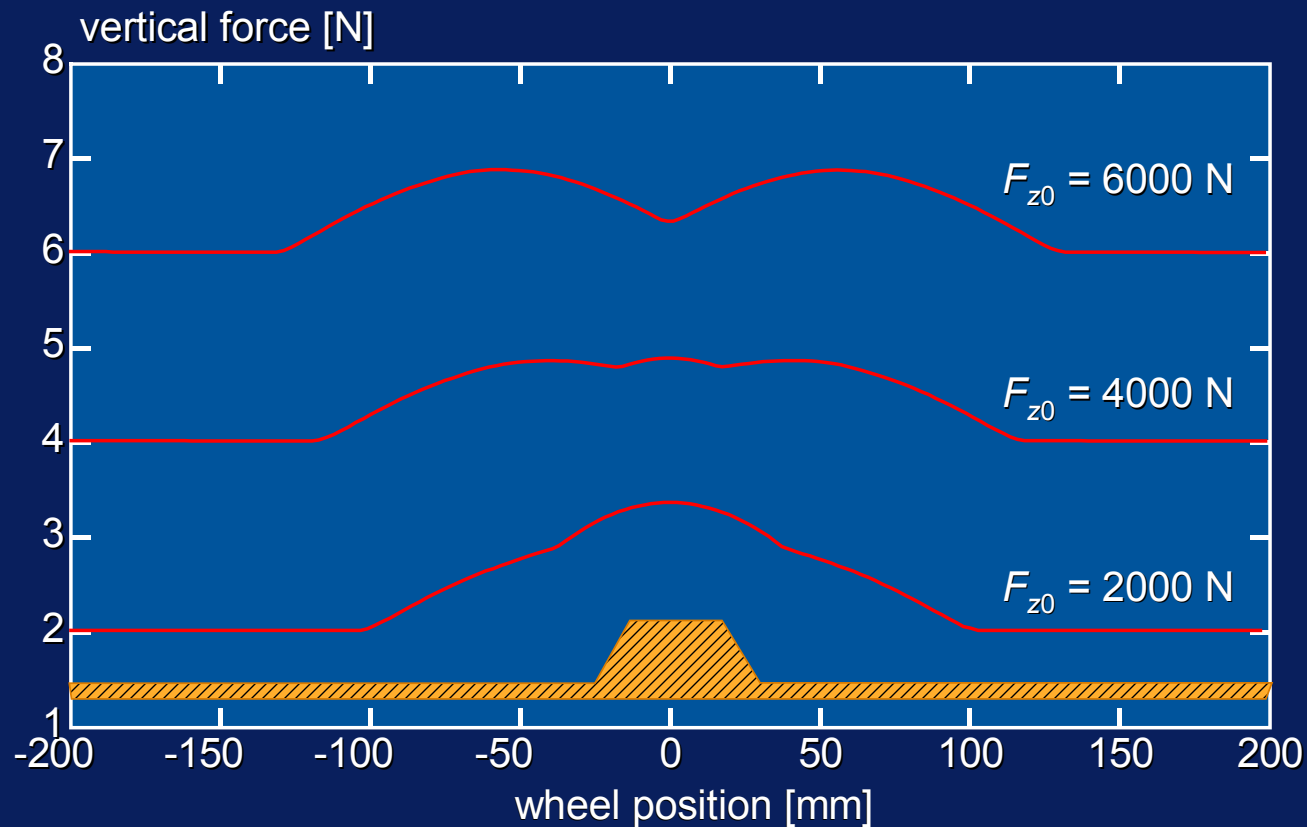
Flat plank, slow rolling to avoid inertia effects



# Tyre enveloping

Rolling over cleats

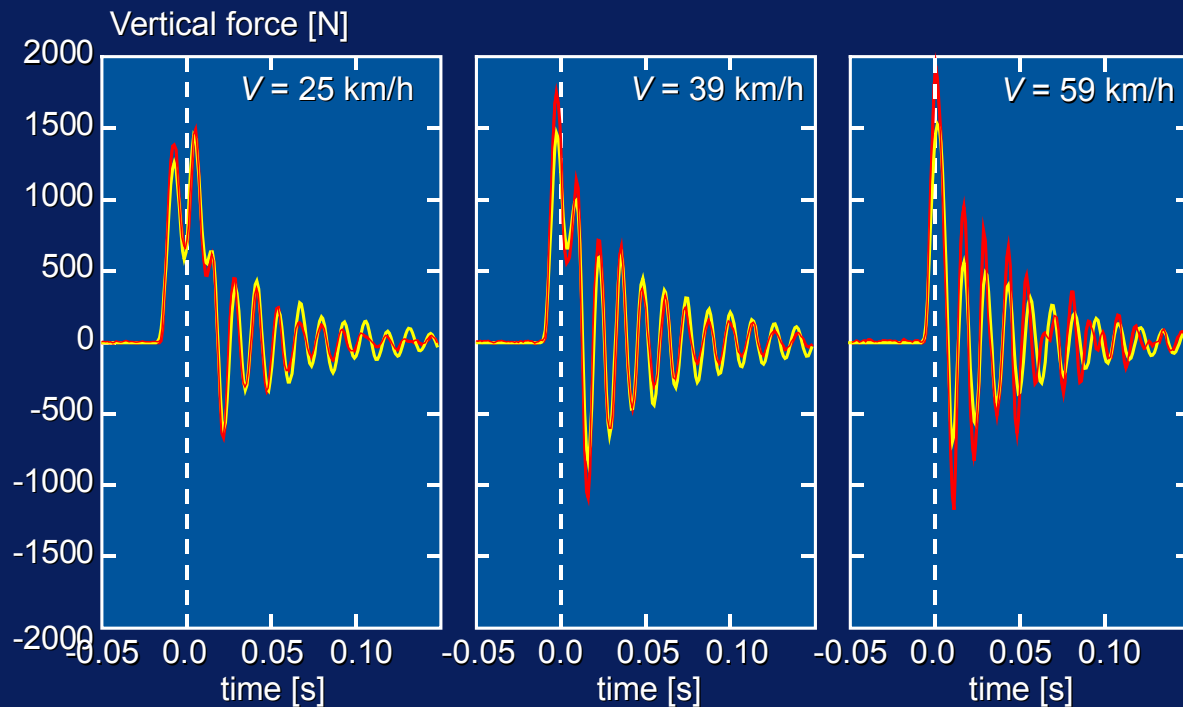
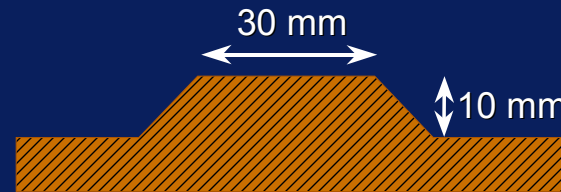
## Vertical force



# SWIFT compared to test data

## free rolling over cleat

Vertical force  
free rolling, trapezoid cleat



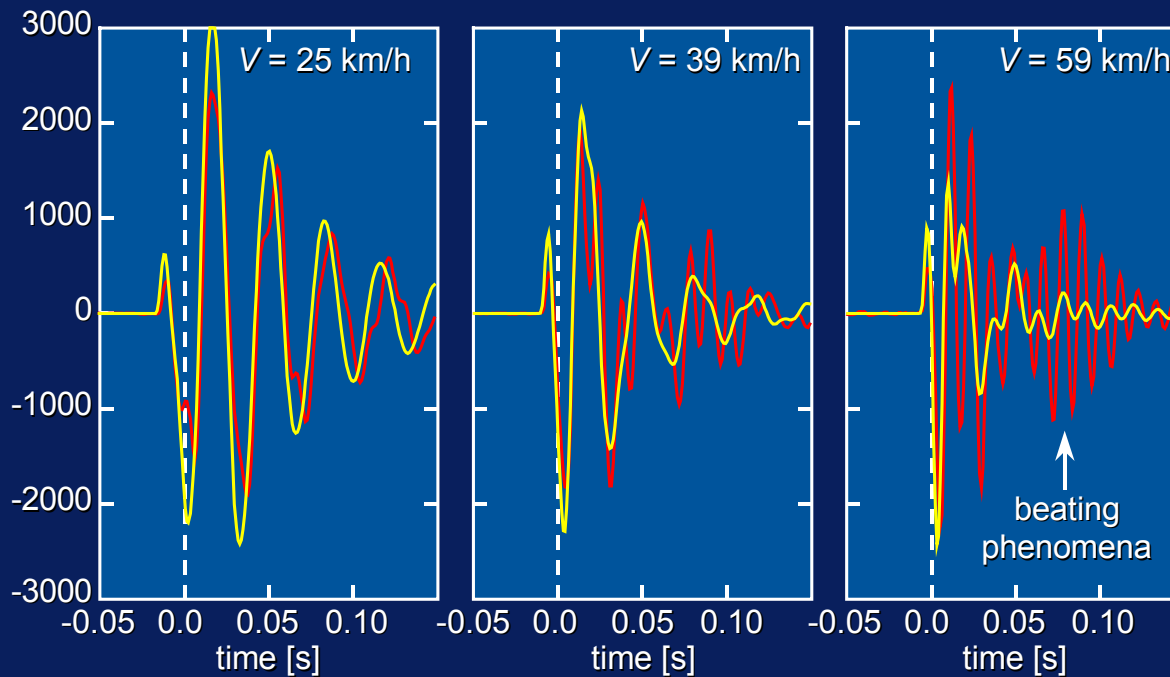
— measurement — simulation

# SWIFT compared to test data

free rolling over cleat

Longitudinal force

free rolling



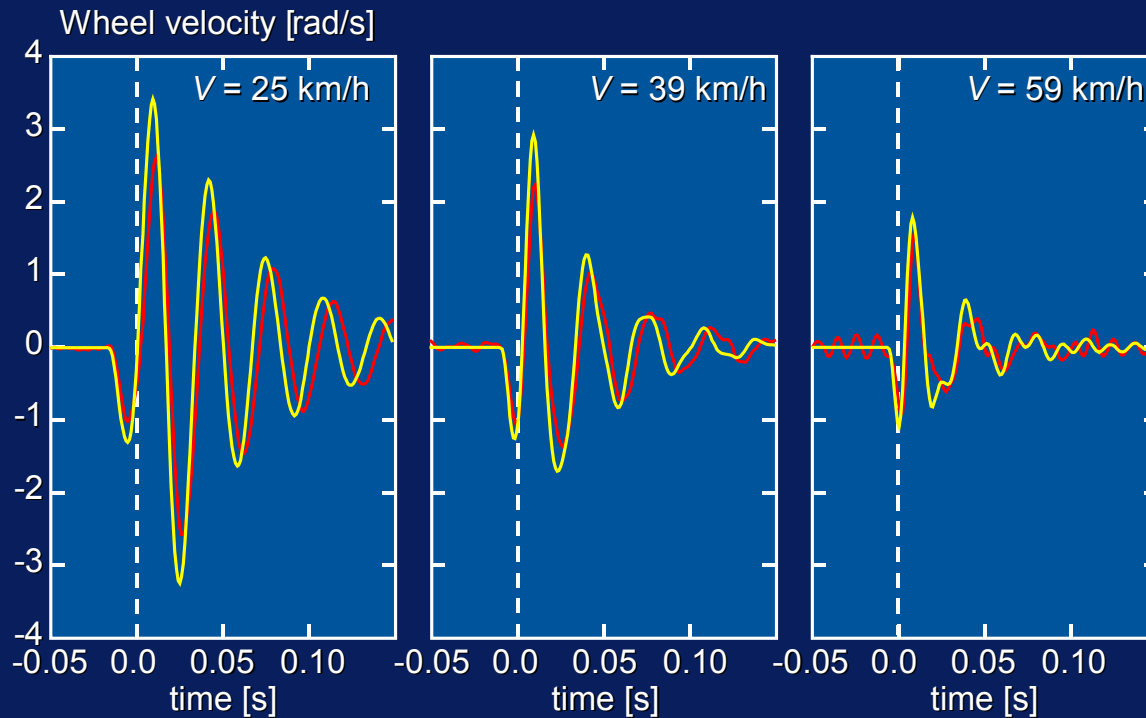
— measurement — simulation

# SWIFT compared to test data

free rolling over cleat

Rotational rim velocity

free rolling

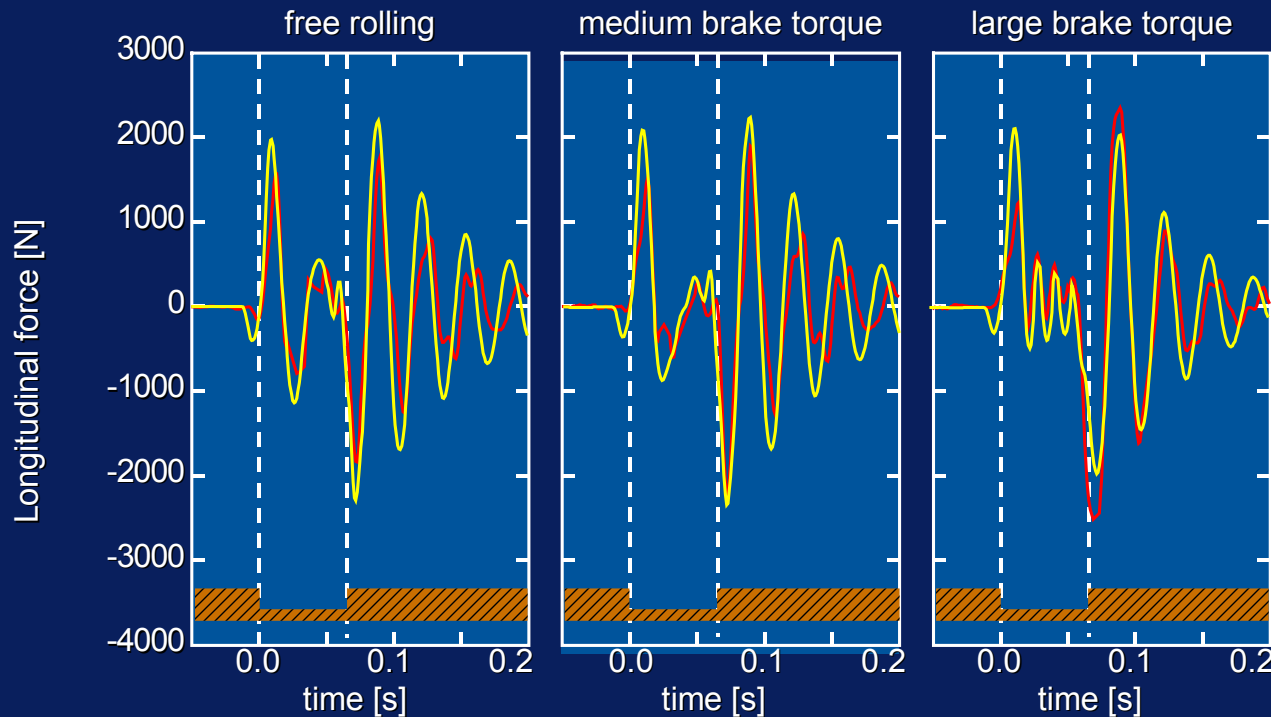


— measurement — simulation

# SWIFT compared to test data

rolling over pot hole during braking

Longitudinal force  
influence of brake torque



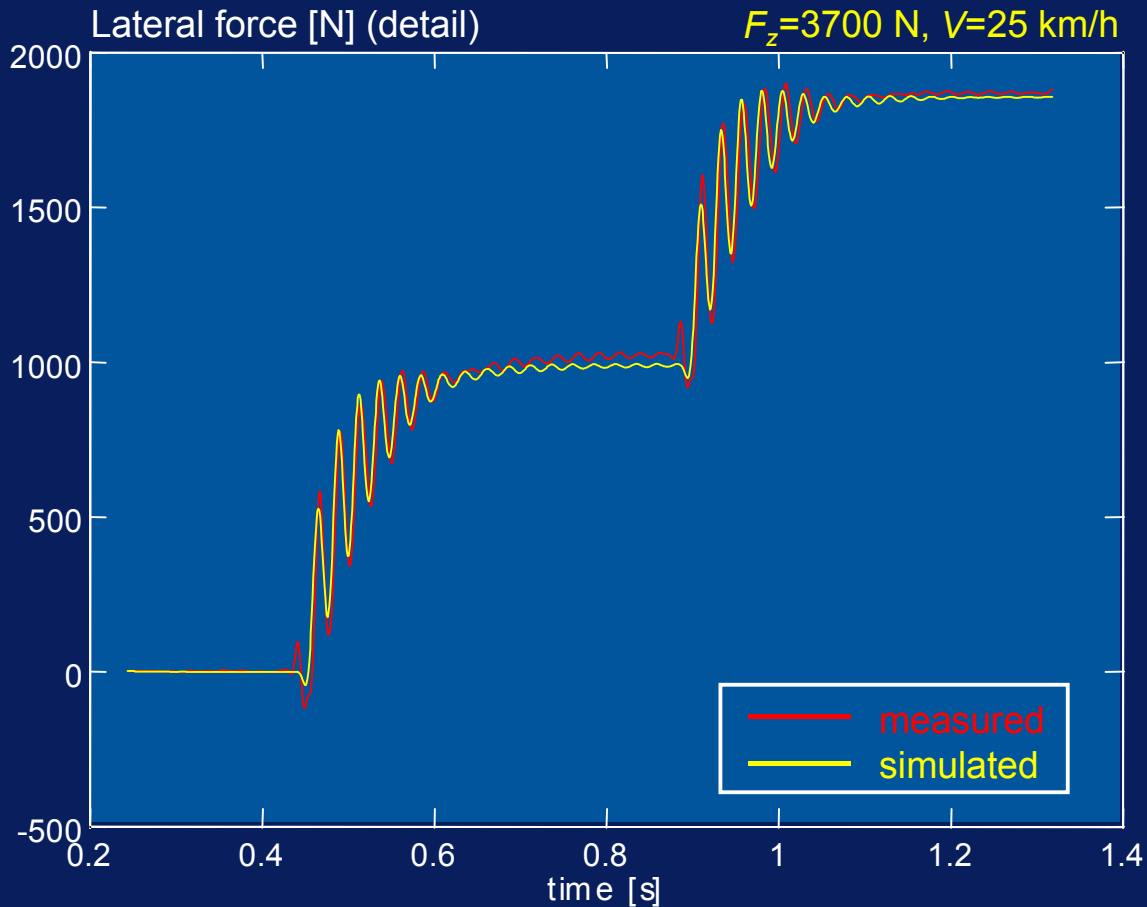
V = 25 km/h

— measurement — simulation



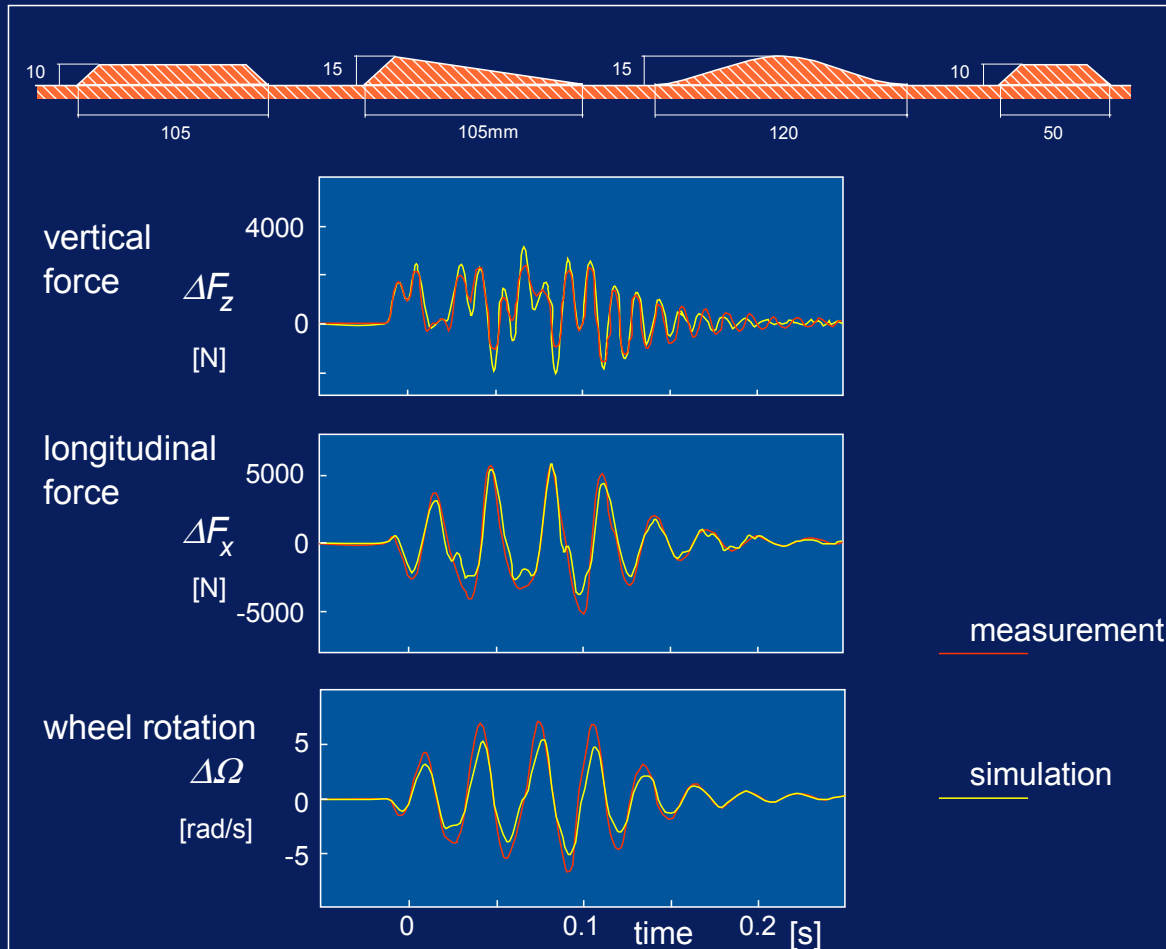
# SWIFT compared to test data

## step slip angle input



# SWIFT compared to test data

## free rolling over a sequence of cleats

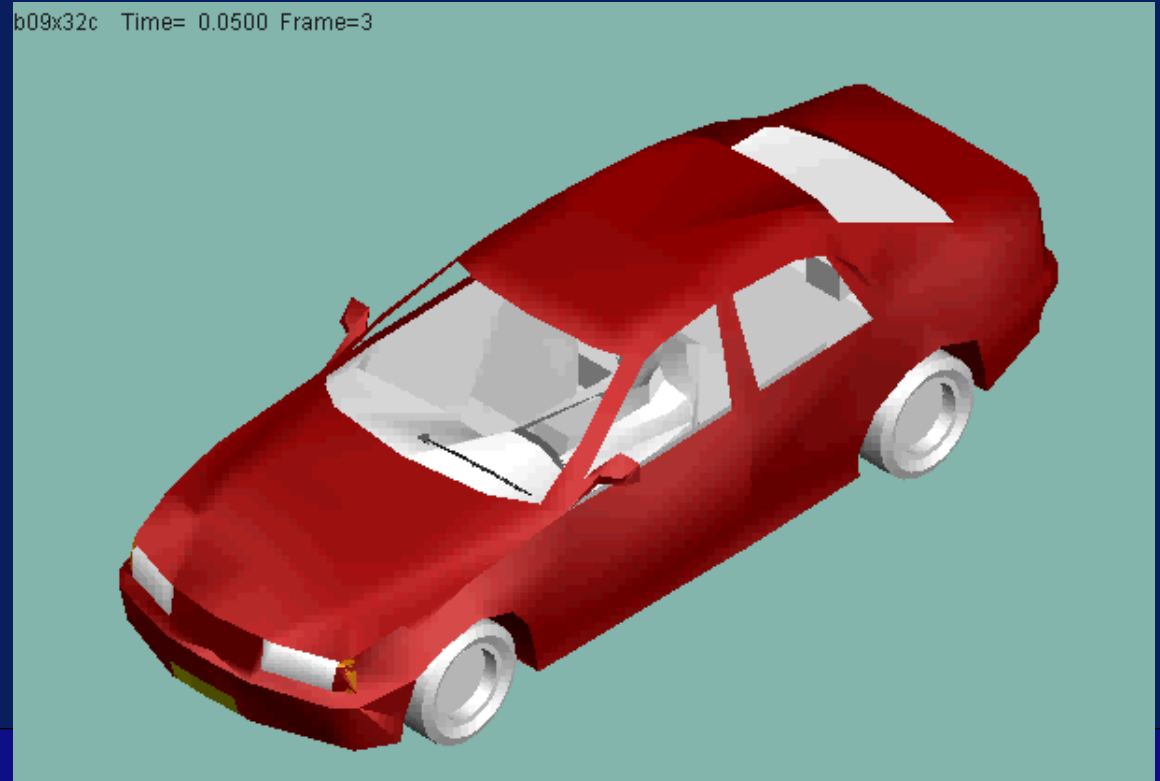


# SWIFT compared to test data

full vehicle over uneven road

Validation by a SWIFT user:

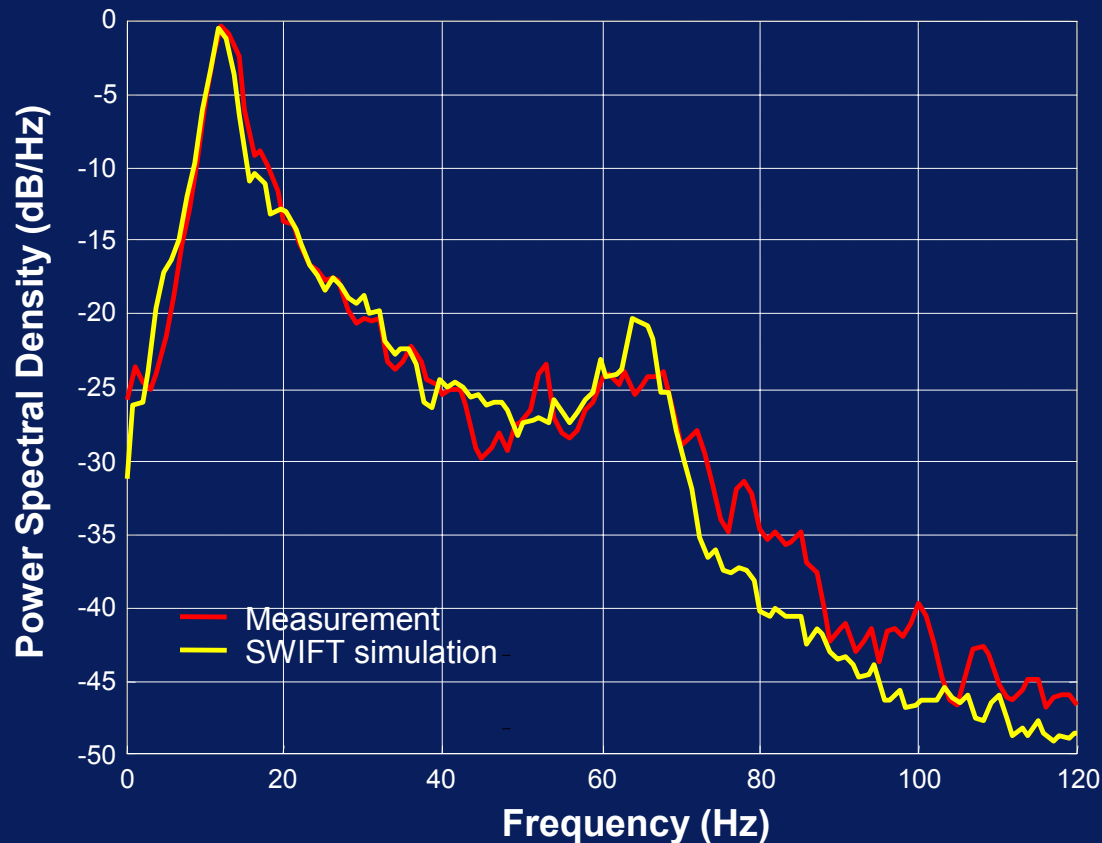
- Driving over uneven road at 55 mph
- Test vehicle vs. full vehicle model
- vertical axle accelerations



# SWIFT compared to test data

full vehicle over uneven road

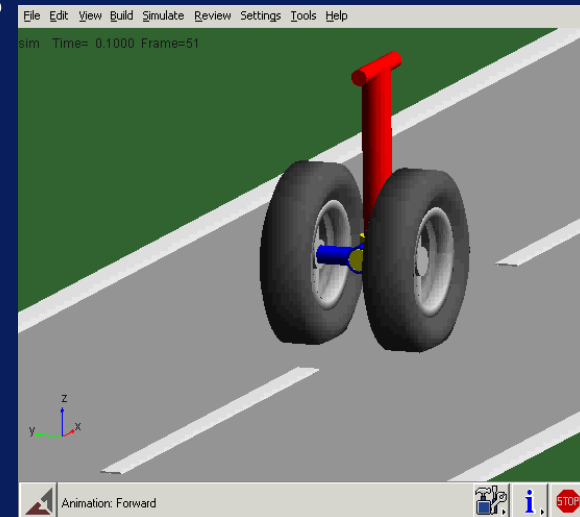
Vertical axle acceleration model vs. test vehicle data



# Applications of SWIFT-Tyre

- Comfort & Ride, also linearisation and frequency domain calculations are supported
- 4 post rig ride testing
- Chassis control systems (ABS, ESP, VDC, ..)
- Combined dynamic braking, cornering and ride
- Steering system and braking vibrations
- Drive line vibrations
- Shimmy analysis
- Calculation of durability load cases
- ..

**Note:** Basic handling similar to MF-Tyre  
For all kinds of tyres



# SWIFT-Datasets

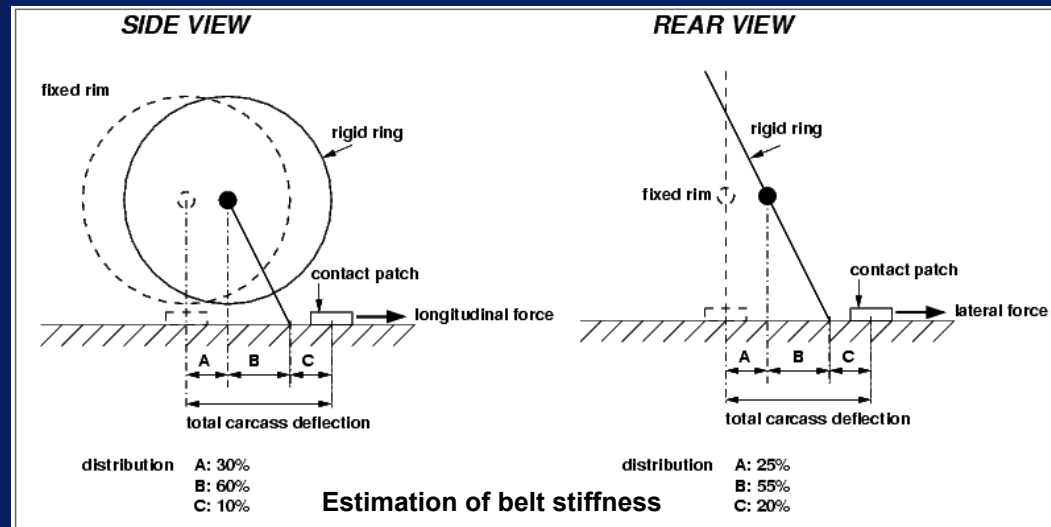
- **SWIFT-Dataset Library**
- **Full estimation of a specific tyre**
  - fast and low cost
  - based upon experience
  - only basic tyre property data required
- **Testing of a specific tyre**
  - Basic steady state tyre testing (MF testing)
  - Loaded and effective rolling radius testing
  - Cleat testing at low speed (Tyre enveloping)
  - Cleat testing at moderate speeds (Tyre belt natural frequencies)
- **Estimation and test protocol free available**
- **Supported by tyre manufacturers**

# SWIFT-Datasets

## Estimation method

### Required data:

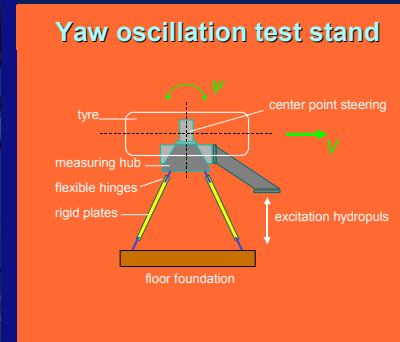
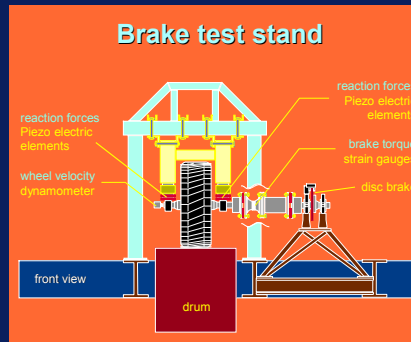
- Unloaded tyre radius
- Tyre mass and inertia
- Nominal tyre load
- Lateral relaxation length or non-rolling lateral stiffness
- Longitudinal relaxation length or non-rolling longitudinal stiffness
- Slip or Cornering stiffness
- Tyre F&M data, or MF-coefficients



# SWIFT-Datasets

## Testing

- Only conventional test equipment required
- Data processing supported by SWIFT-Tool+
- TNO co-operates with tyre manufacturers for 'in-house' SWIFT testing
- TNO can support with test facilities



# SWIFT-Datasets

## Tyre Data Requirements (IAVSD tyre model benchmark, draft)

	Loads	Speed	Other conditions	SWIFT-Tyre	F-Tire	RMOD-K	CD-TIRE
<b>Geometry and Material information</b>							
Size tyre and rim				x	x	x	x
Free tyre radius				x			
Tyre mass				x	x	x	x
Polar tyre moment of inertia				x			
Diametrical moment of inertia				x			
Tread height					x	x	x
Tread width					x	x	x
Tread modulus/ShA					x	x	x
Tread stiffness ratio longitudinal/lateral						x	x
Tread friction					x	x	x
Belt width, radius, angle & cross section						x	x
Belt cord stiffness						x	x
Tread and belt mass						x	x
<b>Stationary test data</b>							
Non-rolling tyre							
Vertical stiffness on flat surface	0 - 1.3 x Fz ETRTO			x	x	x	x
Longitudinal stiffness on flat surface	0.5, 0.8, 1.1 x Fz ETRTO			x	x		x
Lateral stiffness on flat surface	0.5, 0.8, 1.1 x Fz ETRTO			x	x		x
Footprint (paper copy)	0.5, 0.8, 1.1 x Fz ETRTO			x	x	x	x
Vertical stiffness on cleat			20x20mm		x		
Rolling tyre							
Rolling at various speeds (loaded radius testing)	0.5, 0.8, 1.1 x Fz ETRTO	20, 60, 100 km/h		x	x		
Steady state F&M testing lateral (MF testing)			TIME test procedure	x	x	x	x
Steady state F&M testing longitudinal (MF testing)	0.5, 0.8, 1.1 x Fz ETRTO		>40% slip	x	optional	x	x
<b>Dynamic test data</b>							
Modal Analysis							
Eigenfrequencies			0 - 300 Hz, not loaded, fixed rim		x	x	x
Modal damping			0 - 300 Hz, not loaded, fixed rim		x	x	x
Modal shapes			0 - 300 Hz, not loaded, fixed rim		x	x	x
Cleat testing							
rectangular cleat 90 deg with wheel plane	0.5, 0.8, 1.1 x Fz ETRTO	< 5, 30, 60 km/h	fixed axle height, 5x20mm, 10x20mm	x	x	x	x

 Often confidential data

# SWIFT-Tool+

Supports efficient tyre data exchange between tyre and vehicle manufacturers and automotive suppliers.

In addition to MF-Tool+ functionality:

- **estimation method**  
**SWIFT-Datasets on basic tyre properties**
- **fitting of test data from cleat testing**
  - low speed testing (tyre enveloping)
  - moderate speed testing (tyre belt stiffness and damping rates)
- **supports mixed partly estimation and partly testing**
- **visualisation of tyre dynamic and enveloping properties**

# SWIFT-Tyre in SIMPACK

- <to put the avi of bmw in simpack>

# Concluding

## SWIFT-Tyre:

- **SWIFT-Tyre is available in SIMPACK**
- **is an upgrade of MF-Tyre**
- **can handle tyre 3D behaviour up to 60 Hz, vertical up to 100 Hz, driving over any obstacle/uneven road**
- **required effort for SWIFT-Datasets is low:**
  - library
  - estimation
  - testing
- **process from data/estimation to Datasets supported by SWIFT-Tool+**
- **support of tyre manufacturers**