

# Dynamical Simulation of Gear Shift Processes in BMW Motorcycle Gear Boxes.

Roland Zettler, BMW Group

Matthias Anders,  
Bastian Bredl,

Petar Baruncic



BMW Motorrad

SIMPACK  
User Meeting

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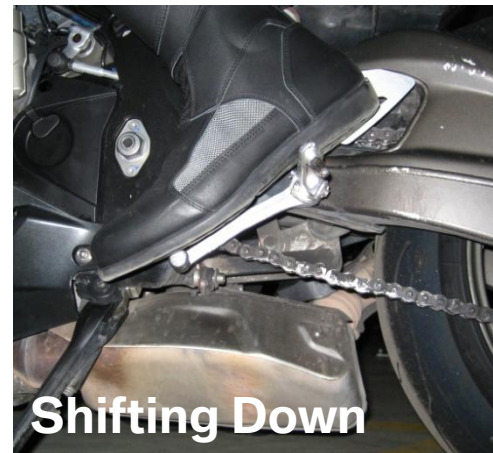
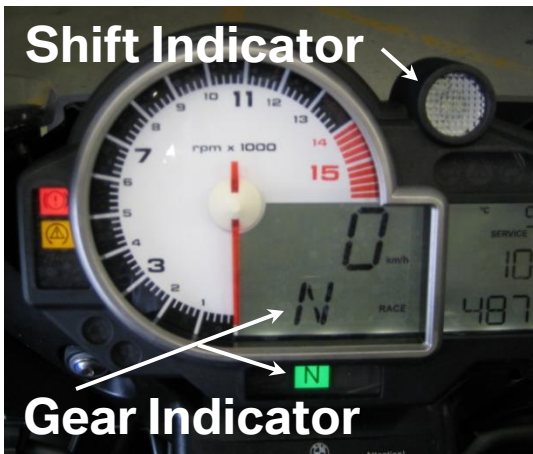
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- 2005: Development of Force Element 67 by Dr. Nussbaumer, Dr. Bencker (BMW Group) and SIMPACK
- Adaption of Force Element 67 for Motorcycle Gear Boxes
- Shifting Process Simulation & Postprocessing
- Gear Box & Drivetrain Modelling
- Randomization and Parameter Variation
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- Summary / Outlook

# Motorcycle Shifting Process. Basics.



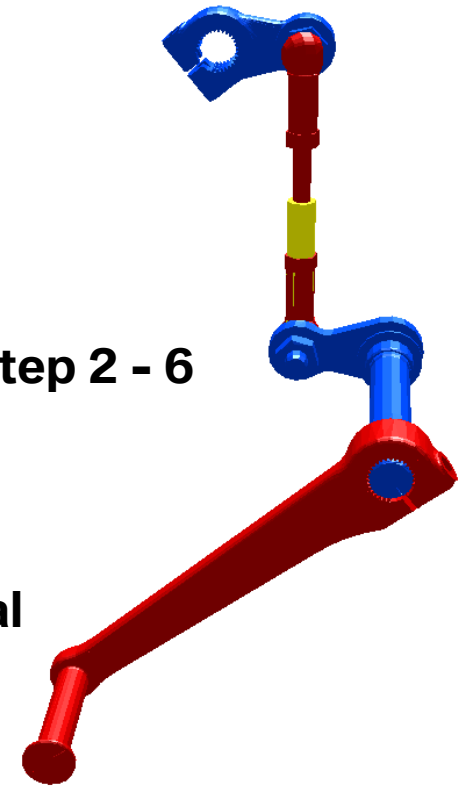
Gear step 2 - 6



Neutral  
(N)



Gear step 1



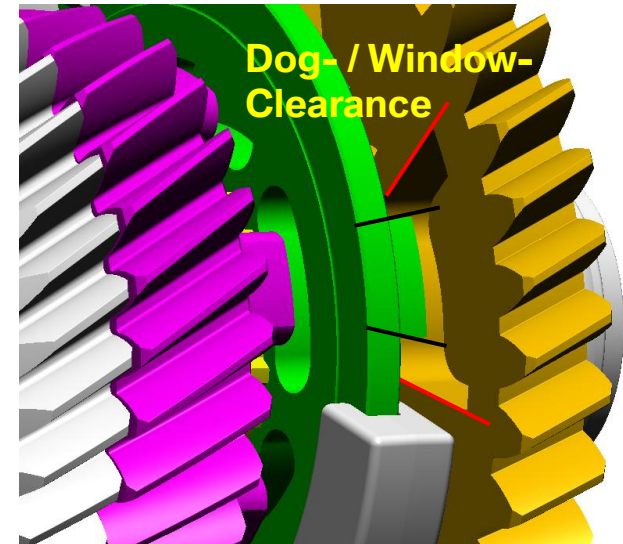
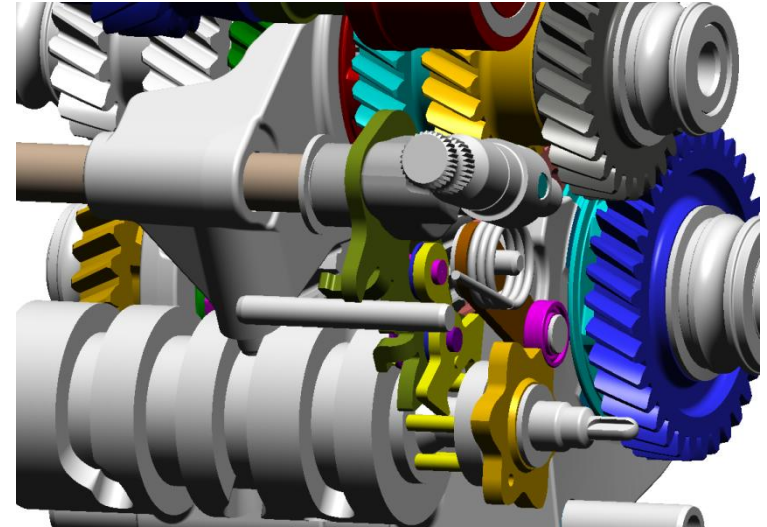
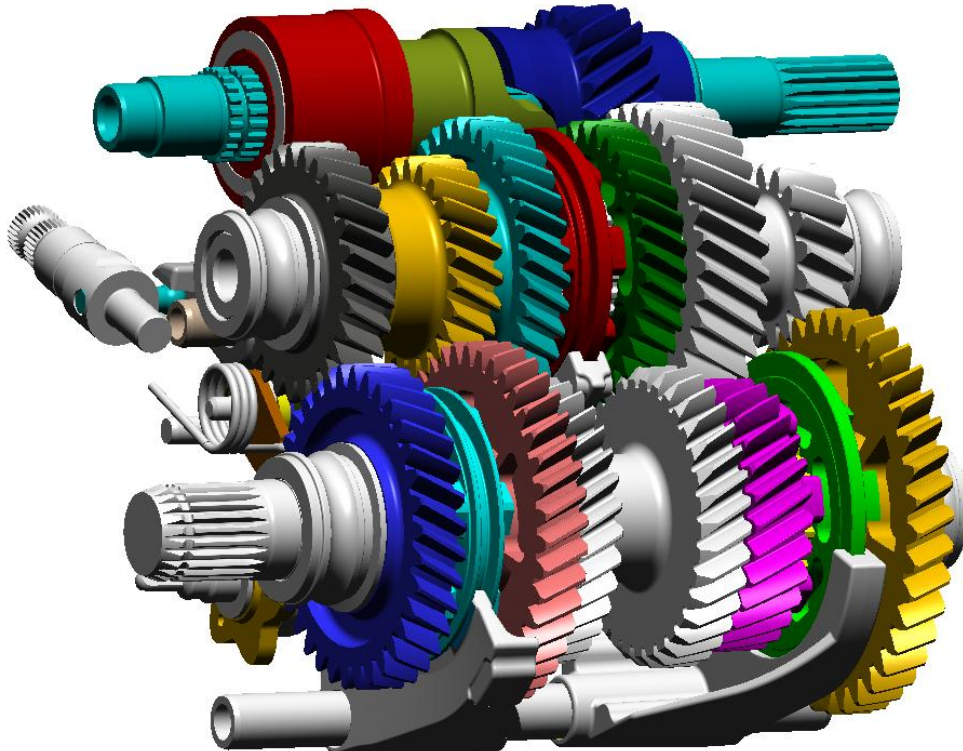
- **Neutral** between 1st and 2nd gear
- **Sequentially** shifting only
- Power shifting possible (shifting w/o clutch; **shifting assistant** w. engine control intervention)
- Gradual increase of **CVT**, **dual clutch** and **automated shifting** market shares

# Motorcycle Shifting Process. Gear Box Design.



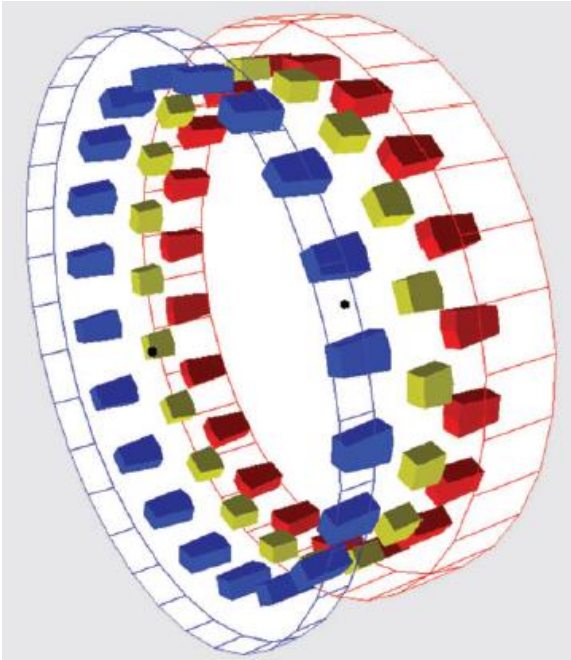
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- **straight-cut** gear wheels with **sliding gears** or
- **helical-cut** with **selector sleeve** are mainly used
- engagement is achieved by constant-mesh **dog-window** contact
- **conflict of objectives:** dog-/window clearance is crucial both for engaging and load alteration



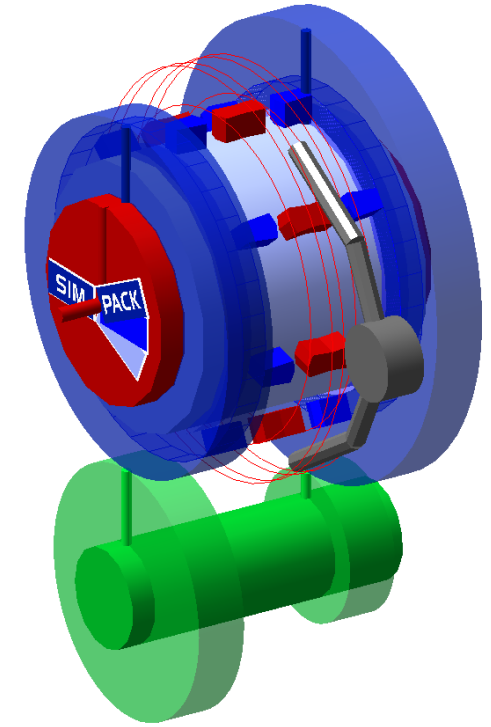
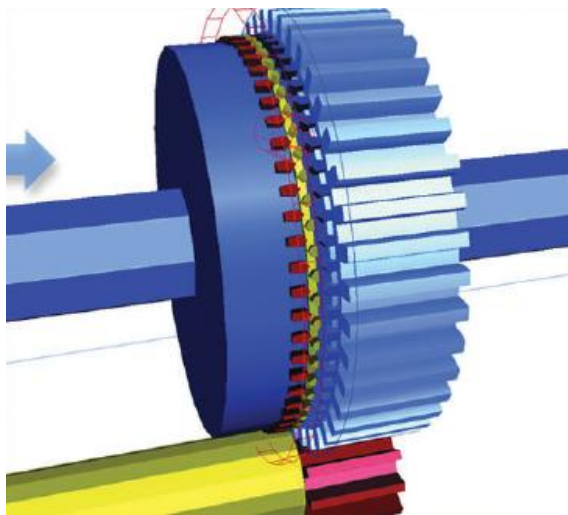
# Shifting Process Simulation.

## History of FE 67.



### SIMPACK News 07/2005

- Development of a **force element** based on a **user routine** by Dr. Nussbaumer and Dr. Bencker (BMW Group) in cooperation with SIMPACK
- FE 67 models interaction of two gears located on the same (non-elastic) axis
- Contact between the gearing can occur at different positions along the teeth
- Contact model is of analytical nature

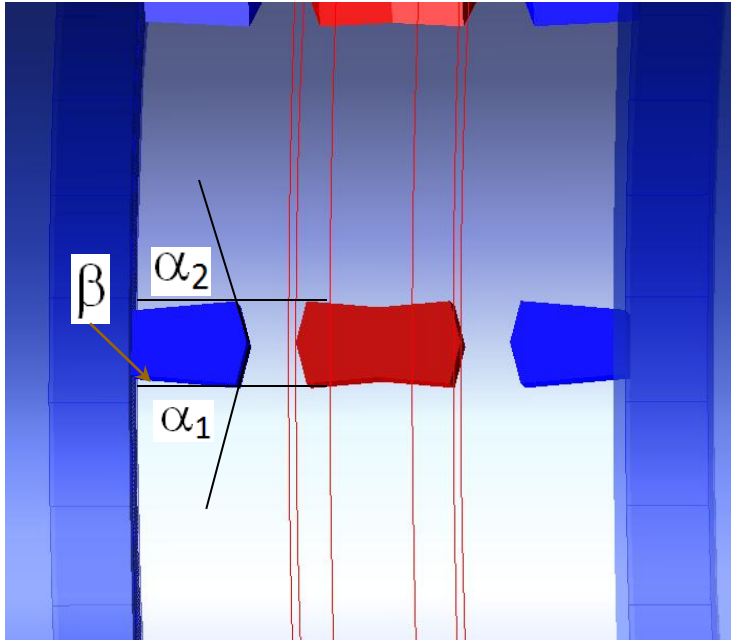


### SIMPACK Example Model

→ FE 67 available in the **Driveline Package**

# Shifting Process Simulation.

## Adaption of FE 67.



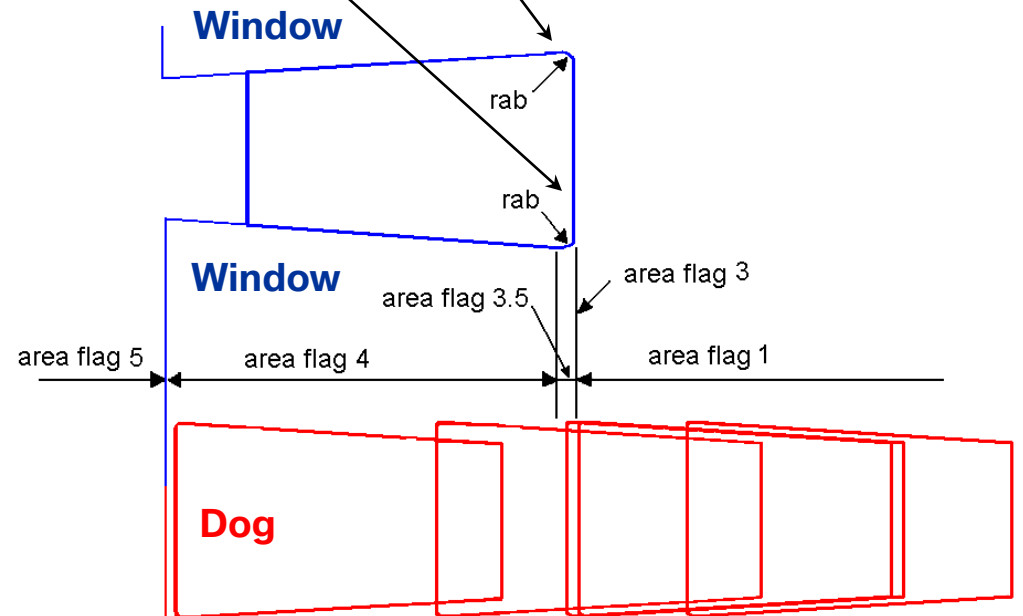
### „Classic“ Model Configuration

- number of dogs
- friction coefficient
- contact stiffness
- contact damping
- ...

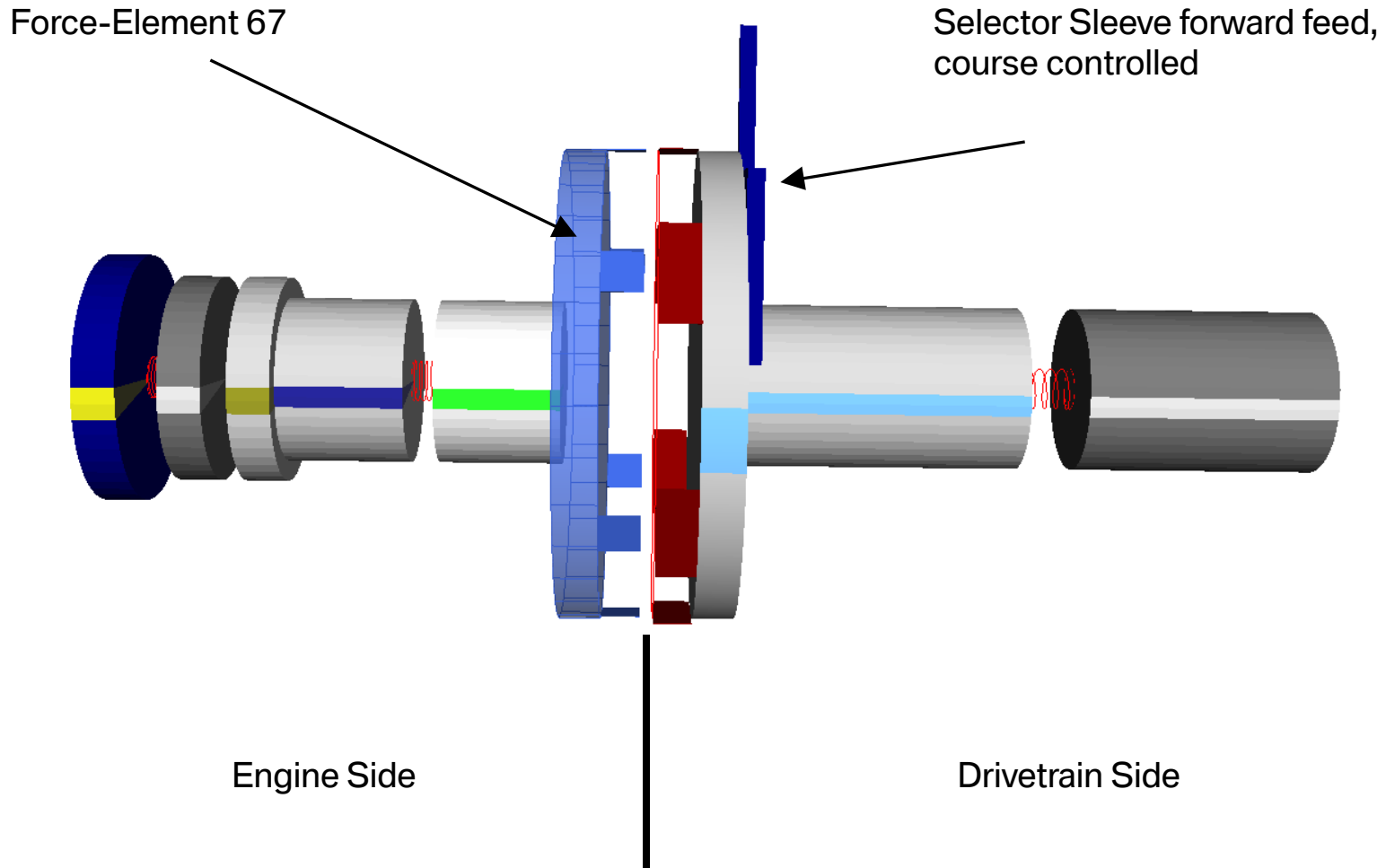
**Model Adaption**  
in order to satisfy  
constant-mesh  
dog-window gear  
wheels

Alpha-beta-plane radius  
implemented

$$\alpha_1, \alpha_2 \rightarrow 90^\circ$$



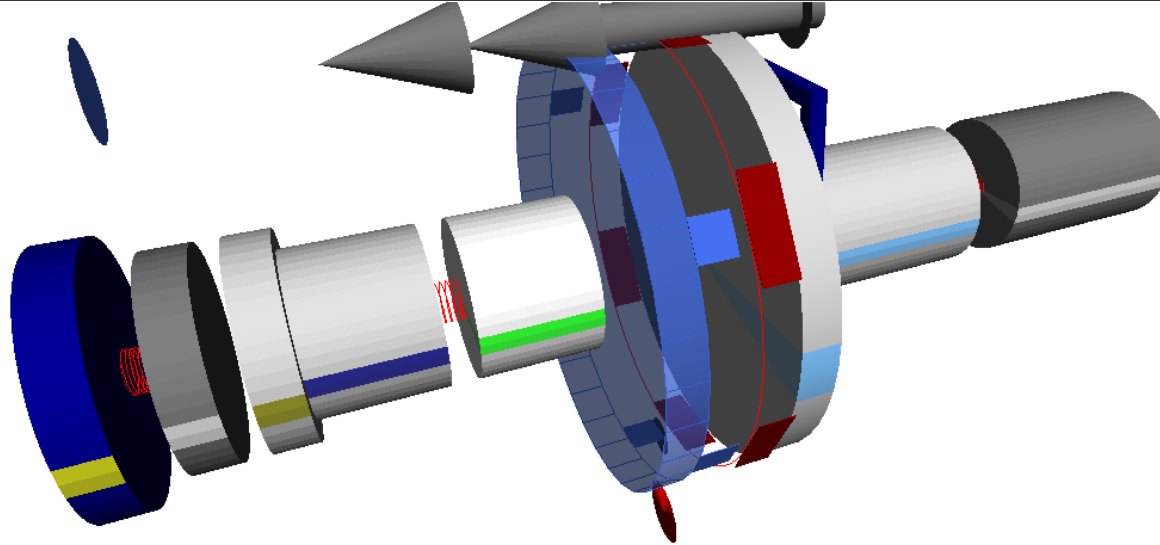
# Shifting Process Simulation. Basic Modelling.



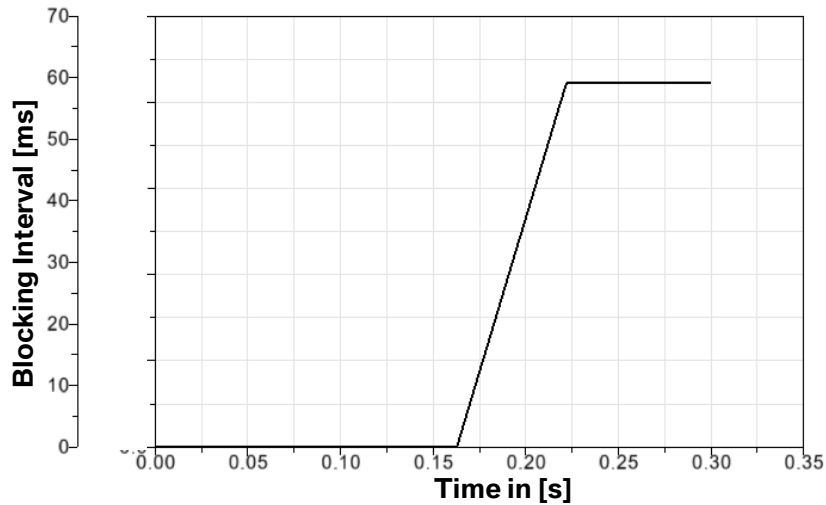
# Shifting Process Simulation.

## Postprocessing.

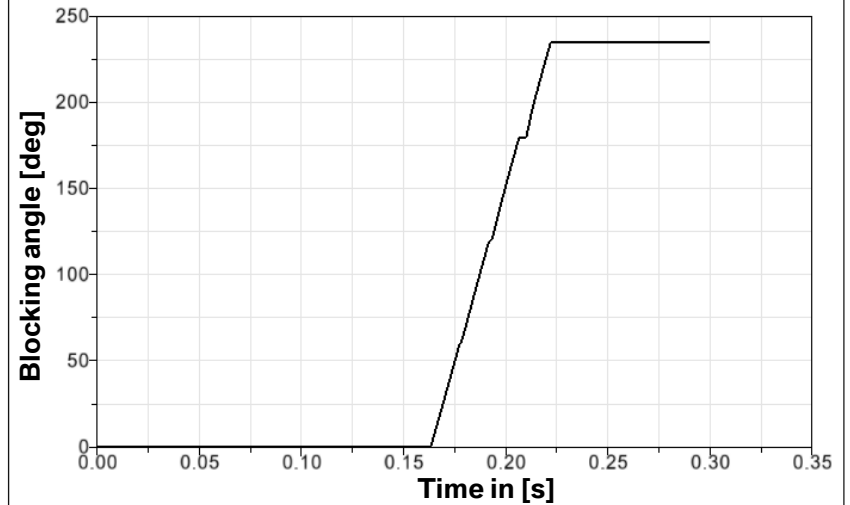
### Visualisation of blocking interval and blocking angle



### Blocking interval



### Blocking angle

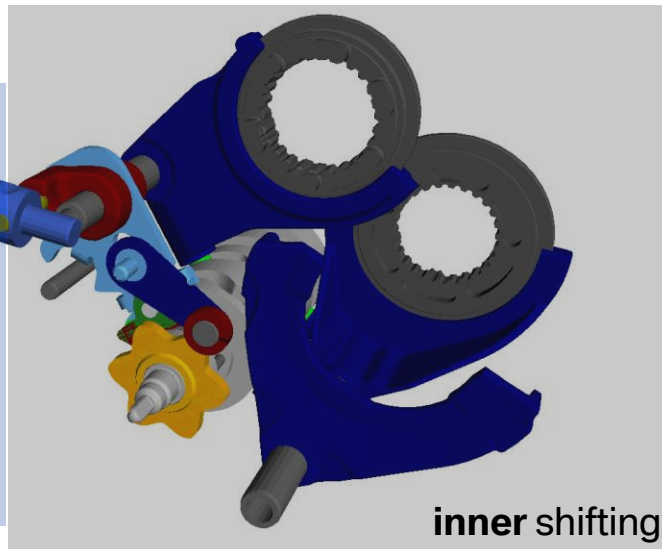
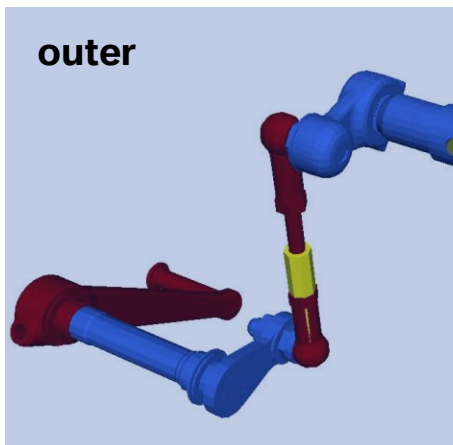
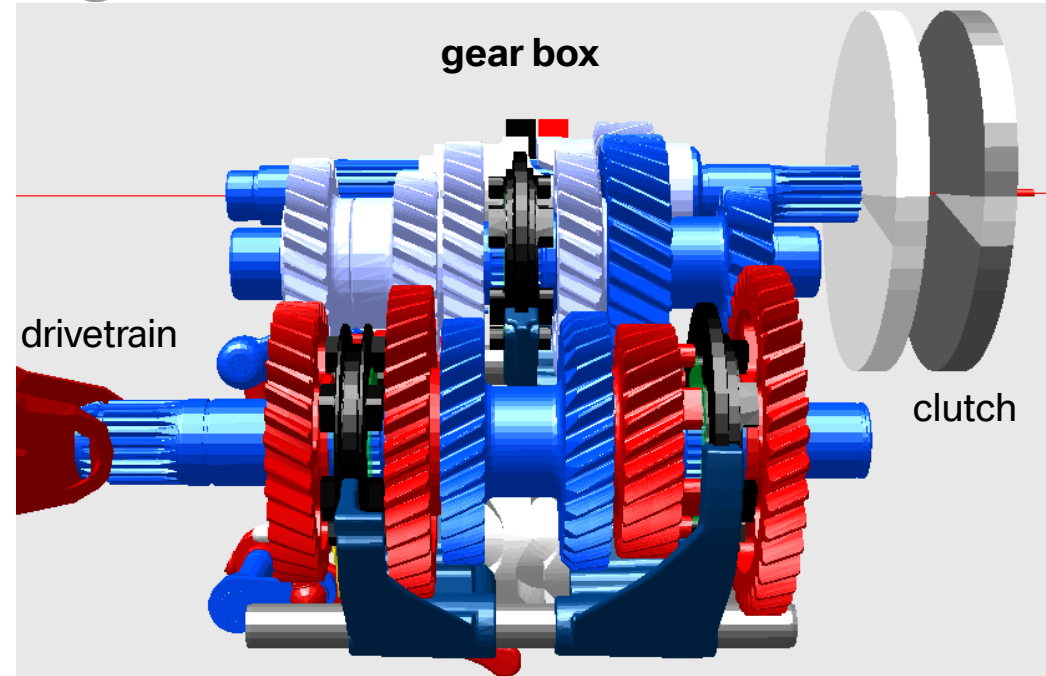


# Shifting Process Simulation.

## Gear Box Modelling.

### Gear box model

- one gear pair per substructure
- gear wheel by constraint type 14
- course-controlled selector sleeve (a.t. beginning)
- substructure coupling of gear box shifting control and shifting model (advanced models)



### Shifting model

- FE 45 curve/curve
  - shifting star, arrestor lever
  - shifting retainer, cylinder wreath
- FE 18 unilateral spring damper
  - retainer stopper
  - shifting drum contour
- substructure coupling of outer shifting and driver's foot substructure

# Shifting Process Simulation.

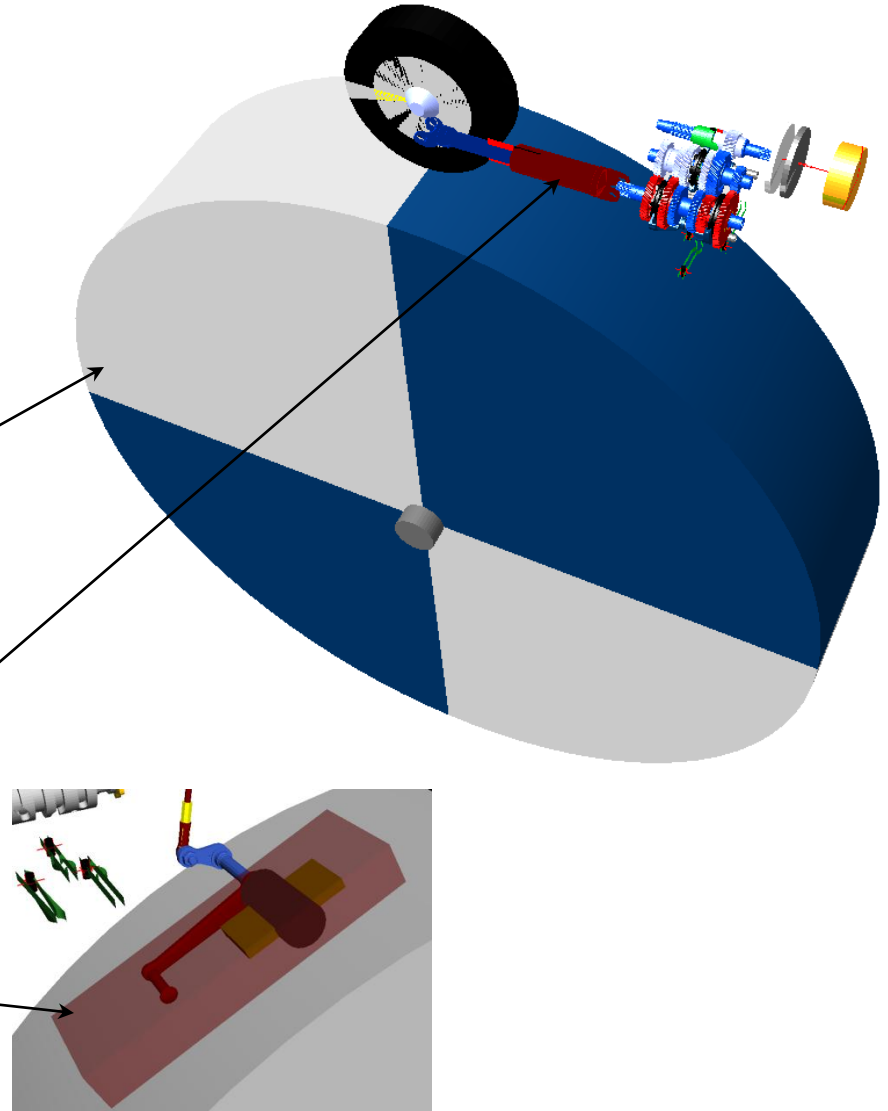
## Drivetrain Modelling.

- Model environment extension: roller test stand with simplified tire behavior is modelled (slip behavior non neglectable)
- damping coefficient of cardan shaft must be evaluated
- model of driver's foot is important for force distribution

roller test stand

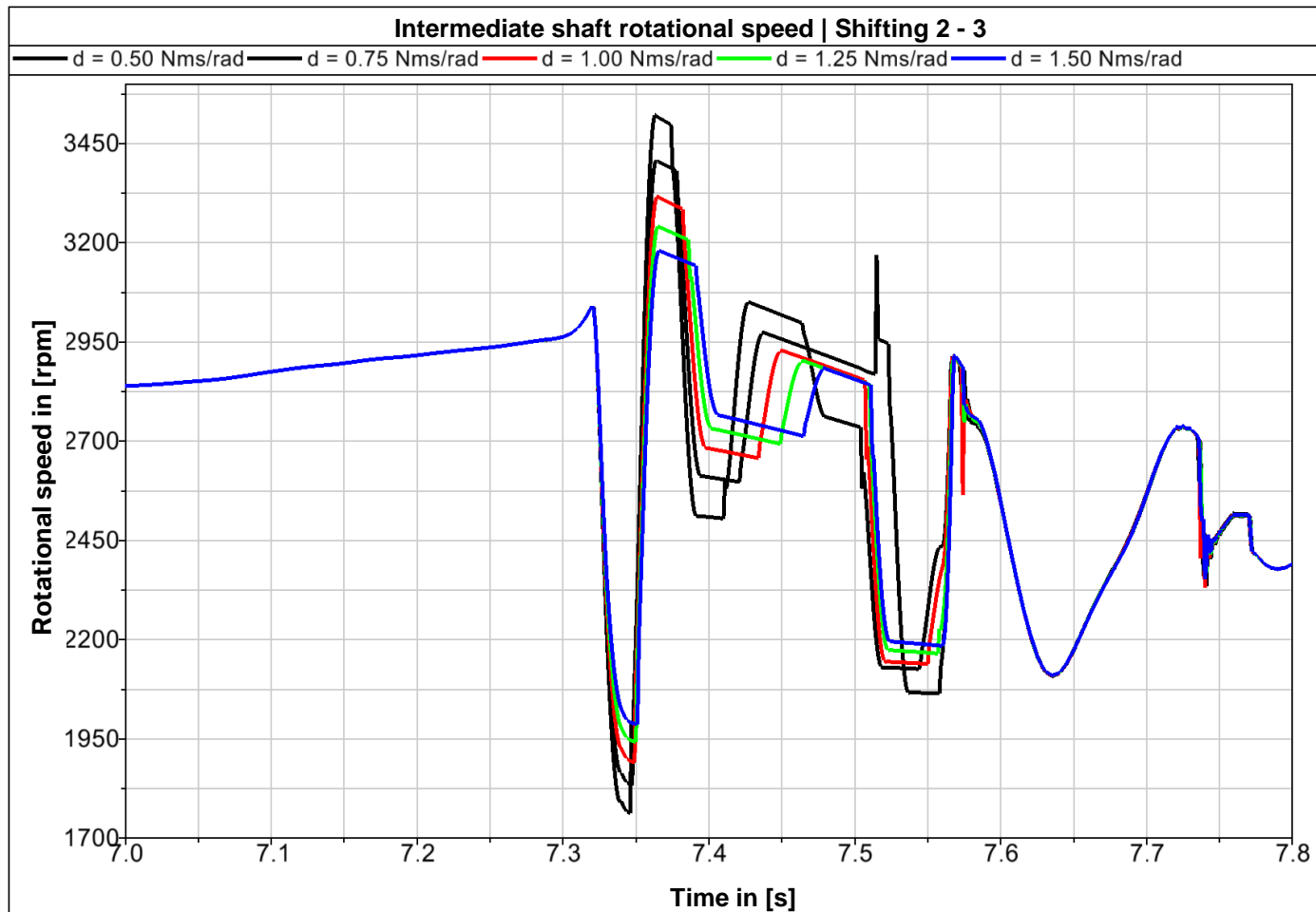
cardan shaft

driver's foot



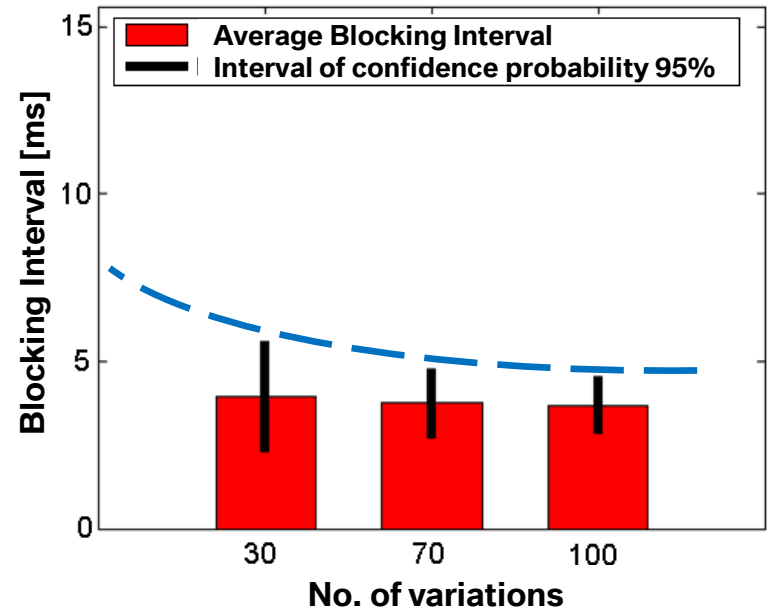
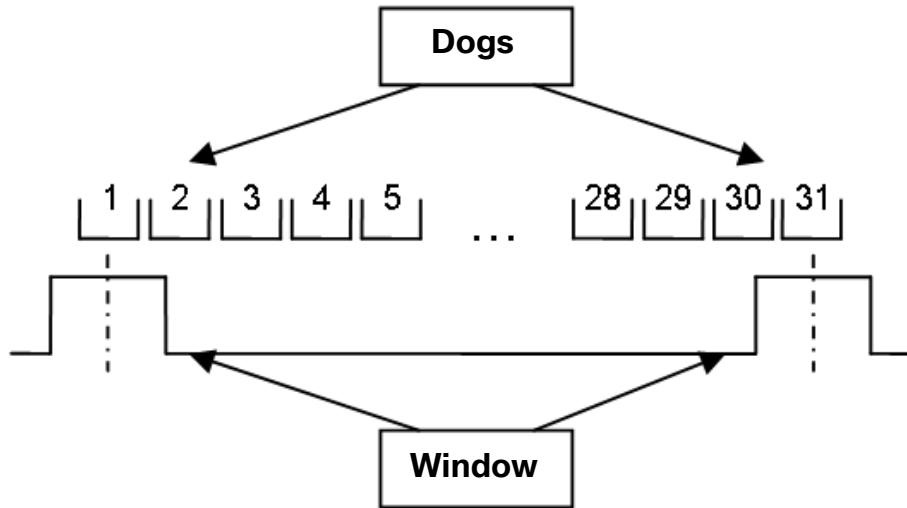
# Shifting Process Simulation.

## Drivetrain Modelling.



- Intense adaption of drivetrain parameters
- Evaluation of simulation models by test rig measurement runs

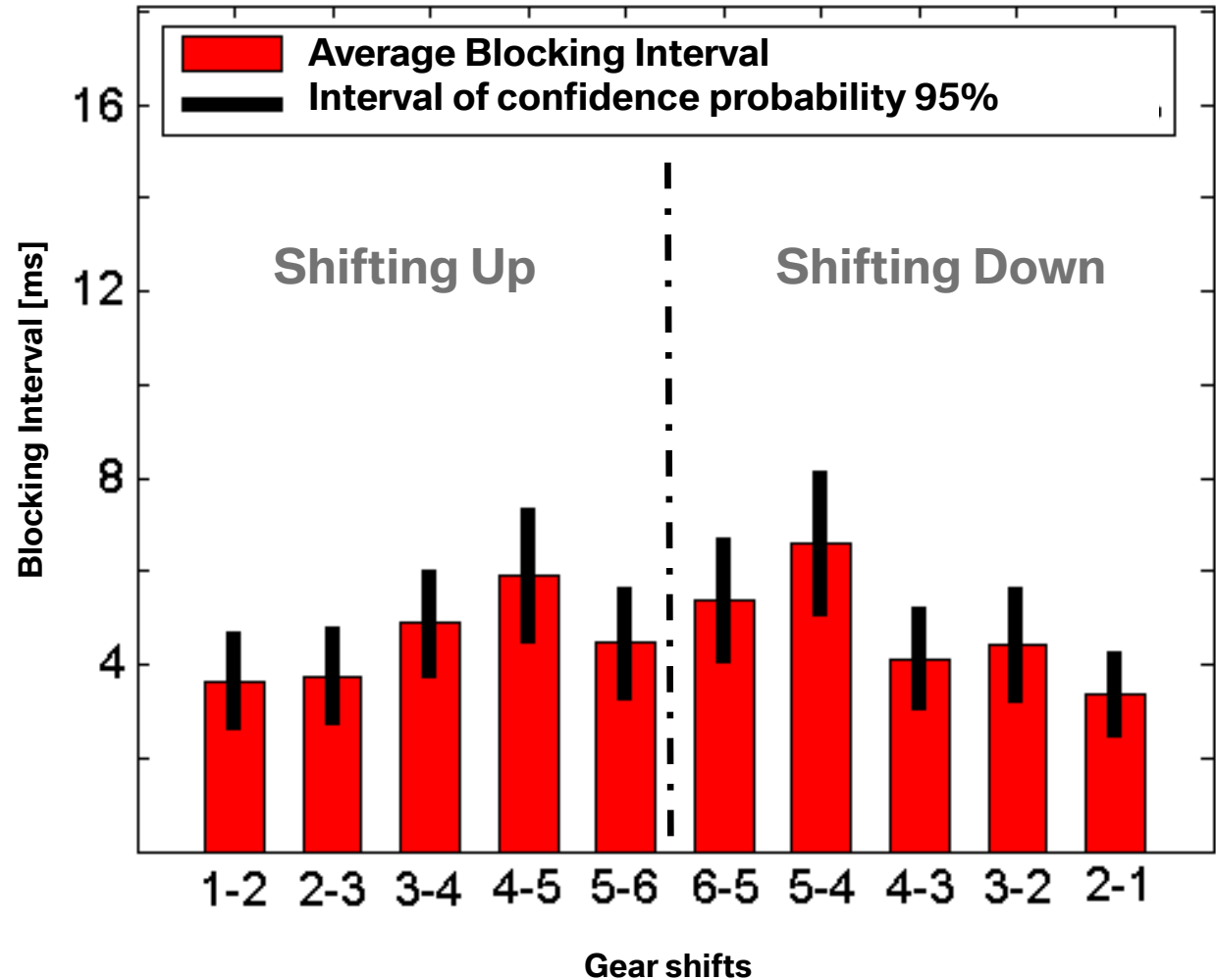
# Randomization and Parameter Variation. Shifting and Statistical Influence.



- Different simulation start positions do create different simulation results
- In order to satisfy statistical influence, a variation of initial position is necessary
- At least 30 variations should be carried out
- MATLAB-based postprocessing (Evaluation of Interval of Confidence plus Plot )

# Randomization and Parameter Variation. Shifting Comfort Evaluation.

- Representative, easy-to-understand diagram, including main simulation results
- Mainly automated postprocessing and data output throughout a large parameter variation



# Summary / Outlook.

- A sophisticated **method of evaluating gear shift comfort** was developed
- **Data extraction:** gear-box **torques**, component **loads** and **durability**, etc.
- Virtual **optimisation topics:** selector drum **contour variation**, component **design variations** of inner and outer shifting, **drivetrain modification**, etc.
- Extension topics: integration of **engine cyclic irregularities**, model **integration** in **vehicle model**, etc.
- Detailed analysis of **statistically distributed shifting rotational speeds** in context of shifting comfort



# Thank you very much for your attention.

User Meeting  
Salzburg  
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