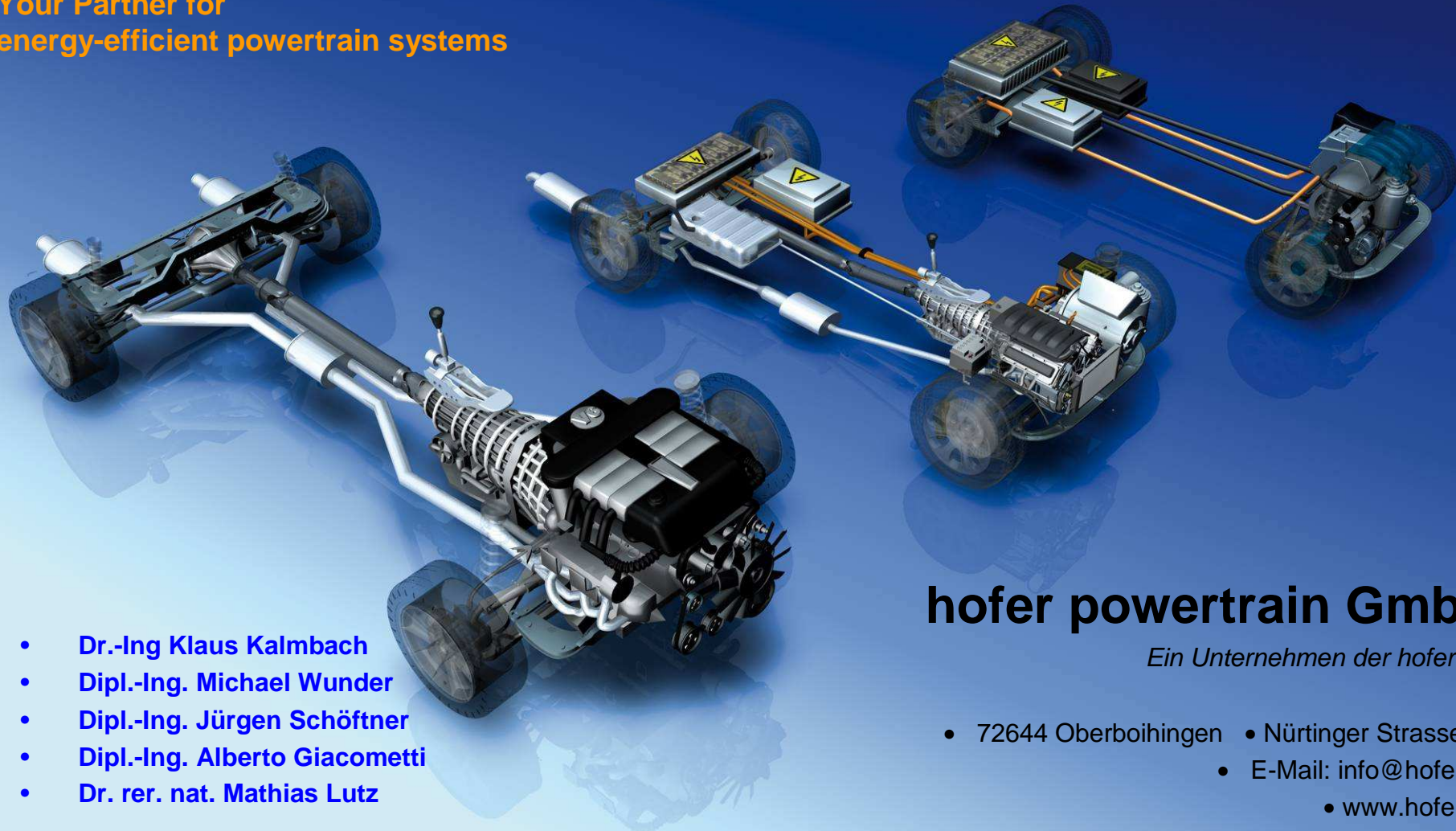# Potentials and development methodology for transmissions with dog clutches

Your Partner for
energy-efficient powertrain systems

- **Dr.-Ing Klaus Kalmbach**
- **Dipl.-Ing. Michael Wunder**
- **Dipl.-Ing. Jürgen Schöftner**
- **Dipl.-Ing. Alberto Giacometti**
- **Dr. rer. nat. Mathias Lutz**

hofer powertrain GmbH

Ein Unternehmen der hofer AG

- 72644 Oberboihingen
- Nürtinger Strasse 78
- E-Mail: info@hofer.de
- www.hofer.de

Content

- Motivation and introduction
- Collision detection and contact model
- Development methodology
- Development examples
  - Motorcycle with dog shift
  - Zero emission drive with dog shift 2-speed transmission
  - Power split transmission with dog shifts
  - Double bump in a synchronizer
  - Automatic transmission with dog shift
  - Virtual evaluation of alternative dog shift systems
  - Commercial vehicle driveline with dog clutches
- Summary and outlook

Motorcycles

Passenger Cars

Trucks

Off-Highway

# Motivation and introduction

Advantages of dog shift systems

- Installation space
- Production costs
- Weight
- Drag torque
- Actuation energy
- Efficiency

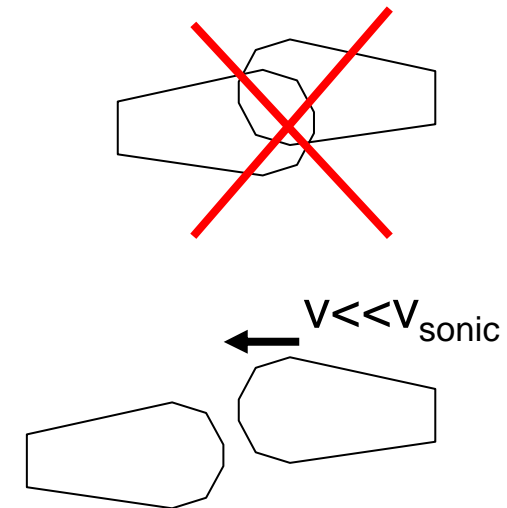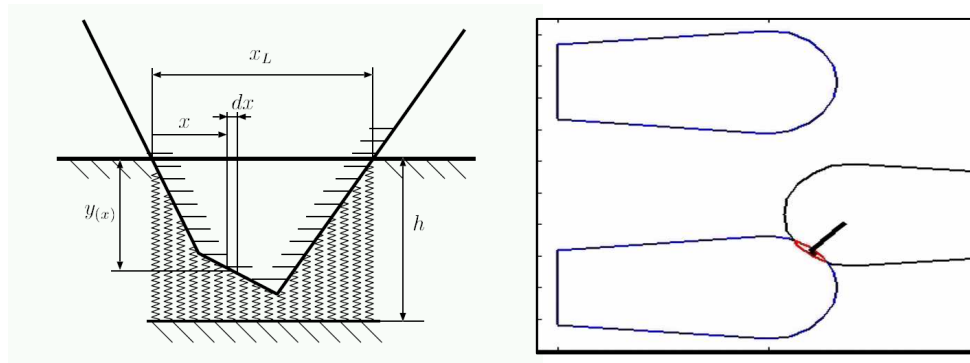→Advantages are combined with <u>high development risks</u>

→System simulation needed to evaluate and optimize systems in advance

Collision detection and contact model

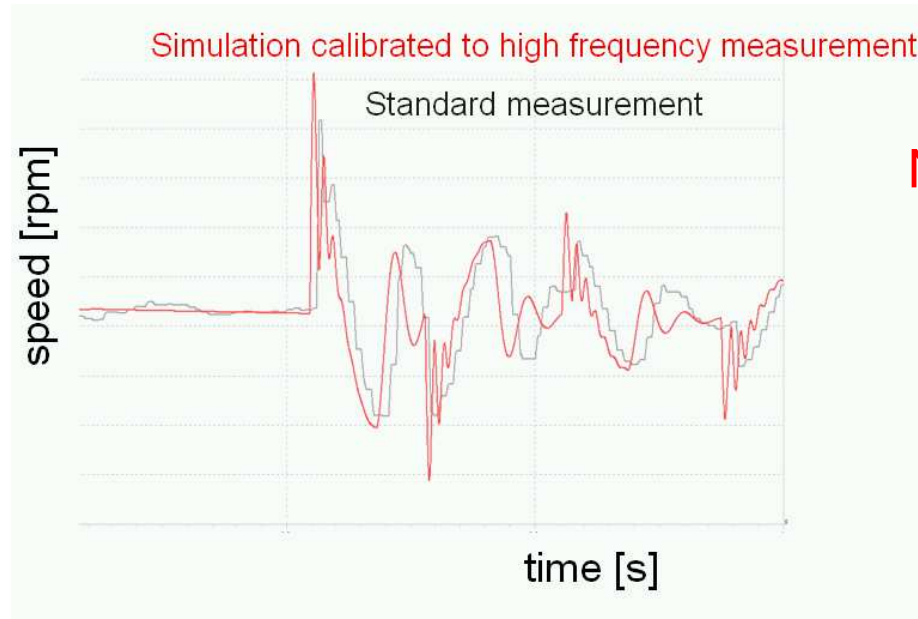- Collision detection methods improve efficiency of contact simulation
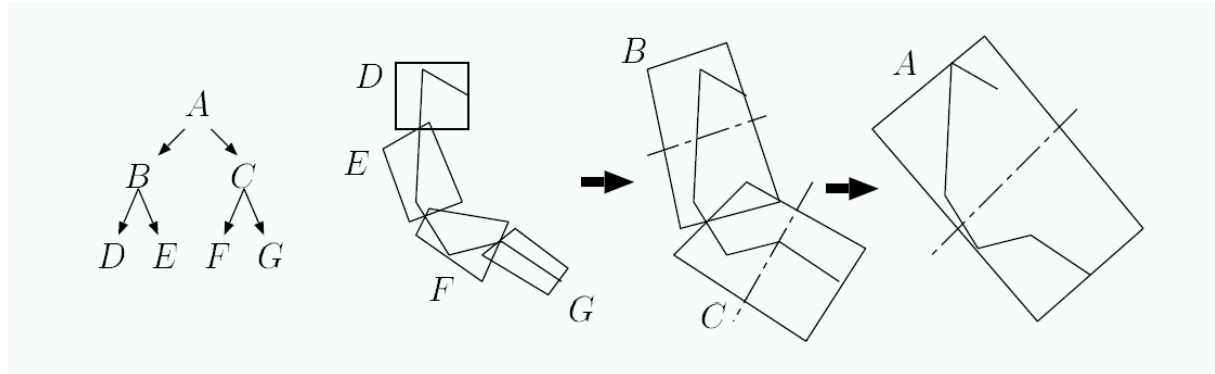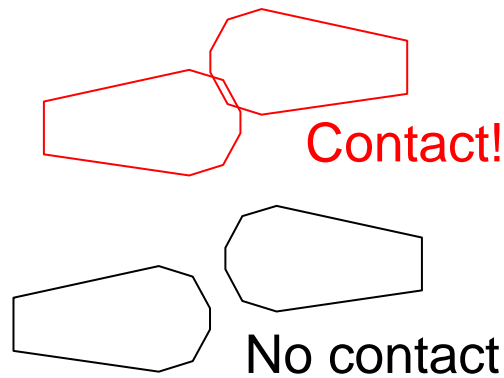
Contact!

No contact

- Contact model with penalty force leads to quick simulation and realistic results
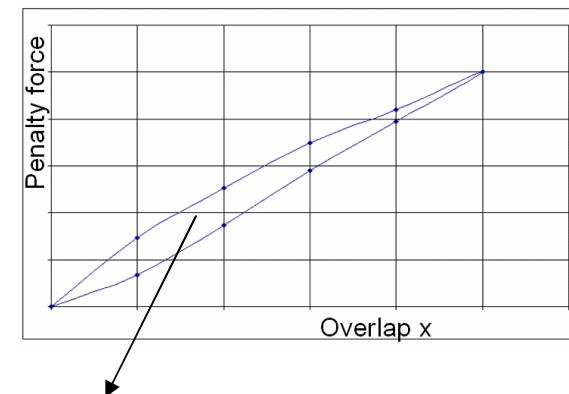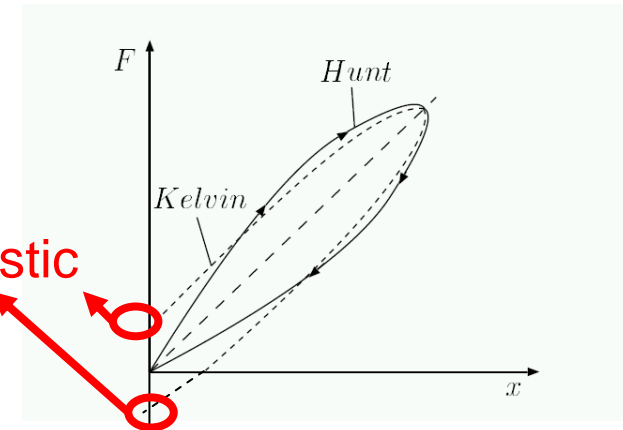
$V \ll V_{sonic}$

Calibration of simulation contact model

- Calibration process is needed to get realistic impact parameters

Not realistic

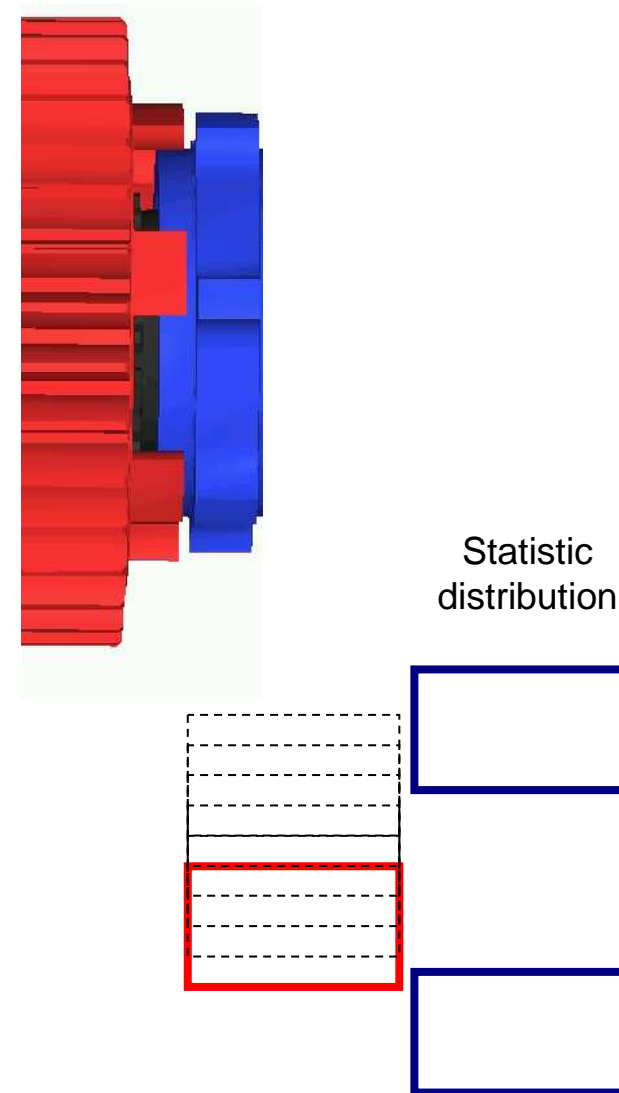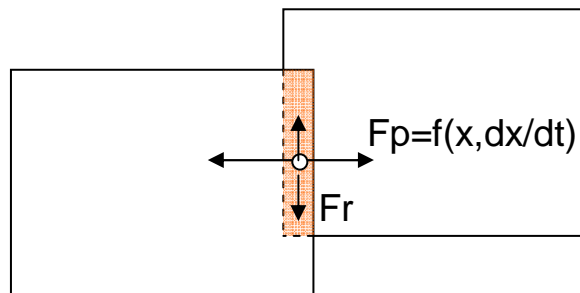→Contact model and parameters have to be able to reproduce high frequency vibrations


Dissipation (hysteresis) is crucial

Simple example

- Very simple geometry

- Can be used for motorcycle dog clutchs

- Model face/face with threshold

- Contact only one-dimensional with 1D-penalty

- Friction including stick slip

Statistic distribution

$Fp=f(x,dx/dt)$

Fr

Advanced example

- Complex but convex geometry

- Can be used widely

- Model area/area without threshold

- Collision detection algorithm necessary

- Contact 2D and changing contact angle

- Friction including stick slip

Fr

Fp=f(A,ds/dt)
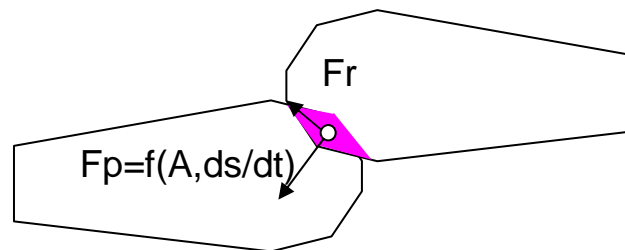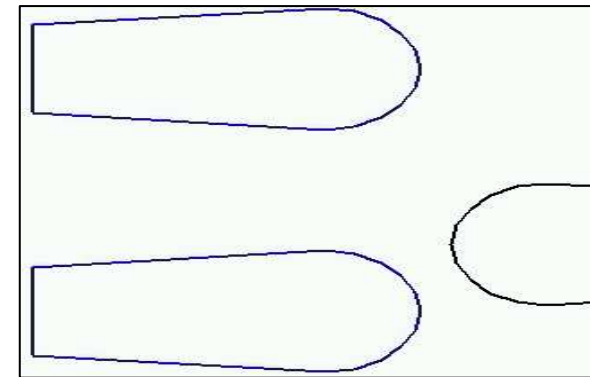
Development methodology

- **Simulation model** of <u>complete powertrain</u> provides functional requirements on dog clutch system
    1. Difference speed and torque requirements
    2. Control requirements (comfort)
    3. Shift time requirements
    4. Safety requirements
- **Safety strategy and FMEA** lead to additional requirements
  →Systematic choice of geometry, actuation system, sensors, logics a.s.o.
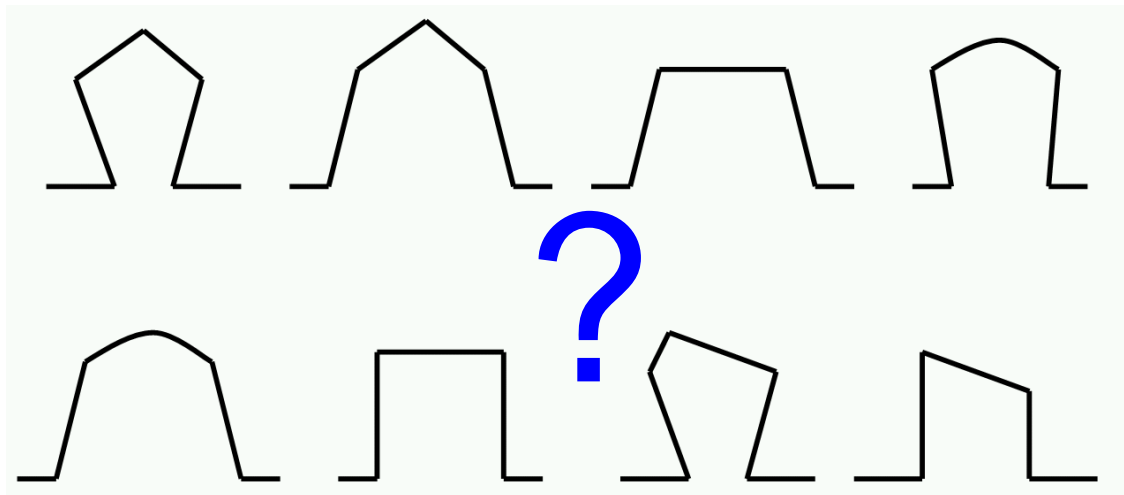
→Definition and simulation of all critical situations, temperature range, statistic dog clutch influences a.s.o.→**virtual verification** (Simulation of complete powertrain and actuation system)

Main influences on shift process

- ■ Actuation system
  - ▪ Electromechanical
  - ▪ Mechanical
  - ▪ Hydraulic
  - ▪ Pneumatic
  - ▪ Magnetic
- ■ Temperature
  - ▪ Drag torque→difference speed
  - ▪ Actuation (e.g. hydraulic)
- ■ Driveline vibrations (inertia, stiffness, damping,…)
  - ▪ Difference speed and torque vibrations
- ■ Statistical distribution of engaging process (engaging „cloud")

x

engaged   T=80°C   T=-10°C

disengaged

t

F

x
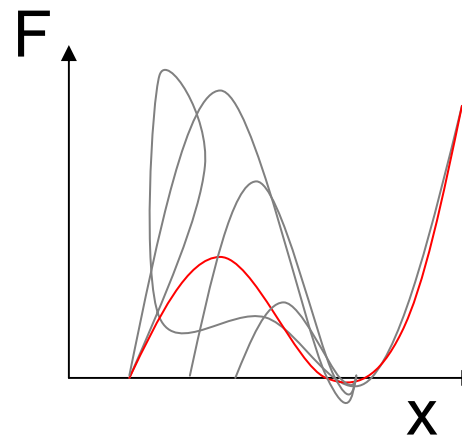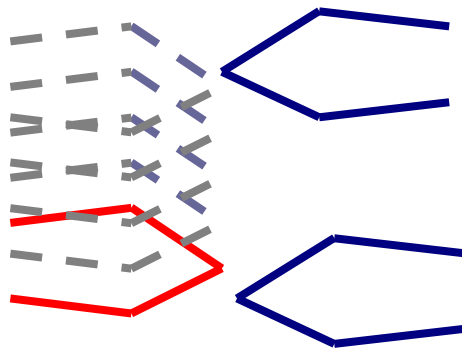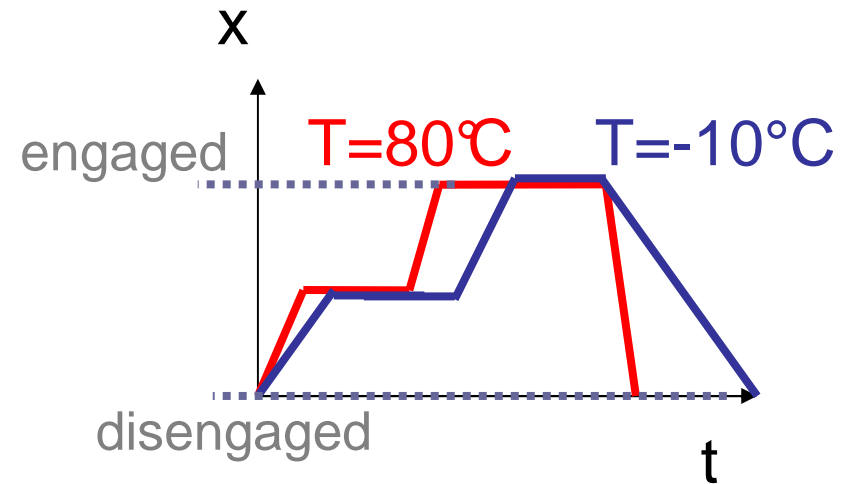
Example motorcycle shift

- Simulation of highly dynamic shift process including contact forces
- Experimental correlation of impact results and subjective evaluation leads to objective evaluation process using only simulation results

Calibration of simulation

high Δn
→noise
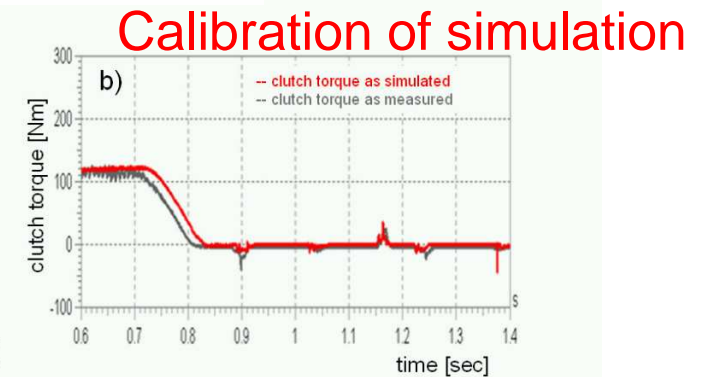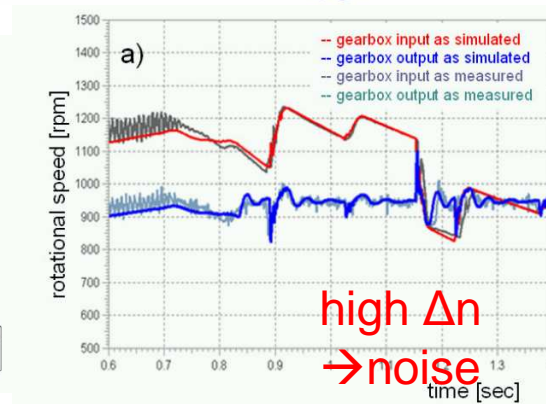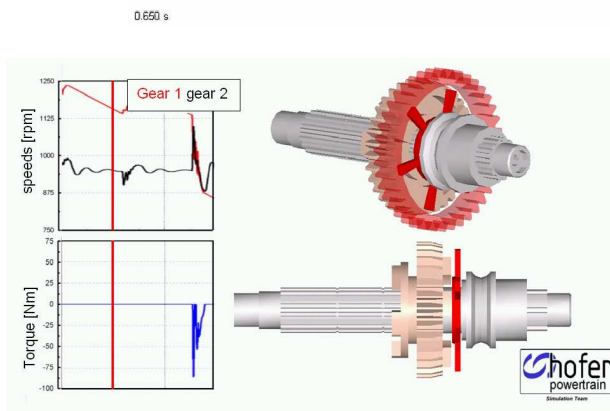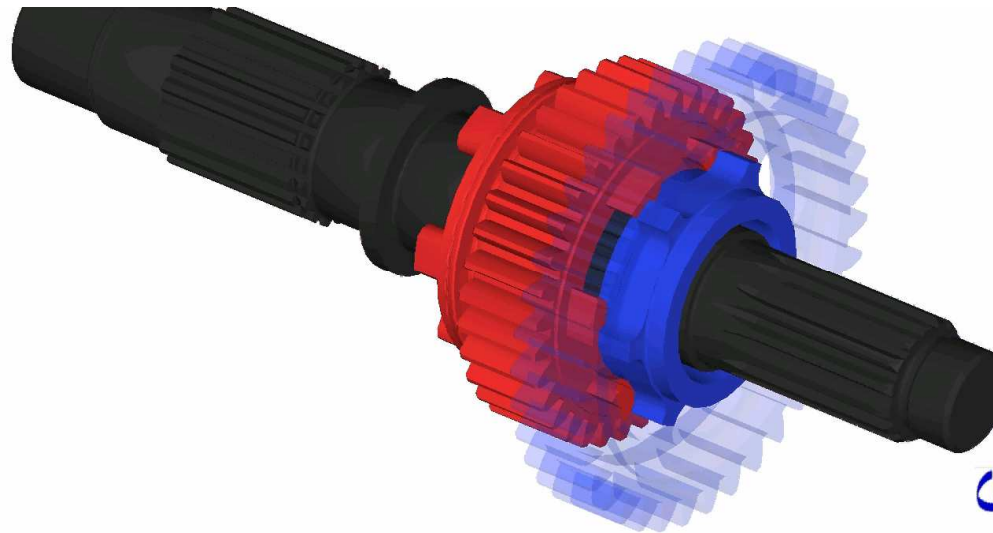
Source: BMW, hofer, FISITA 2006

Example zero emission vehicle
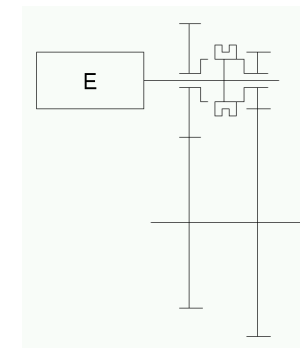
- Electric motor can be combined with 2-speed transmission
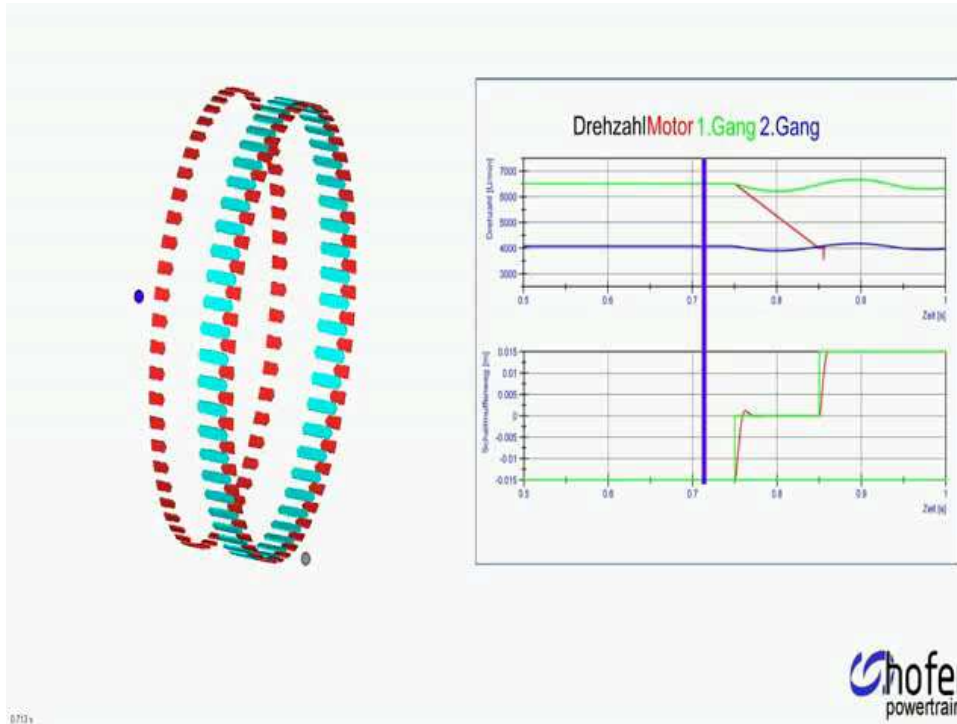
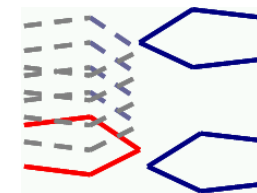**Driveline vibration has to be minimized to avoid high shift noise and nibble (durability)**

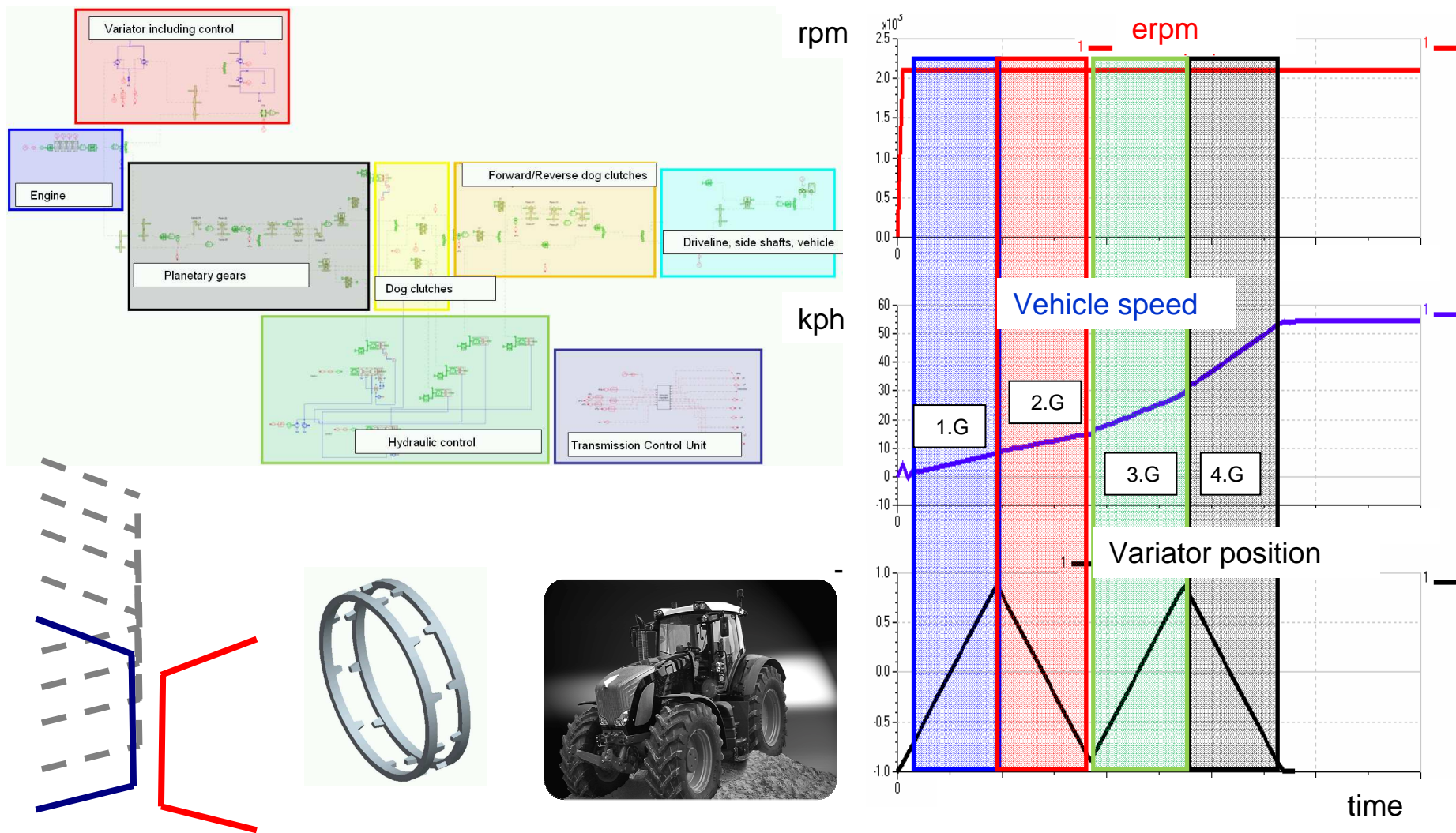| Shift pre-para-tion | Dis-engage | Synchro-nization | Engaging | Post shift |

Torque management
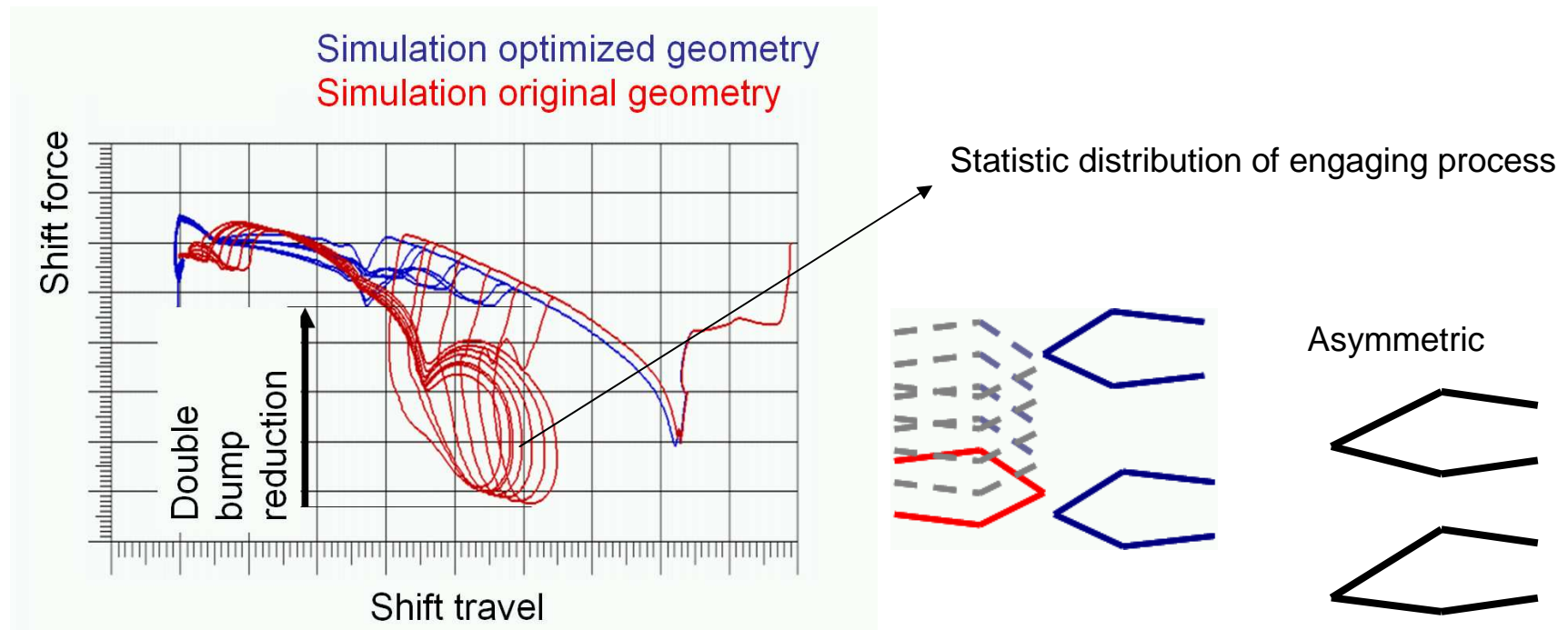
Speed control

Torque management

Example power split transmission

- System simulation model representing the complete powertrain

Example double bump in a synchronizer

- During a synchronizer shift process, the dog shift at the end of the shift is the most challenging phenomenon to simulate and to predict
- Drag torque and driveline vibration leads to speed difference and impact forces


Simulation optimized geometry
Simulation original geometry

Shift force

Double bump reduction

Shift travel

Statistic distribution of engaging process

Asymmetric

Example dog clutch in an AT

- Some multi disc clutches (or brakes) can be replaced by dog clutches
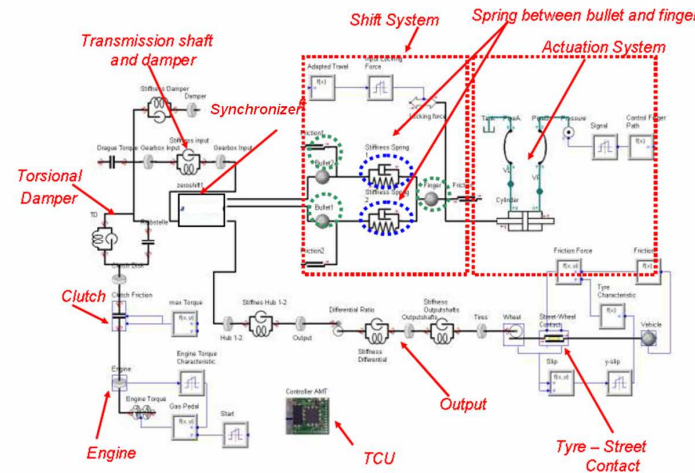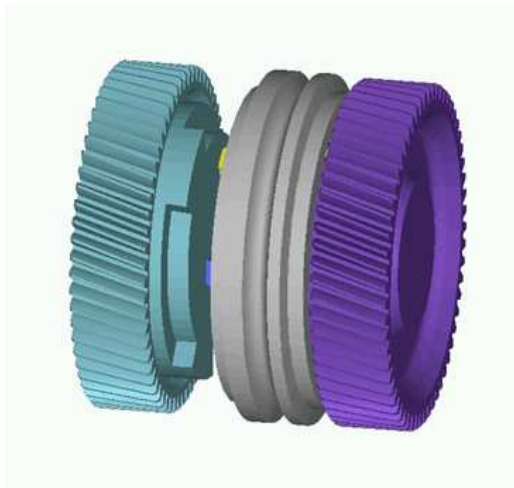- Drag torque can be reduced→ fuel consumption improvements of >2% possible

$M.\Delta\omega$
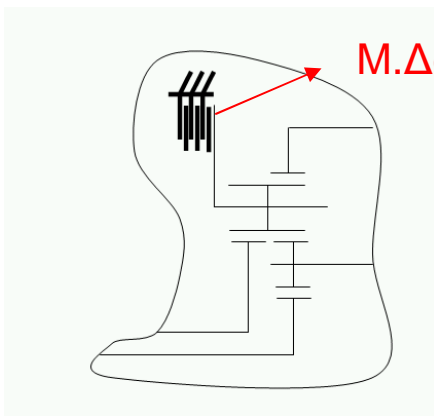
Example RW-gear brake

15.800 s

β

α

NEFZ
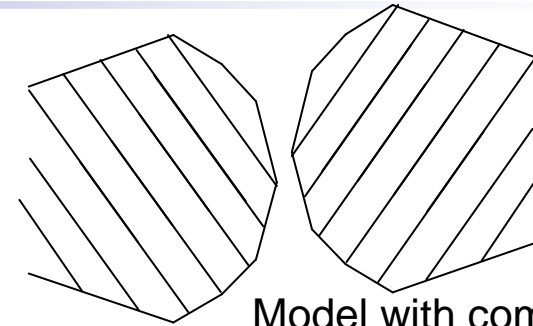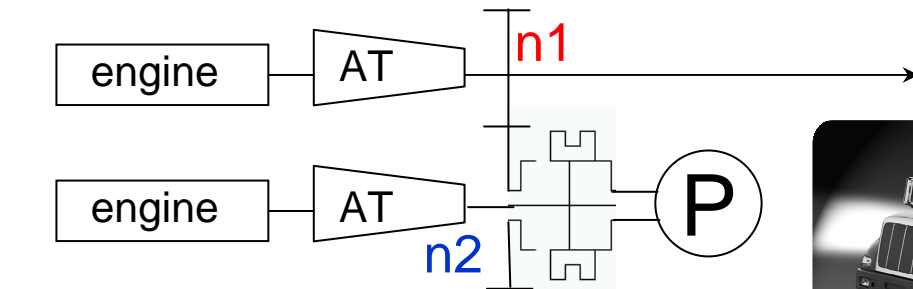

v

t
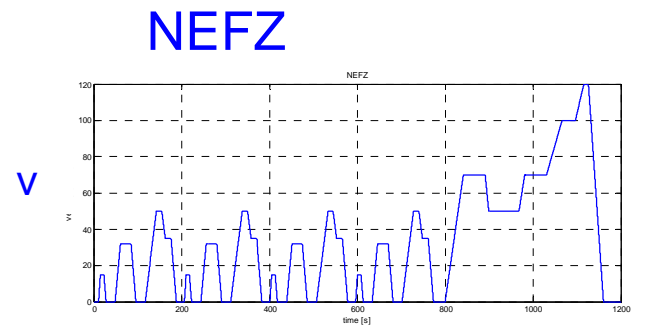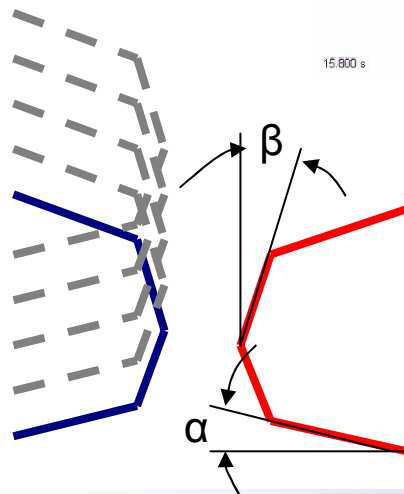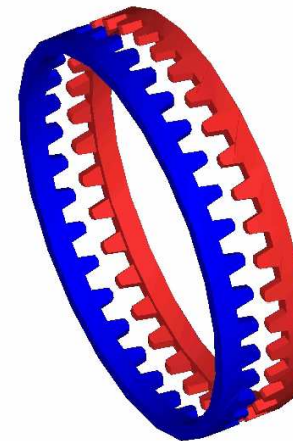
Example advanced development evaluation

- Virtual evaluation of newly emerging systems is needed to avoid costs
- System simulation leads to evaluation quickly

AMT system simulation
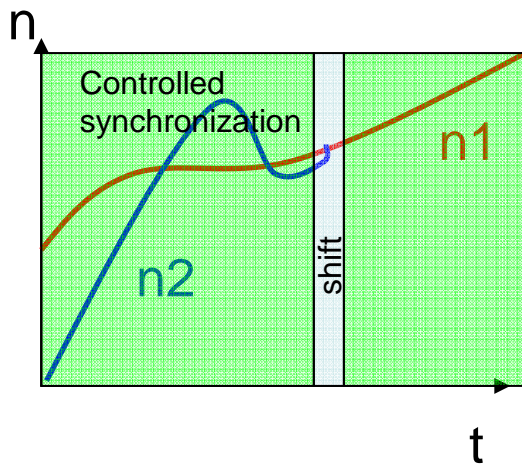
based on calibrated model

Commercial vehicle driveline

Model with complex dog geometry (convex)
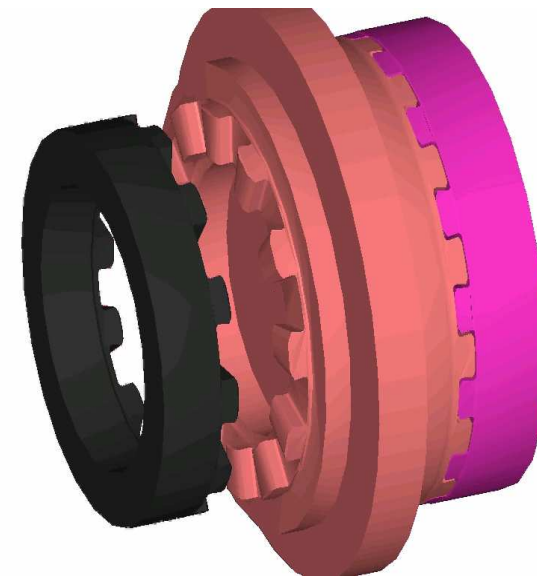
Pneumatic actuation system

0.000 s

Verification and optimization of control strategies using system simulation

→algorithm implementation in software

→System works perfectly under all conditions

Summary and outlook

- Dog clutches have high chance to be re-introduced in high volume transmissions due to

  - Efficiency advantages
  - Reduced installation space
  - Low drag torques
  - Low actuation forces
  - Low production costs
  - Better development tools (system simulation) and higher intelligence of transmission systems (sensors, TCU, actuation)

- Development examples show that system simulation is capable of optimizing dog clutch systems in advance and evaluate new systems without hardware prototypes
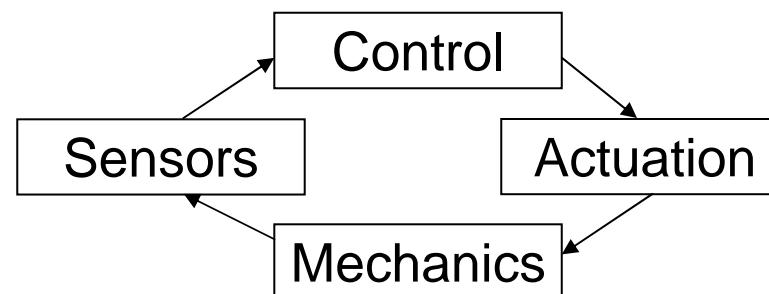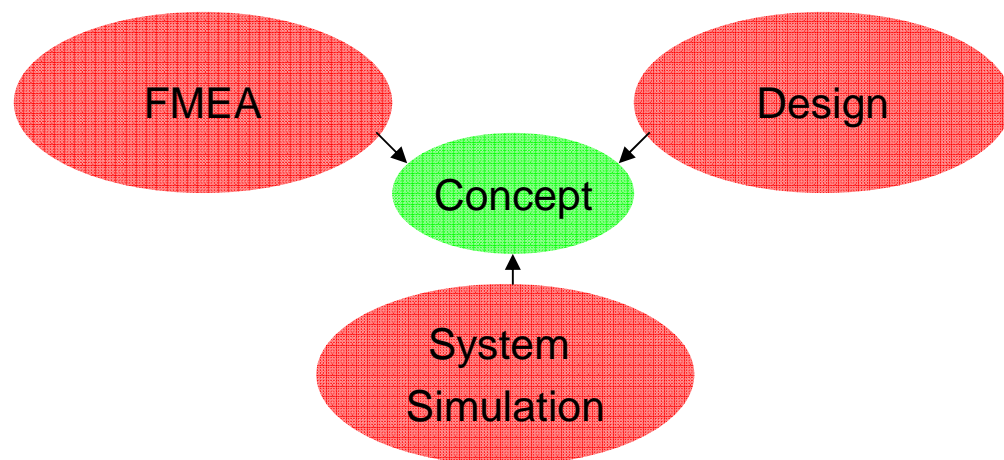
Potentials and development methodology for transmissions with dog clutches

Your Partner for
energy-efficient powertrain systems
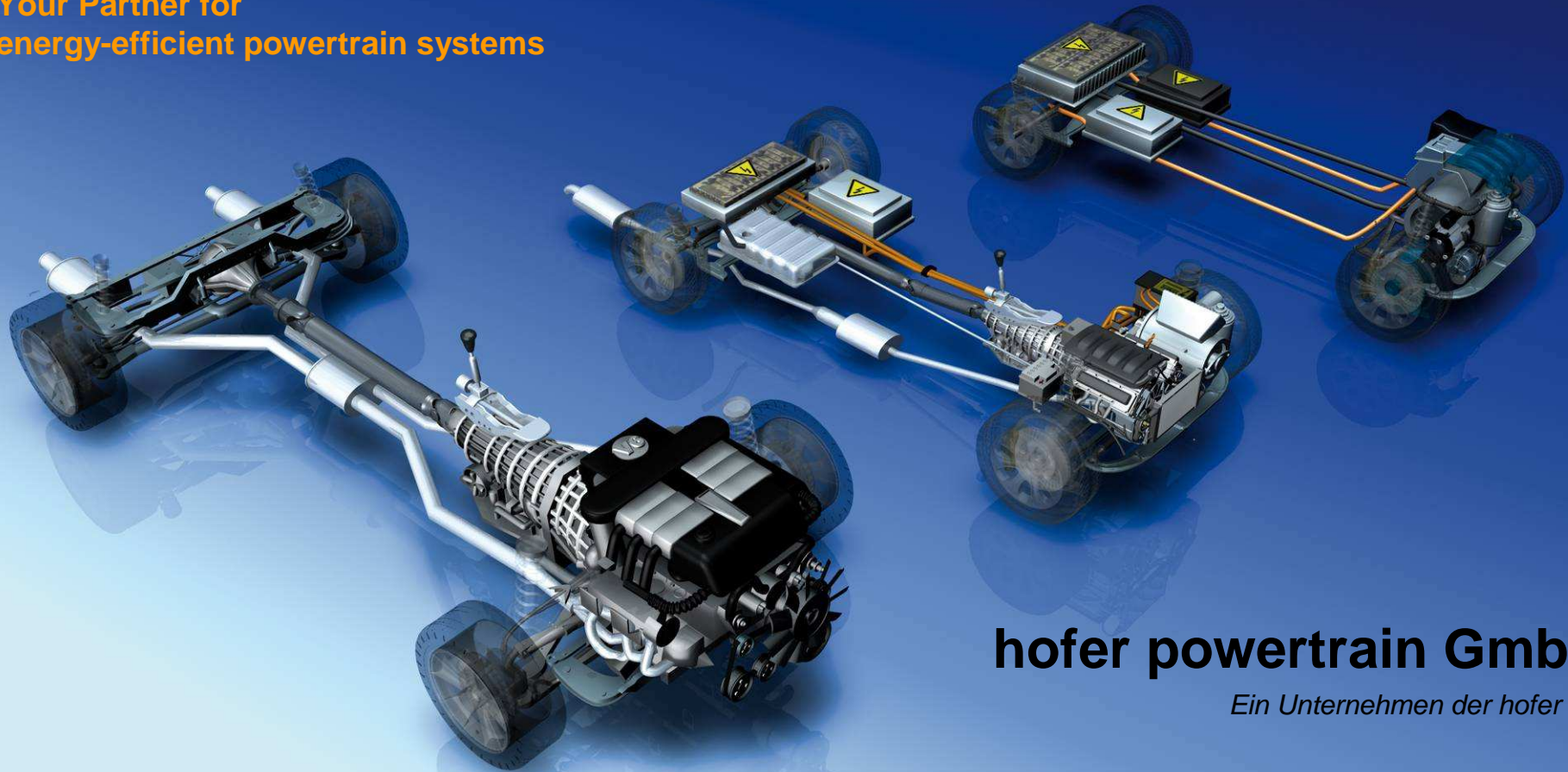
hofer powertrain GmbH

Ein Unternehmen der hofer AG

- 72644 Oberboihingen   • Nürtinger Strasse 78
- E-Mail: info@hofer.de
- www.hofer.de

Thank you for your attention!