Basics of Synchronizers

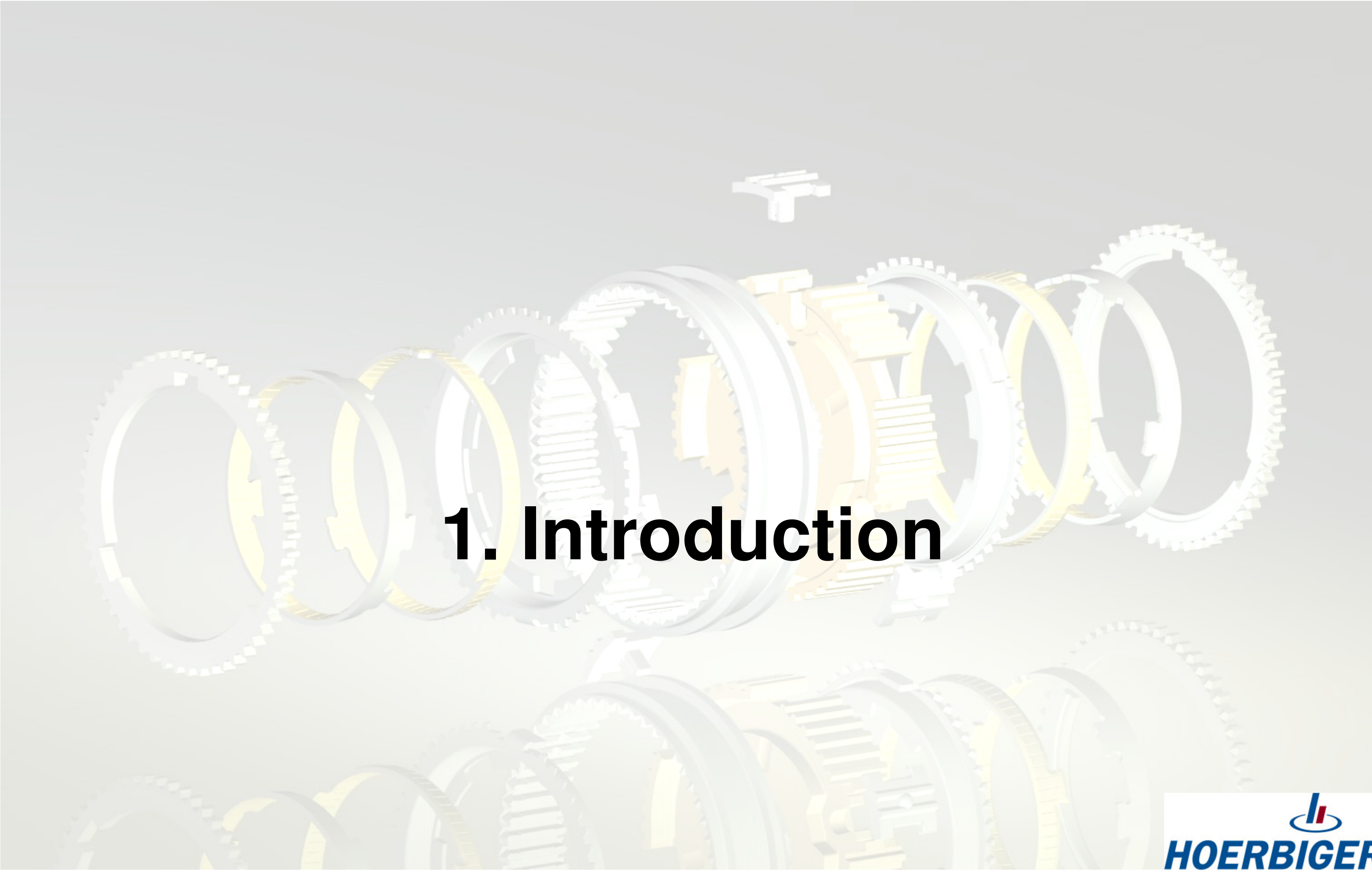
Ottmar Back, Head of Product Management
January 2013

HOERBIGER

Content

HOERBIGER

Copyright by HOERBIGER Antriebstechnik GmbH (Germany), 2013. Any kind of use in part or in full provides HOERBIGER Antriebstechnik GmbH's prior written consent.



1. Introduction

Copyright by HOERBIGER Antriebstechnik GmbH (Germany), 2013. Any kind of use in part or in full provides HOERBIGER Antriebstechnik GmbH's prior written consent.

1. Introduction

Synchronizers are the key elements in manual transmissions (MT) as well as in double-clutch transmissions (DCT) and automated manual transmissions (AMT).

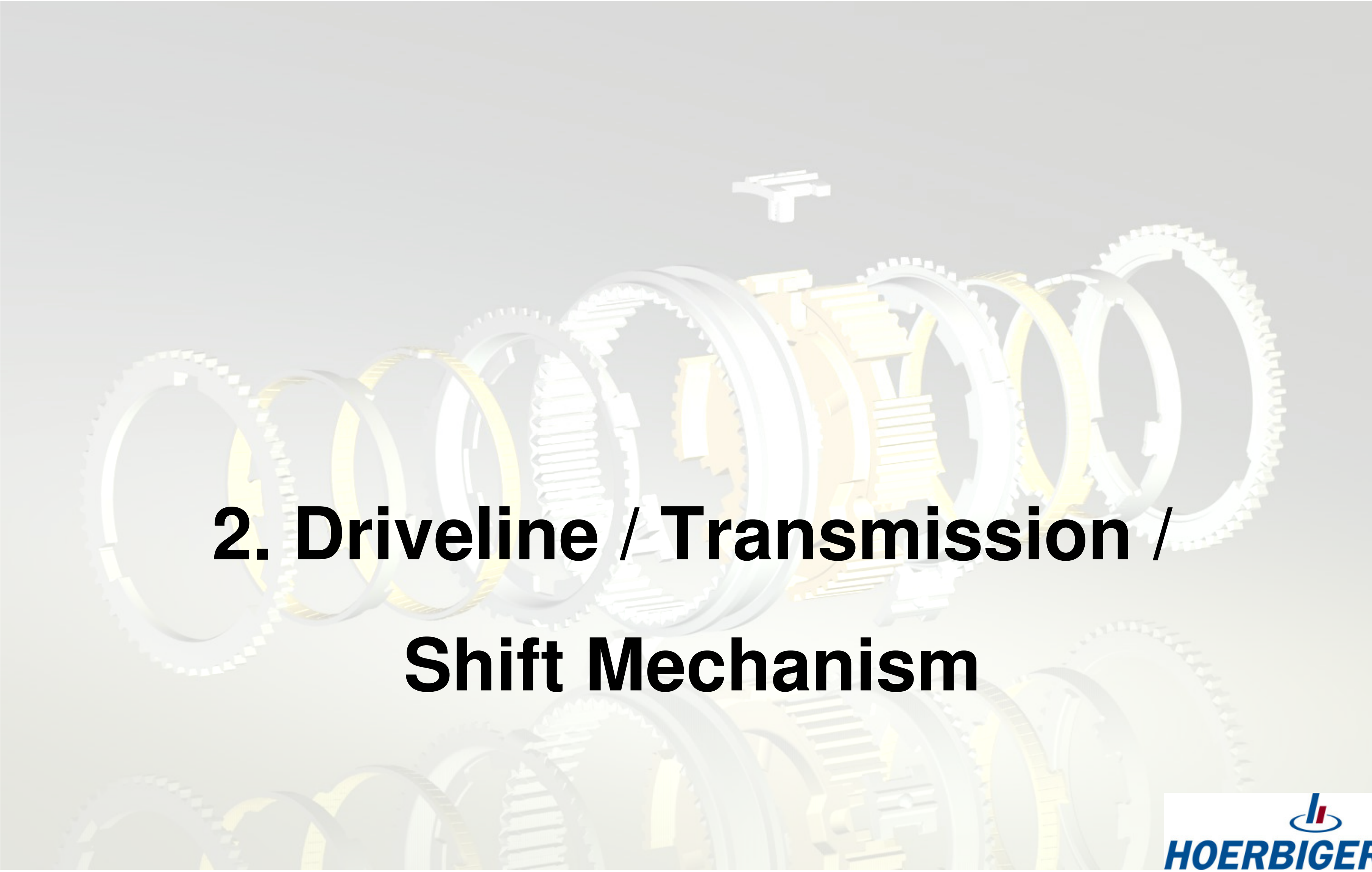
This paper gives an overview of their function, layout and design and explains possible problems and solutions.

Finally it is shown what tools and processes are needed to develop, test and manufacture components and complete synchronizer systems.

As the worldwide largest independent manufacturer HOERBIGER develops and supplies components and systems for all types of manual transmissions, double-clutch transmissions, and automated manual transmissions.

HOERBIGER

Copyright by HOERBIGER Antriebstechnik GmbH (Germany), 2013. Any kind of use in part or in full provides HOERBIGER Antriebstechnik GmbH's prior written consent.



2. Driveline / Transmission / Shift Mechanism

Copyright by HOERBIGER Antriebstechnik GmbH (Germany), 2013. Any kind of use in part or in full provides HOERBIGER Antriebstechnik GmbH's prior written consent.

2. Driveline / Transmission / Shift Mechanism

Synchronizers are the central component of the transmission featuring interfaces to the output, the clutch and, by way of the gear shift, to the driver.

The layout and design of the synchronizers play an essential role in how the driver experiences the gear shift.

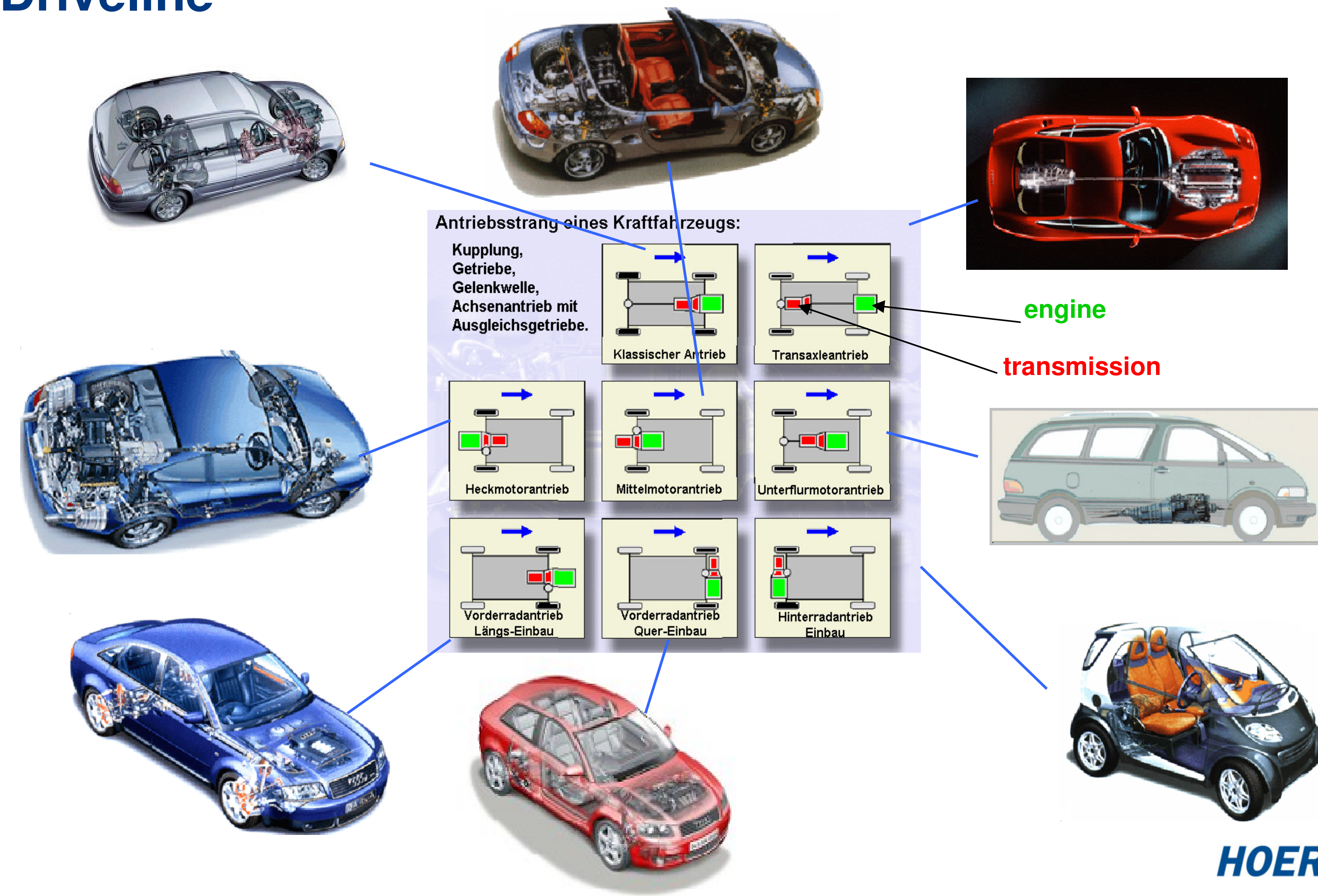
The following pages give an overview of
- **the variety of driveline concepts**
- **the interfaces of the transmission to the vehicle**
- **the interface of the transmission to the driver and**
- **the installation and the interfaces of the synchronizer in the transmission**

The layout and the design of synchronizer systems has to take into account all these aspects. The validation and the assessment of the synchronizer systems have to be made at test rig as well as in the vehicle.

HOERBIGER

Copyright by HOERBIGER Antriebstechnik GmbH (Germany), 2013. Any kind of use in part or in full provides HOERBIGER Antriebstechnik GmbH's prior written consent.

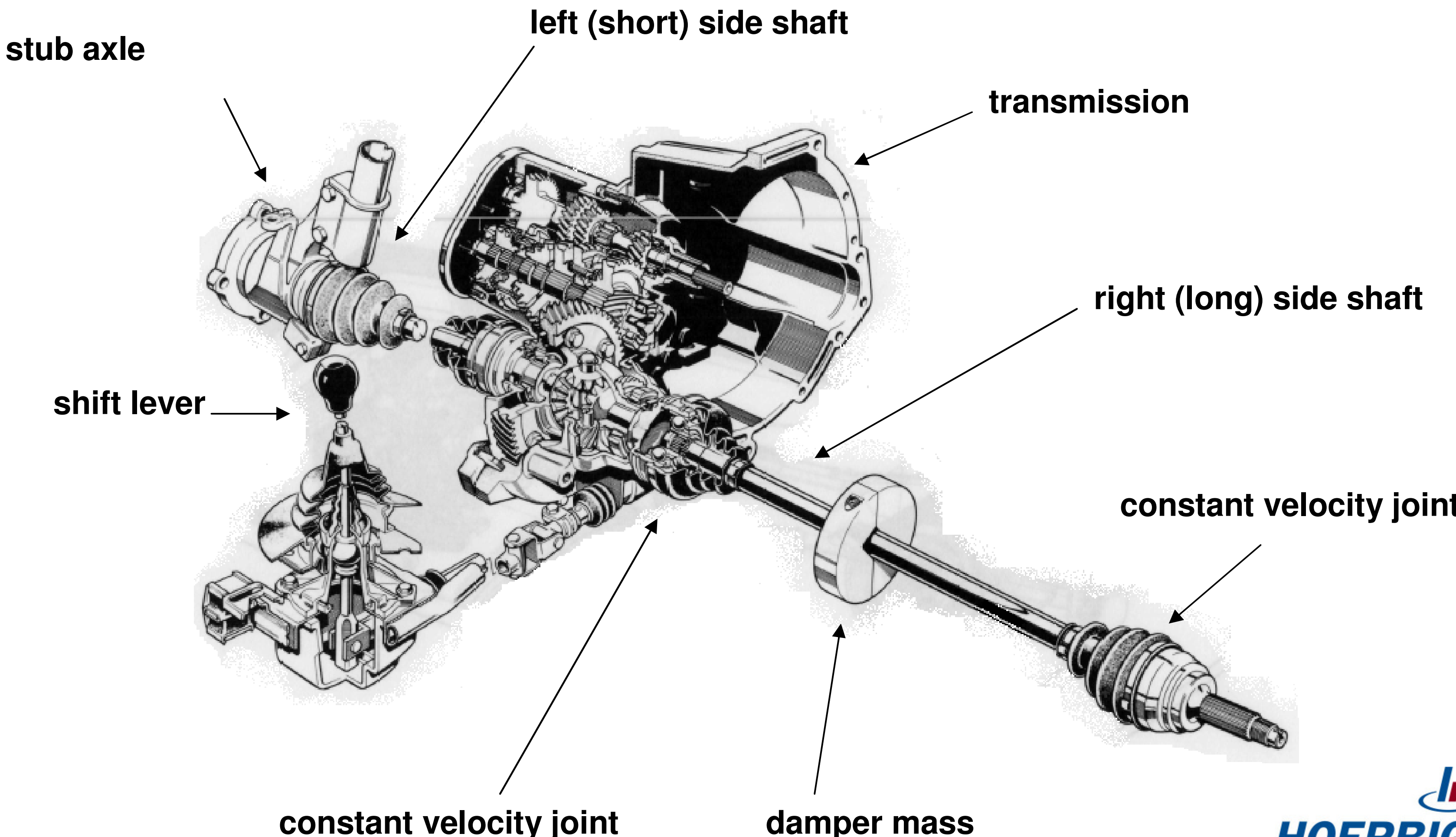
Driveline



HOERBIGER

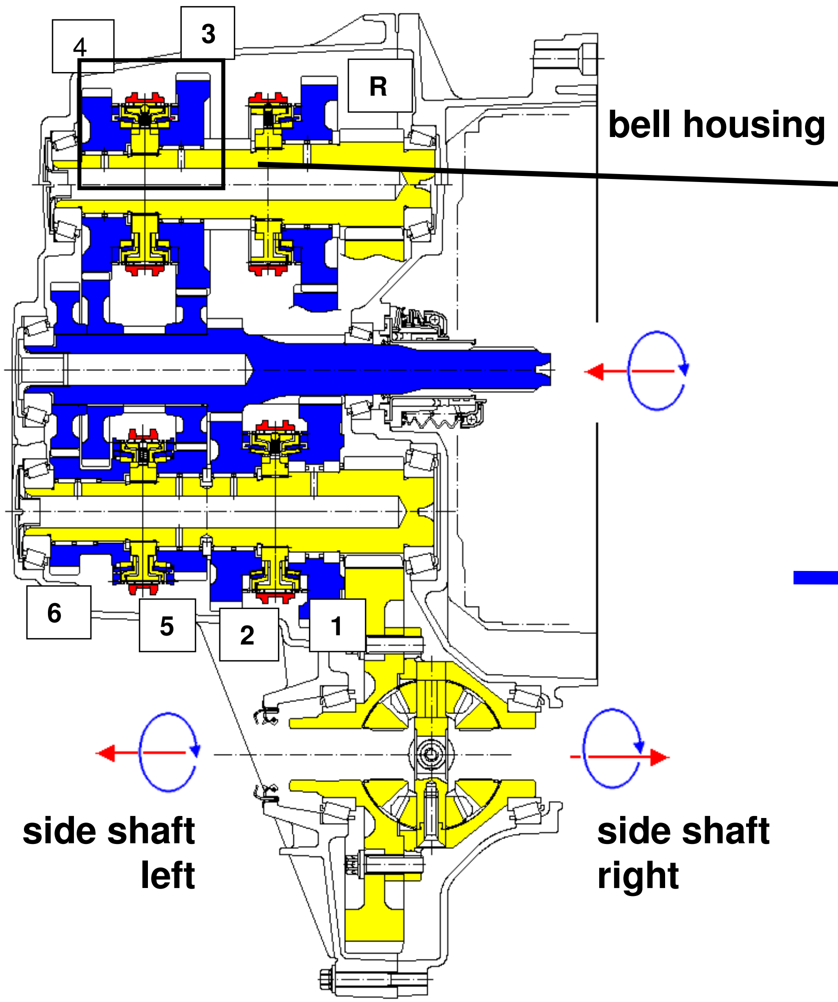
Copyright by HOERBIGER Antriebstechnik GmbH (Germany), 2013. Any kind of use in part or in full provides HOERBIGER Antriebstechnik GmbH's prior written consent.

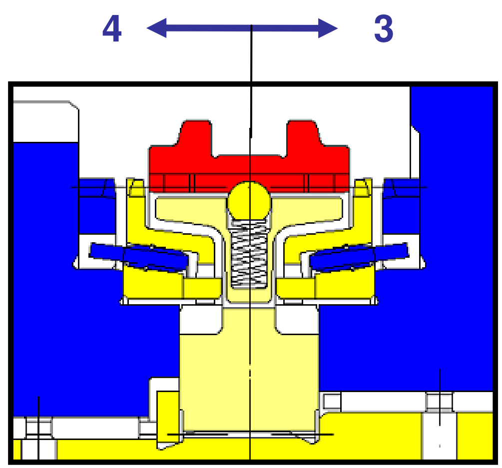
Driveline



Copyright by HOERBIGER Antriebstechnik GmbH (Germany), 2013. Any kind of use in part or in full provides HOERBIGER Antriebstechnik GmbH's prior written consent.

Transmission





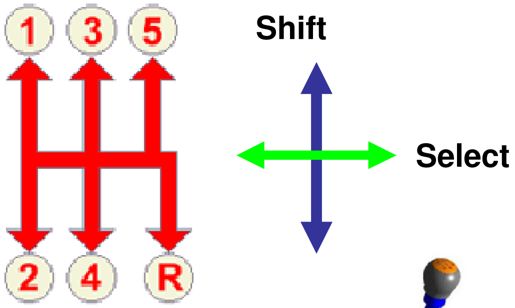
Synchronizers work as cone brakes. They brake or accelerate the components marked in blue and the secondary mass of the clutch.

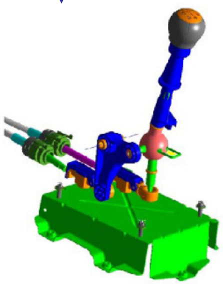
To synchronize means to adjust the speed of shaft and gear wheel!

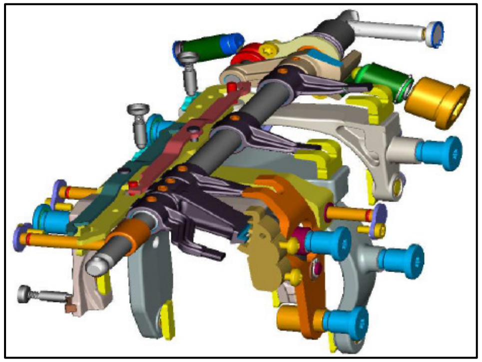
HOERBIGER

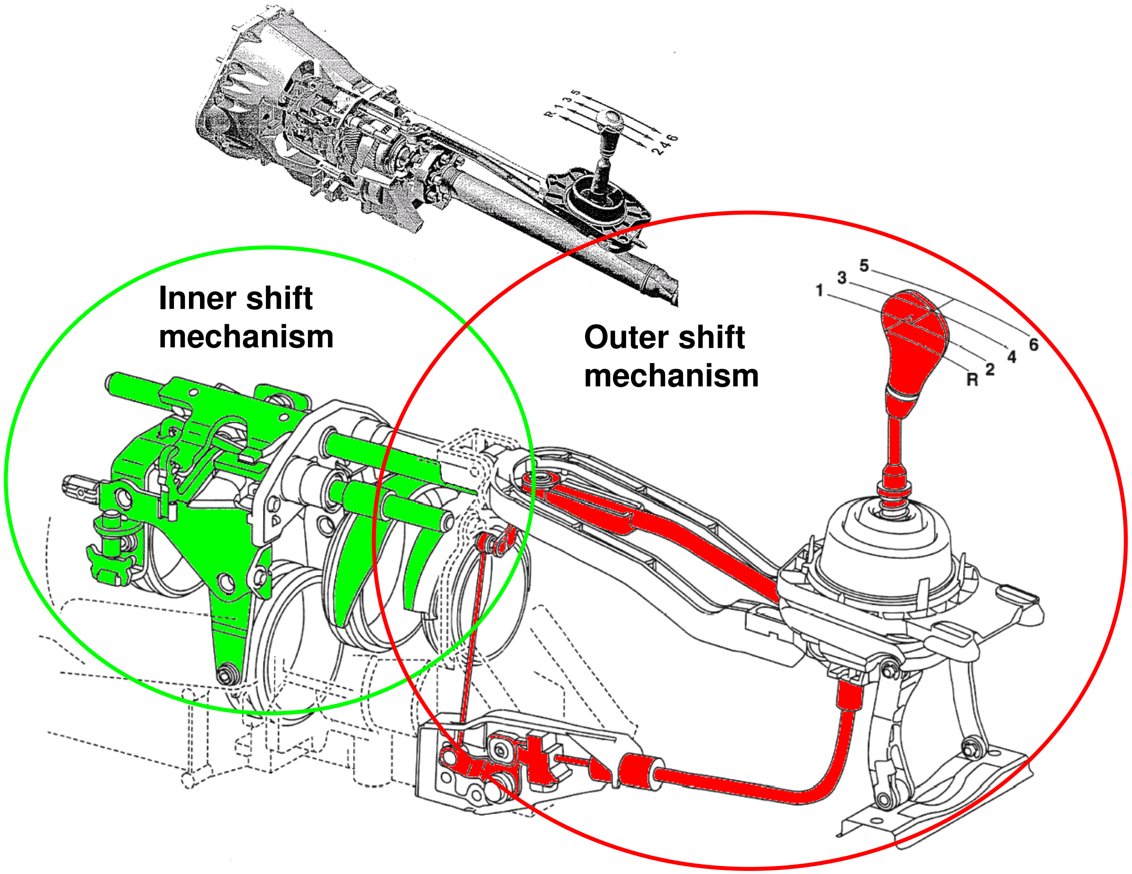
Copyright by HOERBIGER Antriebstechnik GmbH (Germany), 2013. Any kind of use in part or in full provides HOERBIGER Antriebstechnik GmbH's prior written consent.

Shift Mechanism



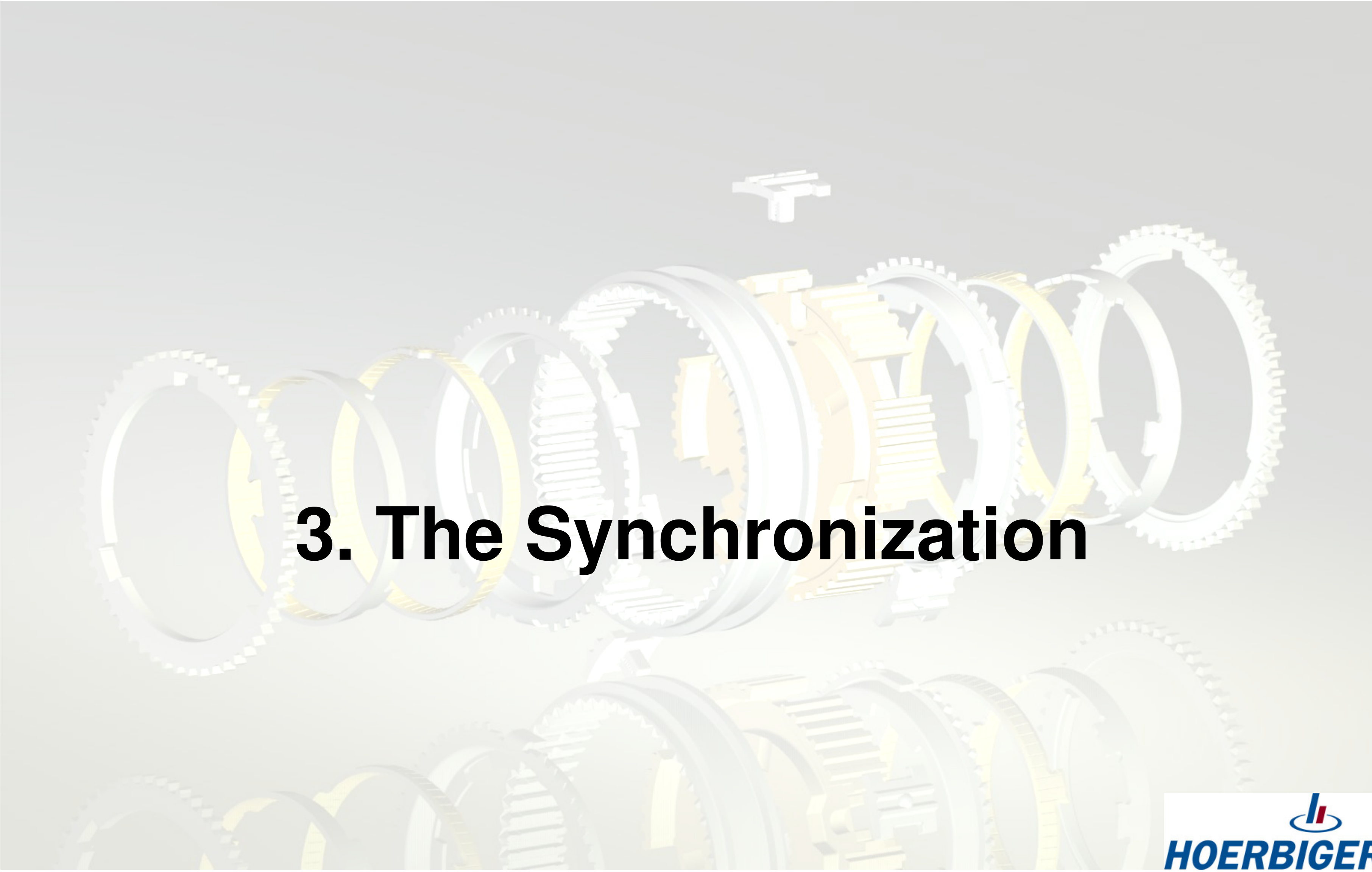






Copyright by HOERBIGER Antriebstechnik GmbH (Germany), 2013. Any kind of use in part or in full provides HOERBIGER Antriebstechnik GmbH's prior written consent.

3. The Synchronization



Copyright by HOERBIGER Antriebstechnik GmbH (Germany), 2013. Any kind of use in part or in full provides HOERBIGER Antriebstechnik GmbH's prior written consent.

3. The Synchronization

Synchronizers can be structured by the number of cones used. The next 3 pages show the exploded views of single-, dual- and triple-cone synchronizers and the descriptions of the single components.

The synchronization process always follows the same sequences. The sleeve is moved by the shift fork towards the gear to be engaged. As long as there is a speed difference between the sleeve/hub-system and the gear wheel the sleeve is blocked by the blocker ring and the synchronizer rings create a friction torque. When the speeds are synchronized the sleeve can be moved further and engages into the spline of the engangement ring at the gear wheel.

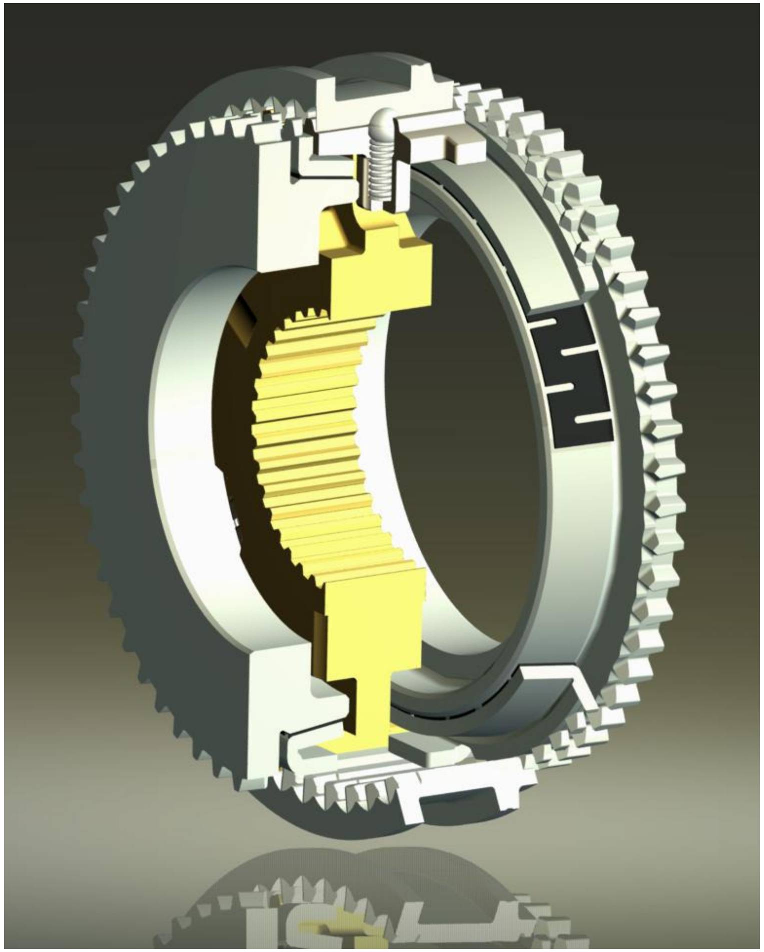
The sequences can be followed by clicking through the pages 16 to 21.

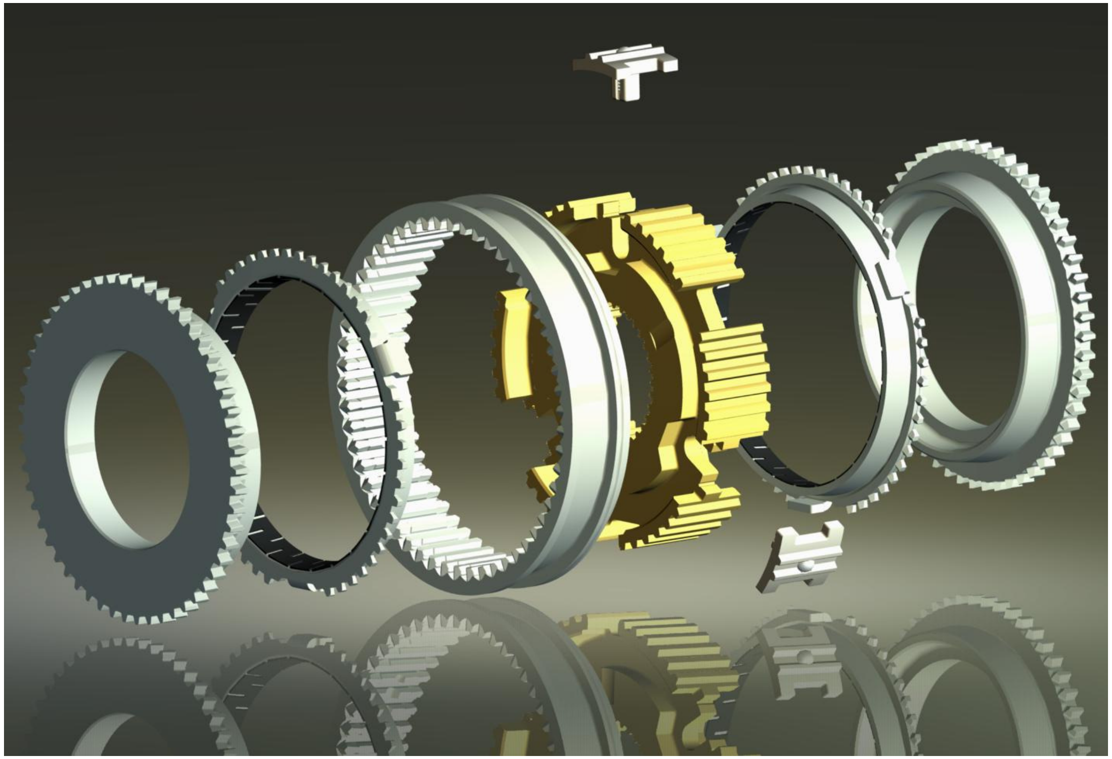
They are then explained in detail on pages 22 to 28.

HOERBIGER

Copyright by HOERBIGER Antriebstechnik GmbH (Germany), 2013. Any kind of use in part or in full provides HOERBIGER Antriebstechnik GmbH's prior written consent.

Single-cone Synchronizer

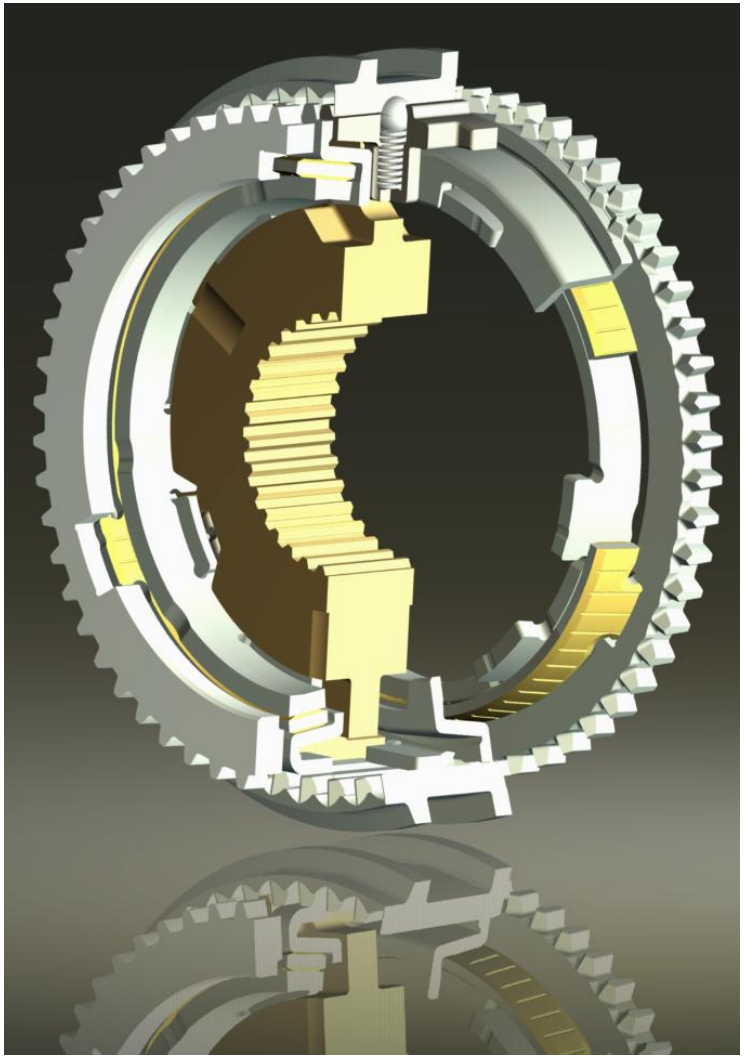


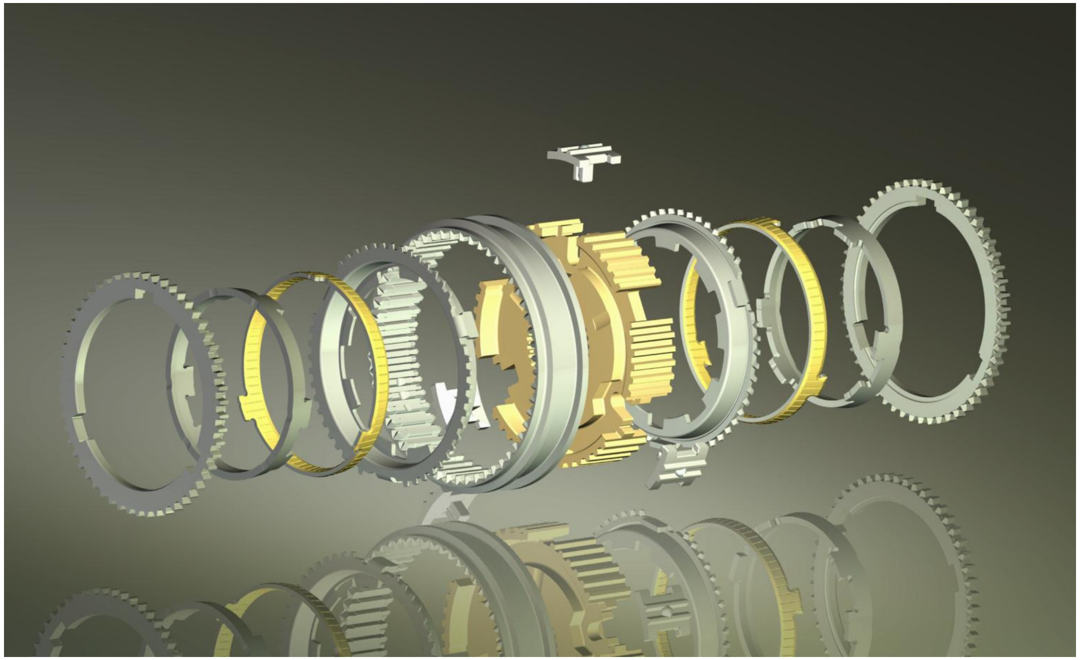


HOERBIGER

Copyright by HOERBIGER Antriebstechnik GmbH (Germany), 2013. Any kind of use in part or in full provides HOERBIGER Antriebstechnik GmbH's prior written consent.

Dual-cone Synchronizer



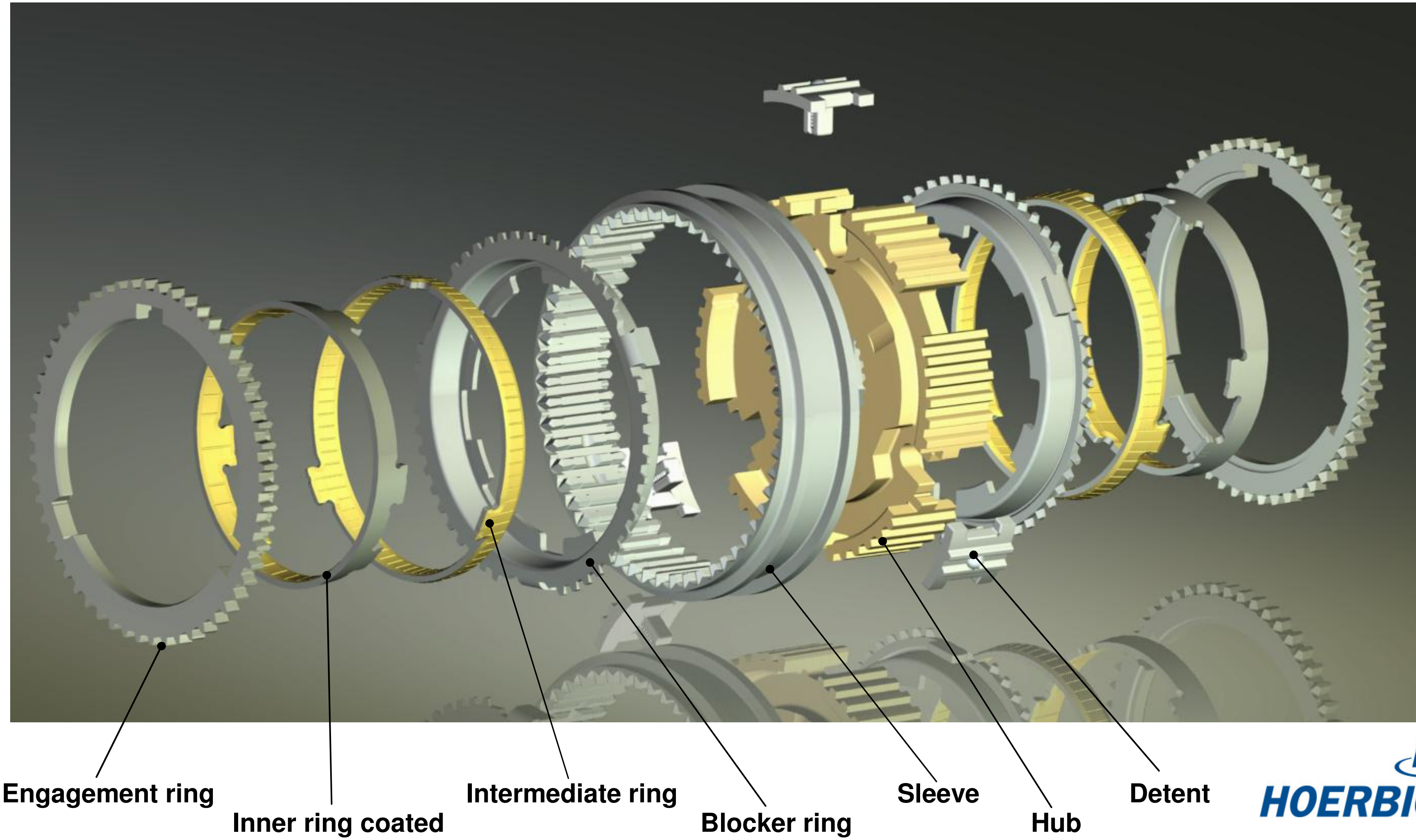


HOERBIGER

Copyright by HOERBIGER Antriebstechnik GmbH (Germany), 2013. Any kind of use in part or in full provides HOERBIGER Antriebstechnik GmbH's prior written consent.

3. The Synchronization

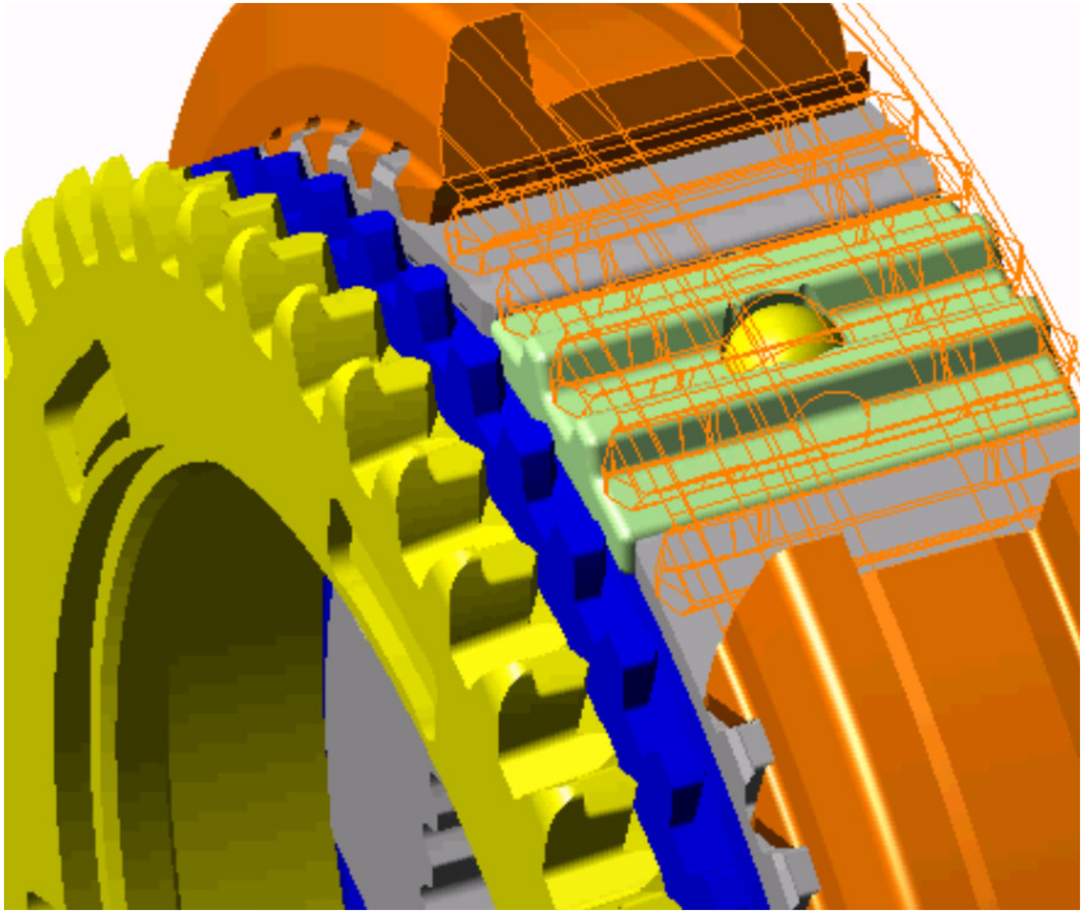
Triple-cone Synchronizer



HOERBIGER

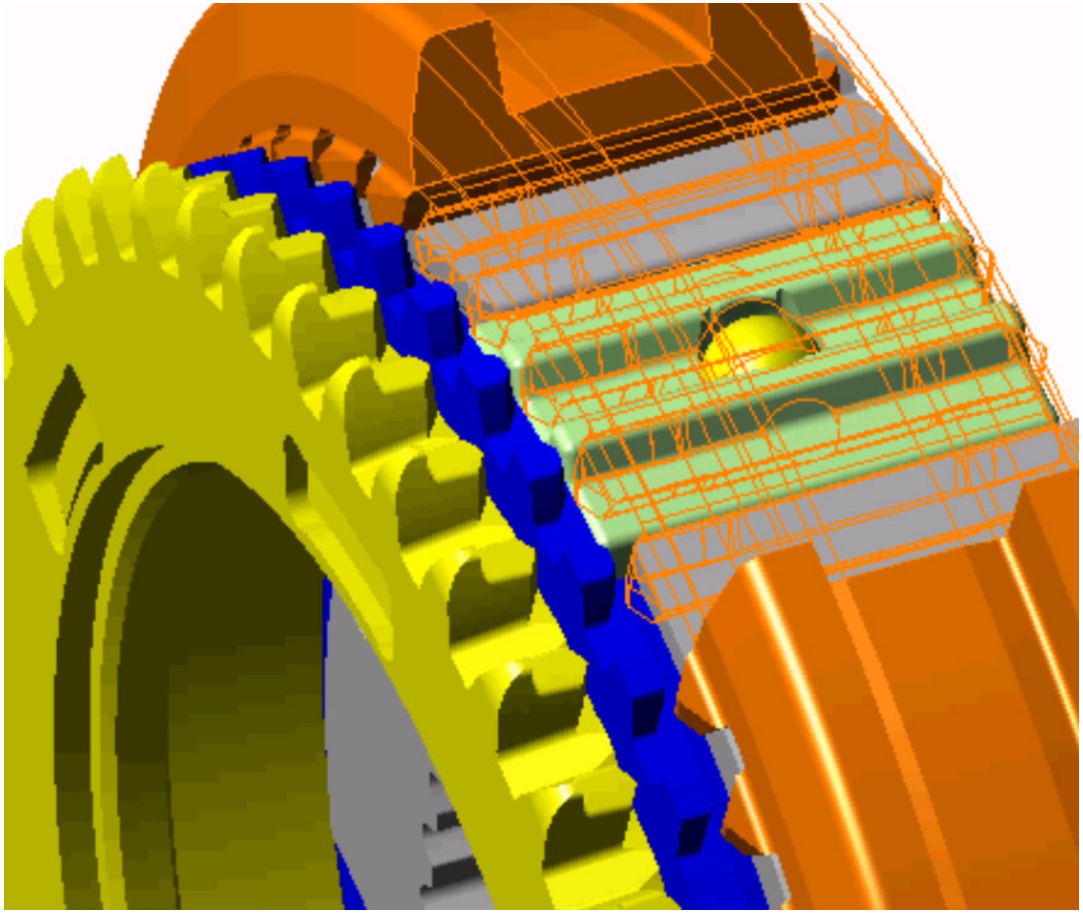
Copyright by HOERBIGER Antriebstechnik GmbH (Germany), 2013. Any kind of use in part or in full provides HOERBIGER Antriebstechnik GmbH's prior written consent.

The Synchronization Process - Neutral



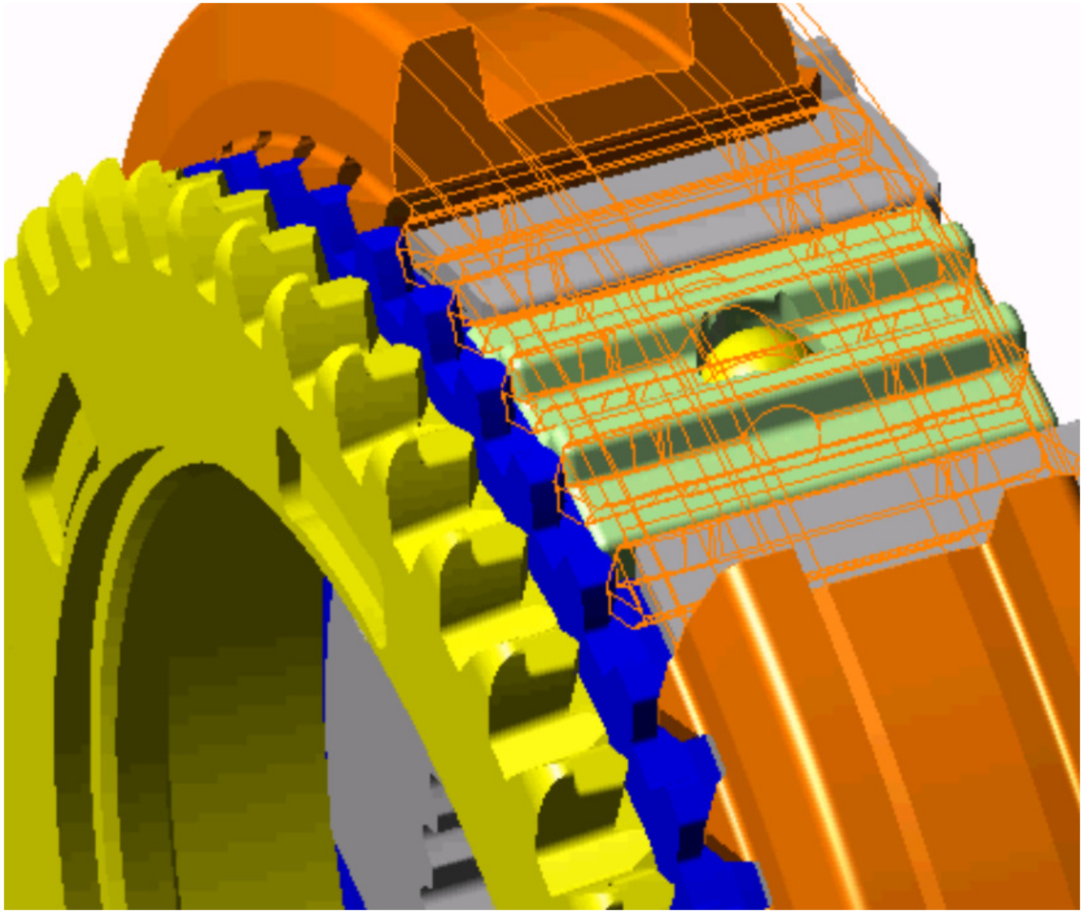
Copyright by HOERBIGER Antriebstechnik GmbH (Germany), 2013. Any kind of use in part or in full provides HOERBIGER Antriebstechnik GmbH's prior written consent.

The Synchronization Process - Presynchronization



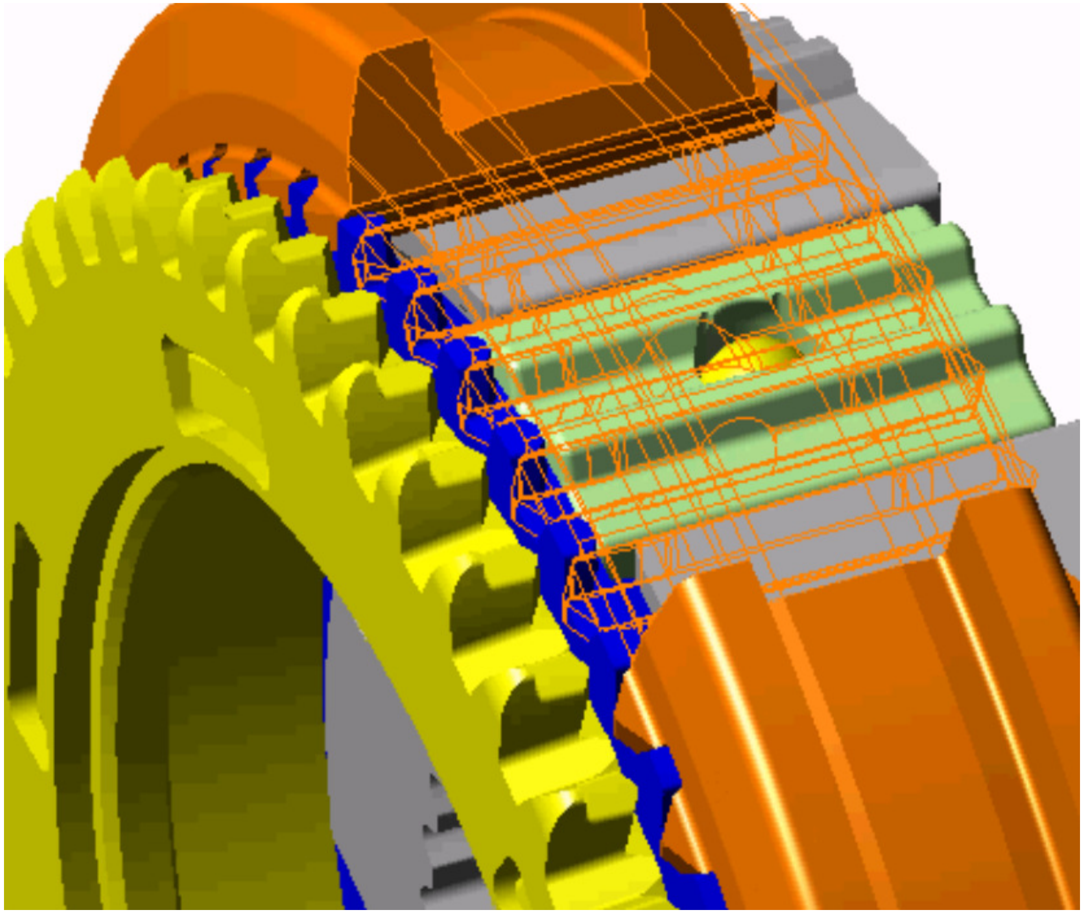
Copyright by HOERBIGER Antriebstechnik GmbH (Germany), 2013. Any kind of use in part or in full provides HOERBIGER Antriebstechnik GmbH's prior written consent.

The Synchronization Process - Synchronization



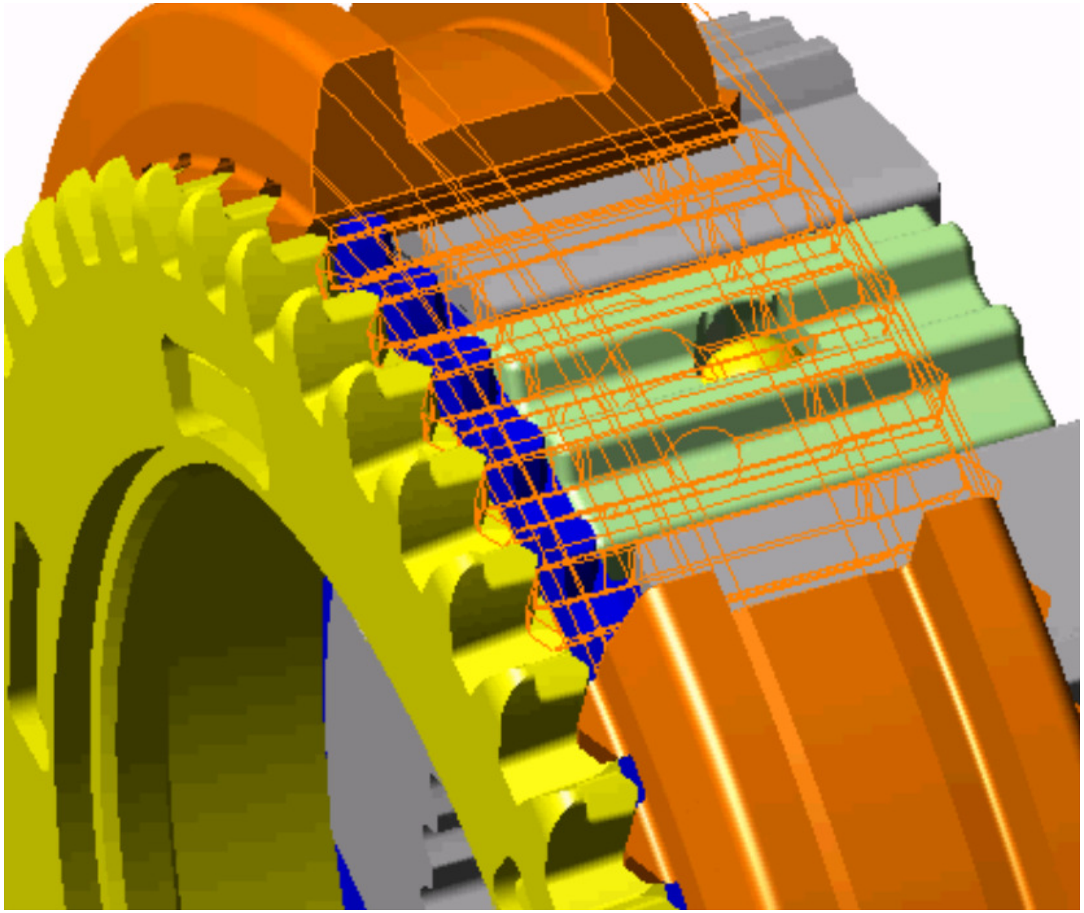
Copyright by HOERBIGER Antriebstechnik GmbH (Germany), 2013. Any kind of use in part or in full provides HOERBIGER Antriebstechnik GmbH's prior written consent.

The Synchronization Process - Blocking Release



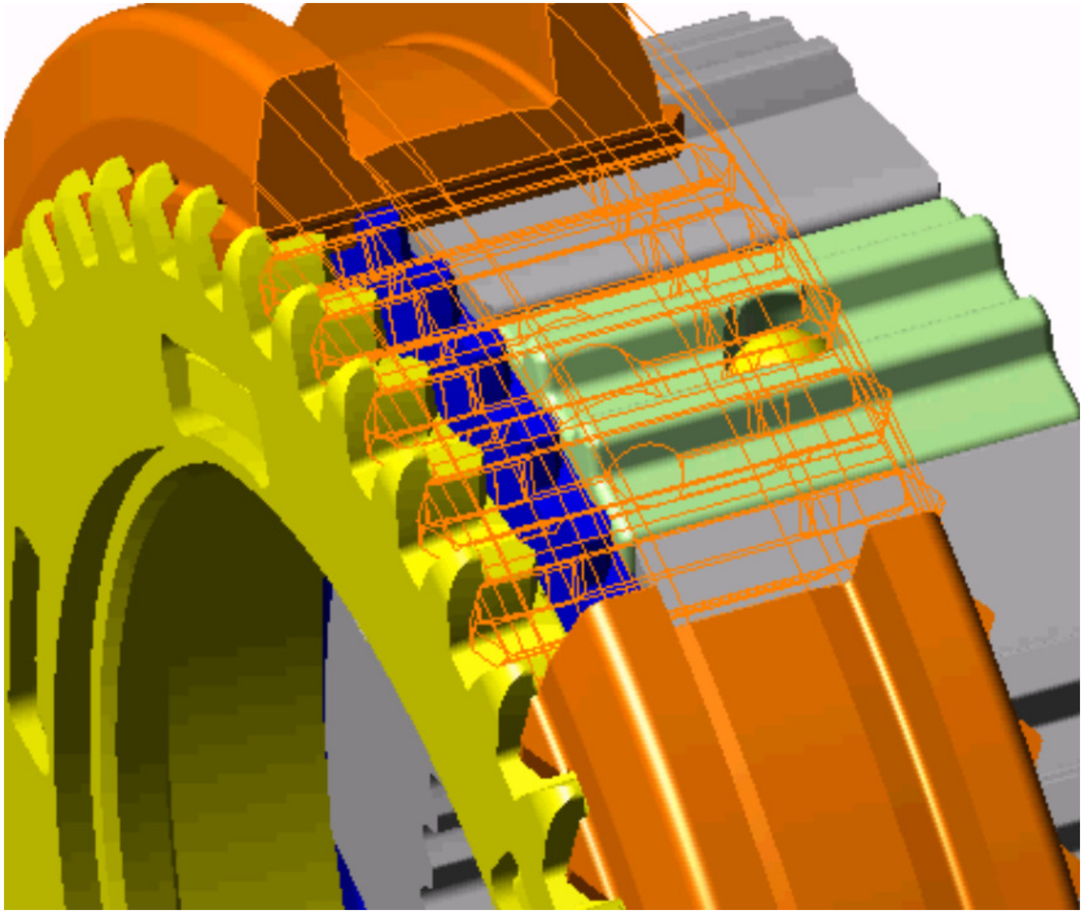
Copyright by HOERBIGER Antriebstechnik GmbH (Germany), 2013. Any kind of use in part or in full provides HOERBIGER Antriebstechnik GmbH's prior written consent.

The Synchronization Process - Engagement



Copyright by HOERBIGER Antriebstechnik GmbH (Germany), 2013. Any kind of use in part or in full provides HOERBIGER Antriebstechnik GmbH's prior written consent.

The Synchronization Process - Gear shifted

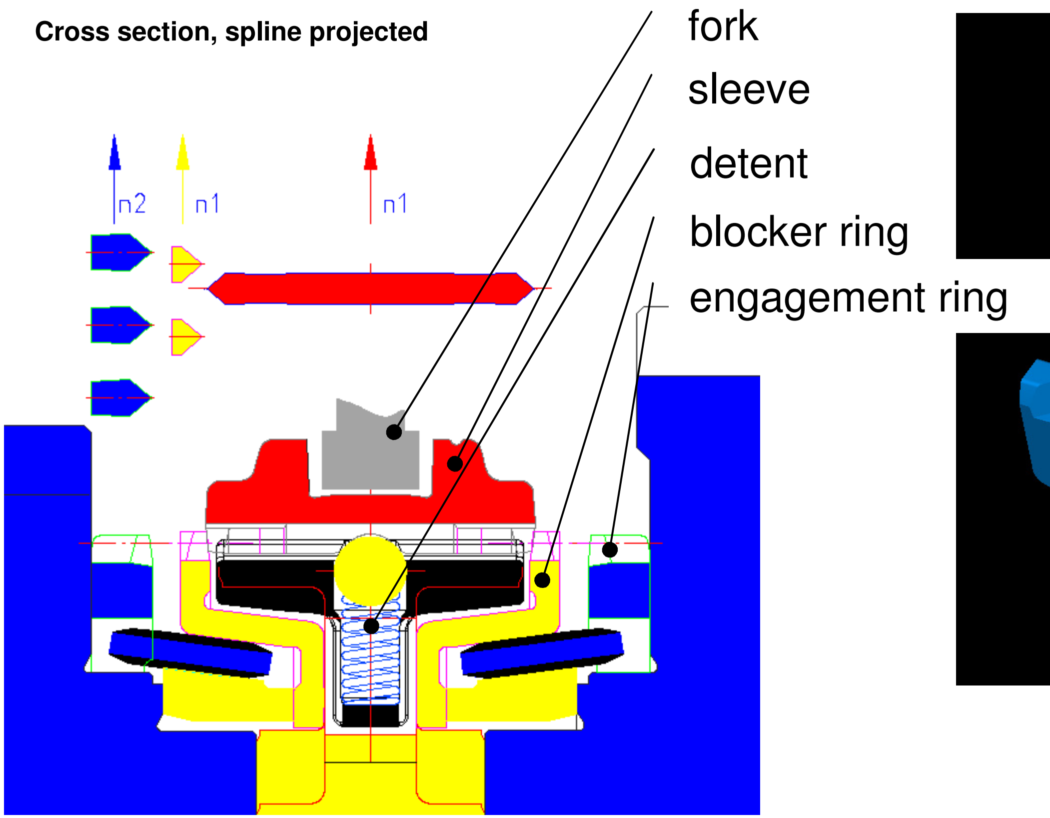


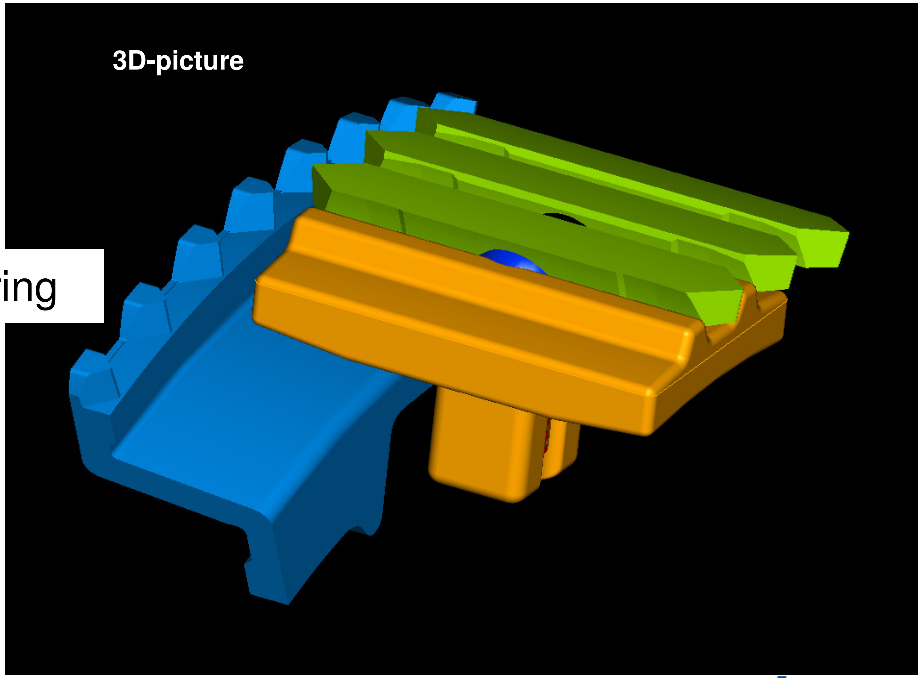
HOERBIGER

Copyright by HOERBIGER Antriebstechnik GmbH (Germany), 2013. Any kind of use in part or in full provides HOERBIGER Antriebstechnik GmbH's prior written consent.

The Synchronization Process - *neutral position*

Cross section, spline projected



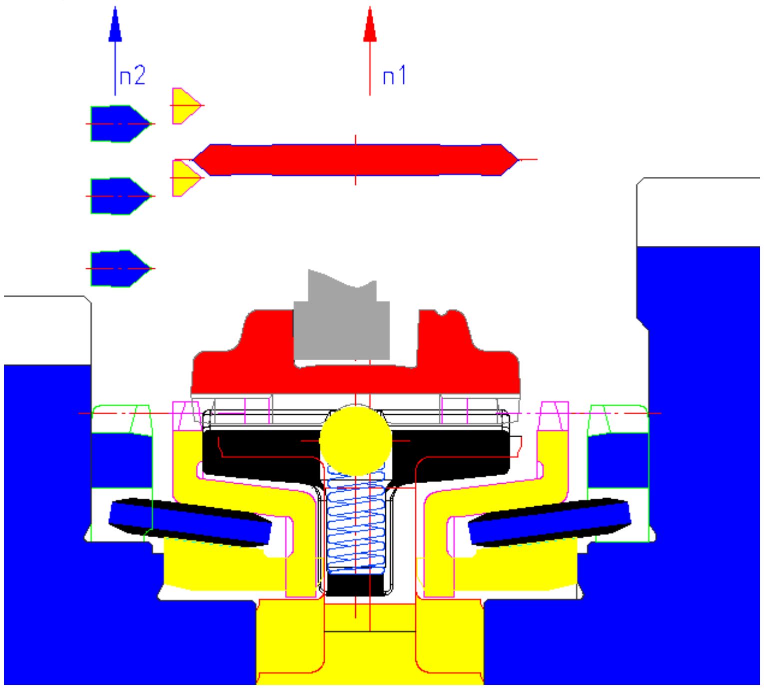


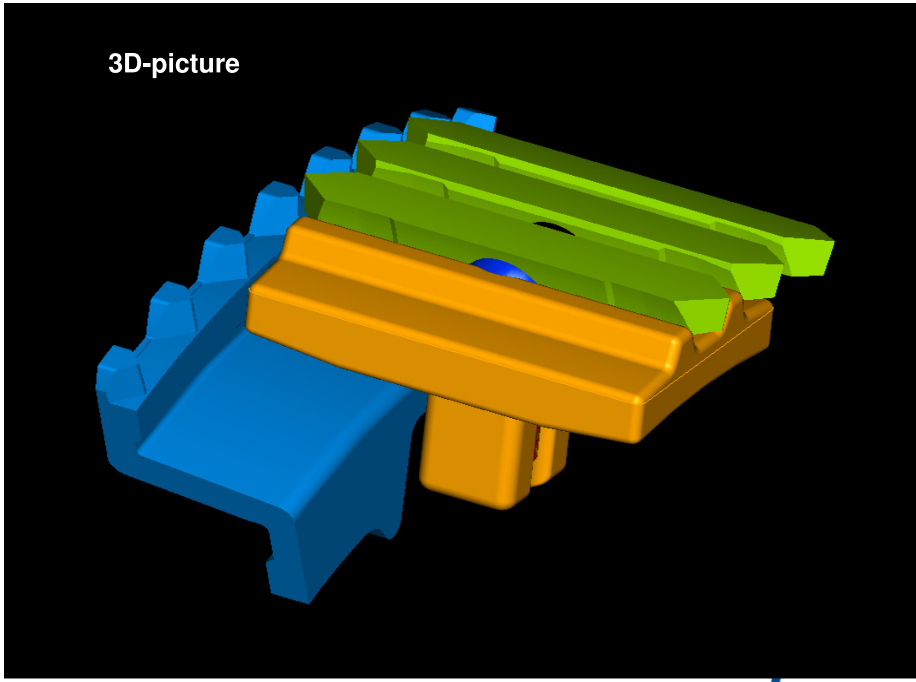
HOERBIGER

Copyright by HOERBIGER Antriebstechnik GmbH (Germany), 2013. Any kind of use in part or in full provides HOERBIGER Antriebstechnik GmbH's prior written consent.

The Synchronization Process - *presynchronization*

- The fork is moving the sleeve in axial direction until the detents have contact with the blocker ring.
- The detent force (50-100 N) creates a friction torque in the synchronizer.
- This friction torque positions the blocker ring radially. I.e. the indexing lugs at the blocker ring bend to the pockets in the hub. This positions the blocking teeth at the blocker ring against the teeth of the sleeve.



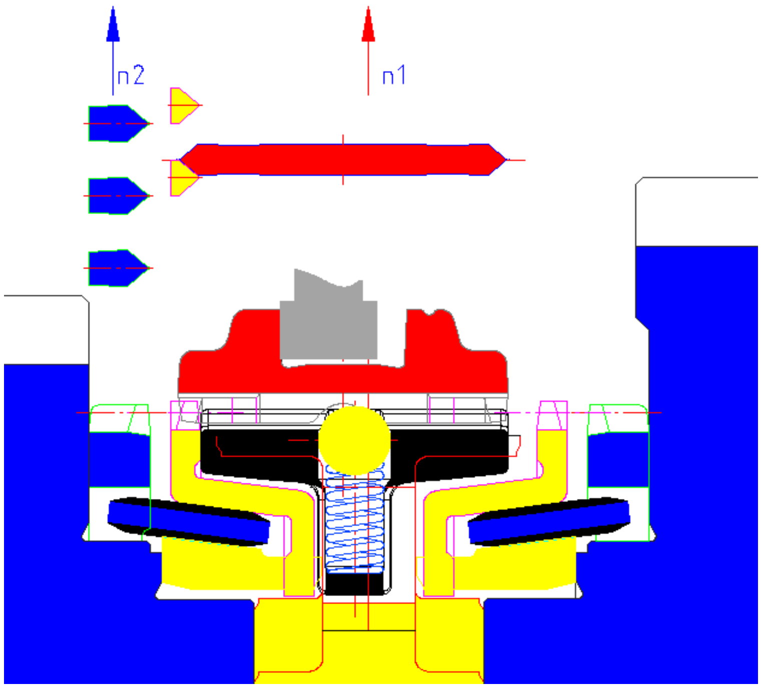


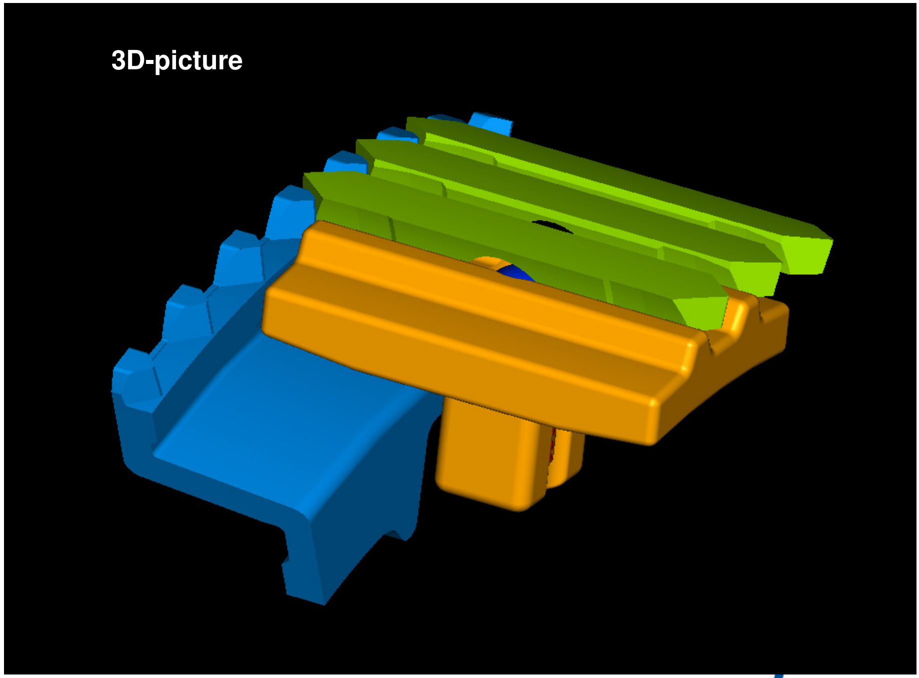
HOERBIGER

Copyright by HOERBIGER Antriebstechnik GmbH (Germany), 2013. Any kind of use in part or in full provides HOERBIGER Antriebstechnik GmbH's prior written consent.

The Synchronization Process - *blocking position*

- With higher shift force the sleeve moves towards the blocking teeth of the blocker ring
- The teeth of the sleeve push against the blocking teeth of the blocker ring
- Speed difference is reduced until n1 = n2



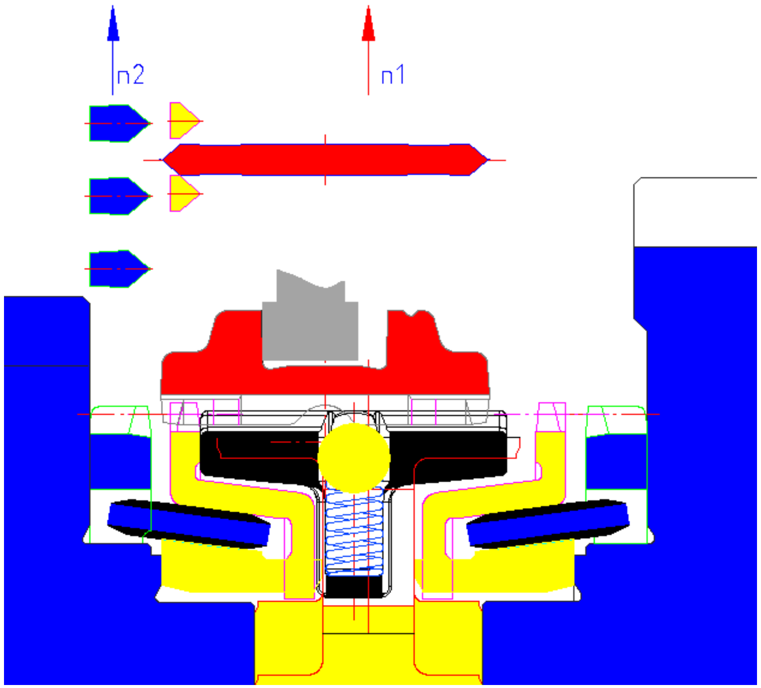


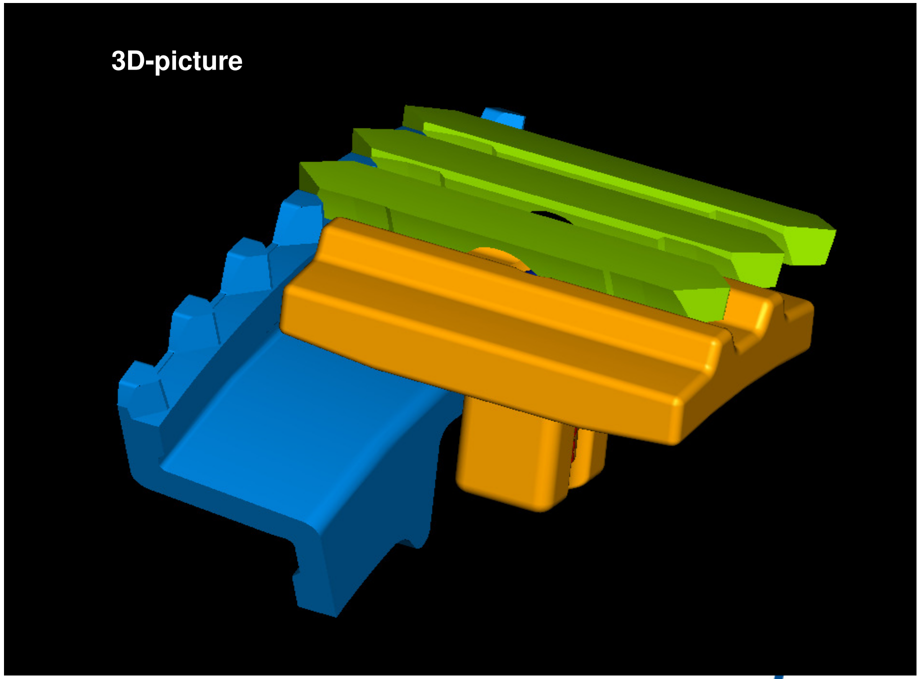
HOERBIGER

Copyright by HOERBIGER Antriebstechnik GmbH (Germany), 2013. Any kind of use in part or in full provides HOERBIGER Antriebstechnik GmbH's prior written consent.

The Synchronization Process - *blocking release*

- At speed difference ‚0‘ i.e. n1=n2 the blocking condition is no longer valid.
- The sleeve can turn back the blocker ring and move forward through the spline of the blocker ring.

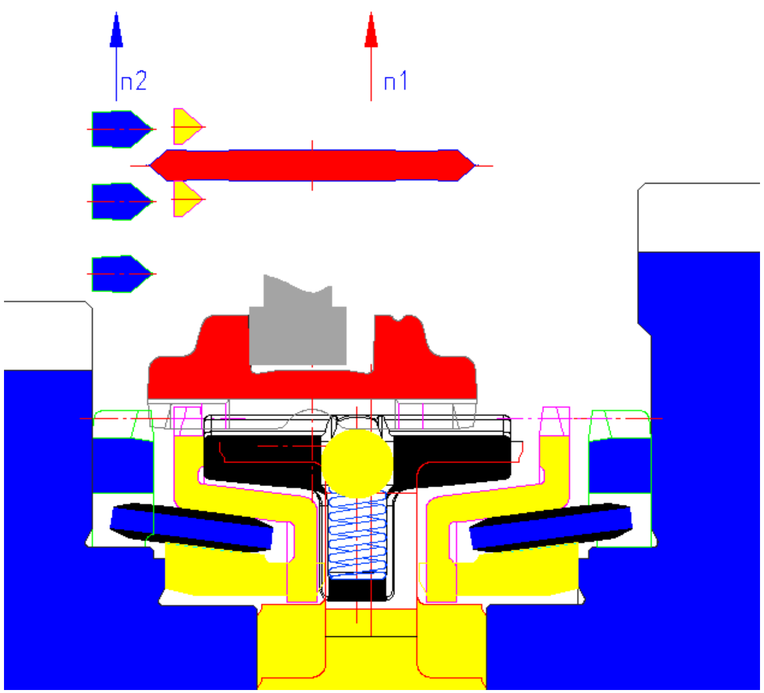


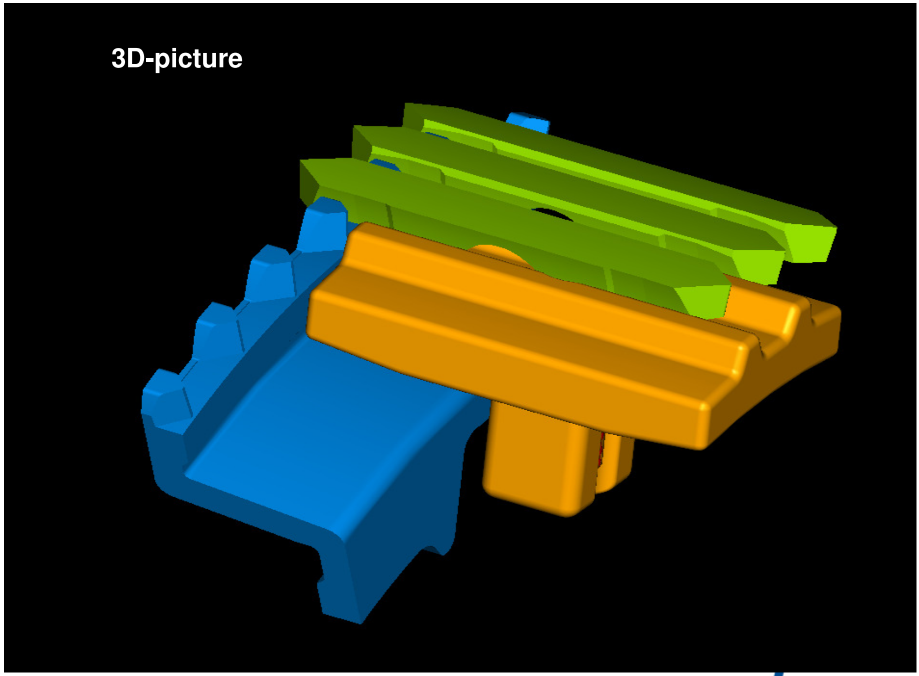


Copyright by HOERBIGER Antriebstechnik GmbH (Germany), 2013. Any kind of use in part or in full provides HOERBIGER Antriebstechnik GmbH's prior written consent.

The Synchronization Process - *free flight phase*

- The sleeve moves forward towards the spline of the engagement ring.
- In this phase a new speed difference between n1 and n2 can occure.

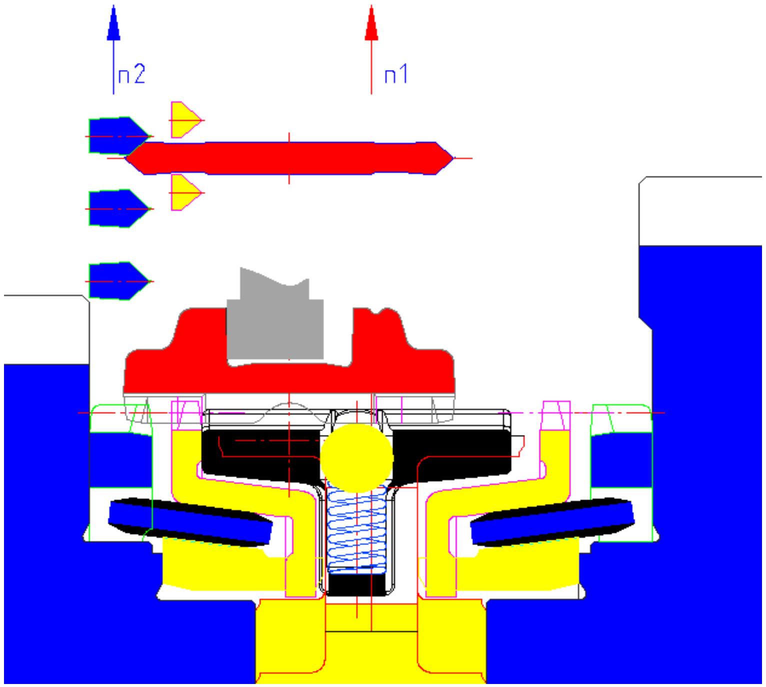


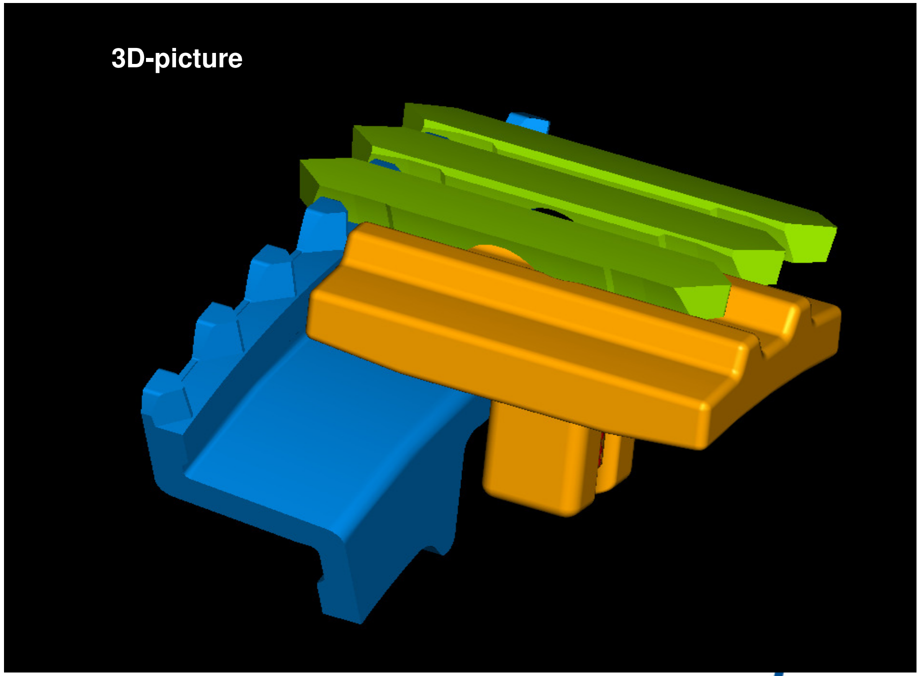


Copyright by HOERBIGER Antriebstechnik GmbH (Germany), 2013. Any kind of use in part or in full provides HOERBIGER Antriebstechnik GmbH's prior written consent.

The Synchronization Process - *engagement*

- The sleeve enters into the engegement ring.
- Speed differences between n1 and n2 can cause bumps at the entering into the engagement ring.



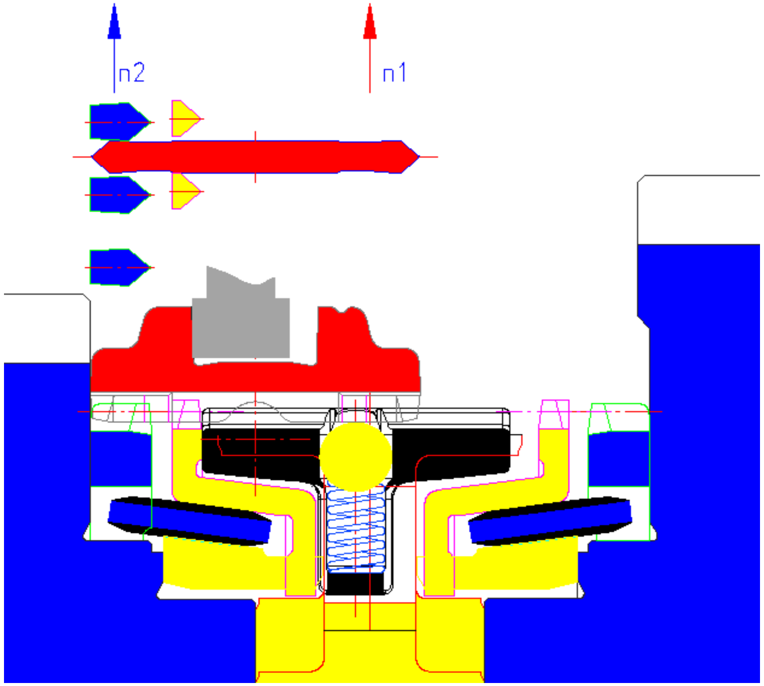


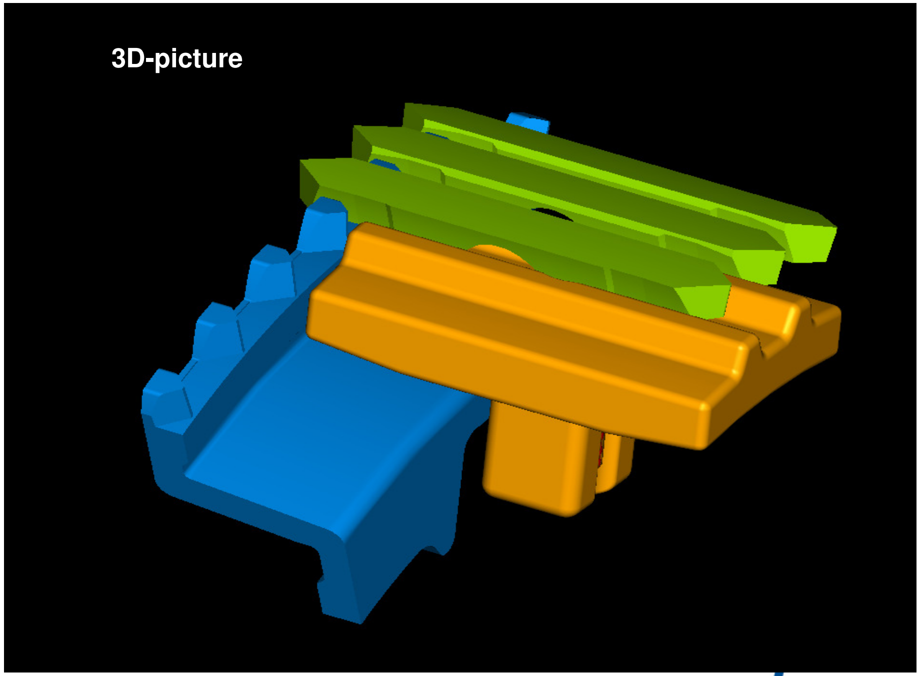
HOERBIGER

Copyright by HOERBIGER Antriebstechnik GmbH (Germany), 2013. Any kind of use in part or in full provides HOERBIGER Antriebstechnik GmbH's prior written consent.

The Synchronization Process - *gear shifted*

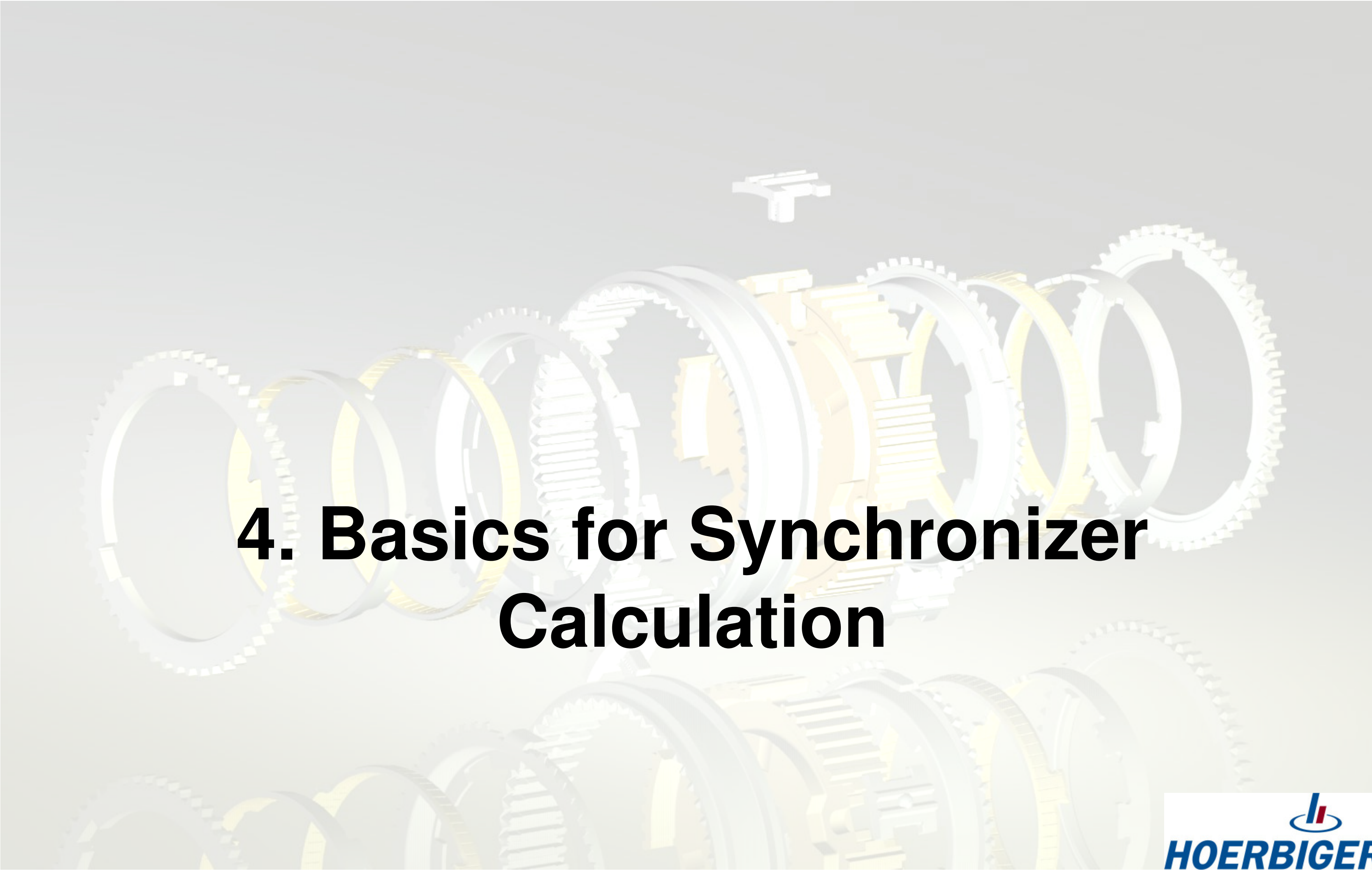
- When the sleeve has completly moved into the engagement ring the gear is shifted.
- Back tapers at the teeth of the sleeve and the engagement ring avoid decoupling under load.





HOERBIGER

Copyright by HOERBIGER Antriebstechnik GmbH (Germany), 2013. Any kind of use in part or in full provides HOERBIGER Antriebstechnik GmbH's prior written consent.



4. Basics for Synchronizer Calculation

Copyright by HOERBIGER Antriebstechnik GmbH (Germany), 2013. Any kind of use in part or in full provides HOERBIGER Antriebstechnik GmbH's prior written consent.

4. Basics for Synchronizer Calculation

The dimensioning and calculation of synchronizers has to take into account numerous parameters. The developer has to ask his customers to provide the relevant data and also has to perform screening tests to determine the c.o.f. level and characteristic of the customer's transmission oil in interaction with the different friction linings.

The capacity of a synchronizer has to be checked for the torque transmission when shifted and the synchronizing of speed difference. For torque transmitting components (sleeve, hub and engagement ring) standard FEM calculations are performed. For the calculation of the synchronizing system specific inhouse tools are in use.

The following pages list the necessary input data which will enter into the calculation sheets. The pages 34 to 40 show the basic formula needed to calculate the blocking saftey and the load data for the friction cones.

The characteristic values for different friction linings can be found in the data sheets in the download sector.

HOERBIGER

Copyright by HOERBIGER Antriebstechnik GmbH (Germany), 2013. Any kind of use in part or in full provides HOERBIGER Antriebstechnik GmbH's prior written consent.

Input

- installation space
- inertia to be synchronized
- speed difference to be synchronized
- torque to be transmitted
- transmission oil
- customers requirements (e.g. synchronizing time, shift travel, shift impulse, shift force, drag torque, load cycles, ...)
- interfaces (spline data, clearance of gear wheels, sleeve groove...)
- test definition for validation

HOERBIGER

Copyright by HOERBIGER Antriebstechnik GmbH (Germany), 2013. Any kind of use in part or in full provides HOERBIGER Antriebstechnik GmbH's prior written consent.

Limiting Factors

The capacity of a synchronizer is limited by

- torque capacity of Sleeve/Hub-System and Engagement Ring
- capacity of Friction Material (sliding speed, surface pressure, friction power, friction work)
- heat dissipation through the oil, the synchro rings and the gear cone
- transmission oil (viscosity and thermal stability) (see also next page)

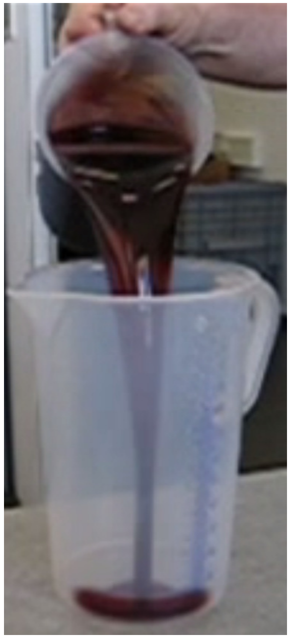
HOERBIGER

Copyright by HOERBIGER Antriebstechnik GmbH (Germany), 2013. Any kind of use in part or in full provides HOERBIGER Antriebstechnik GmbH's prior written consent.

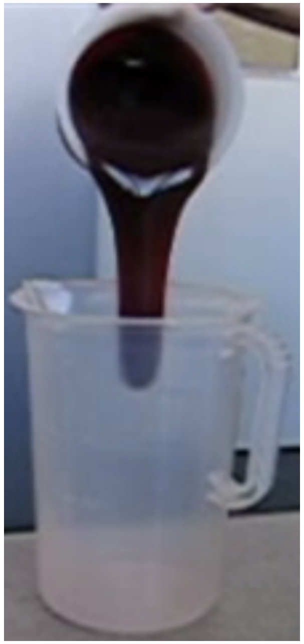
Transmission Oil

basic functions and requirements:

- cooling
- lubrication / wear protection
- corrosion protection
- anti foam
- **friction characteristic**
- compatibility with elastomeres (sealings)
- **temperature and viscosity characteristic**



low viscosity



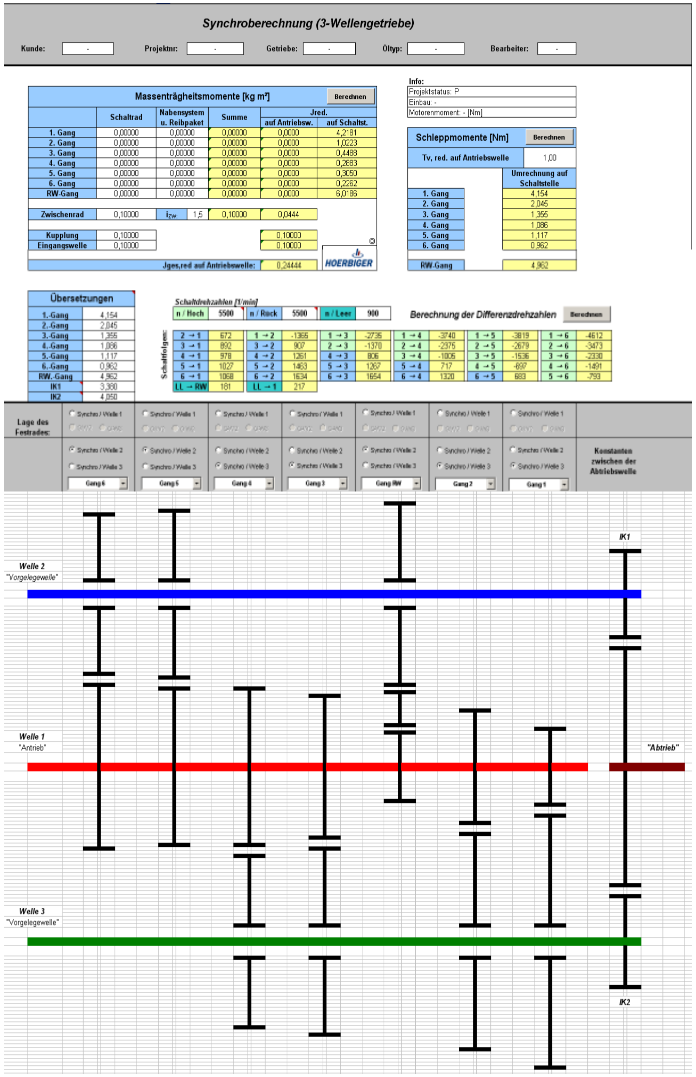
high viscosity

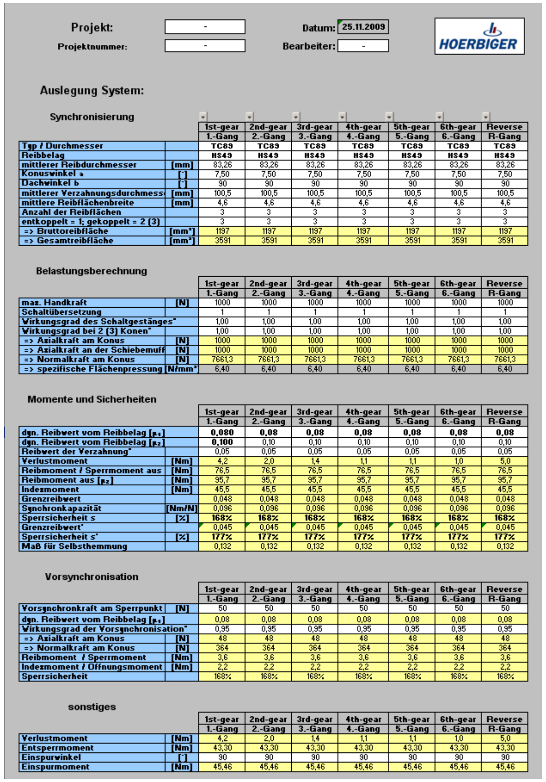
- ➢ screening test is necessary to determine the c.o.f. level and characteristic
- ➢ viscosity determines drag torque and influences shift quality

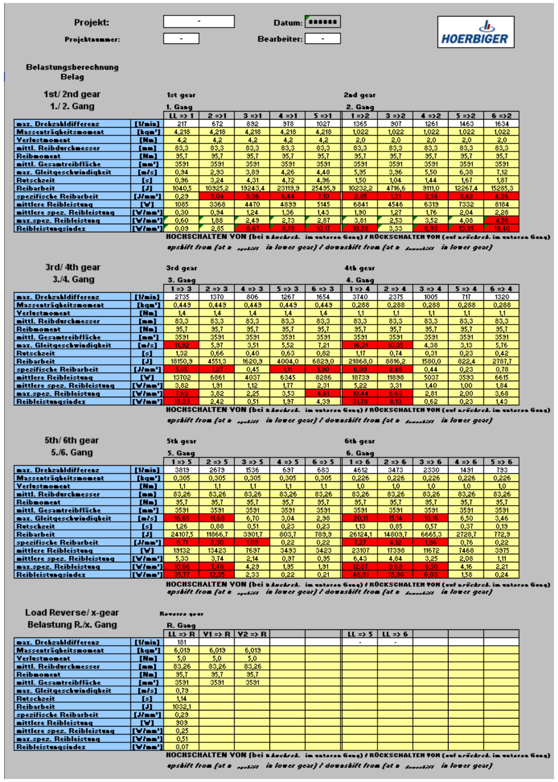
HOERBIGER

Copyright by HOERBIGER Antriebstechnik GmbH (Germany), 2013. Any kind of use in part or in full provides HOERBIGER Antriebstechnik GmbH's prior written consent.

Layout Calculation







HOERBIGER inhouse calculation tools

Copyright by HOERBIGER Antriebstechnik GmbH (Germany), 2013. Any kind of use in part or in full provides HOERBIGER Antriebstechnik GmbH's prior written consent.

Calculation of Blocking Safety

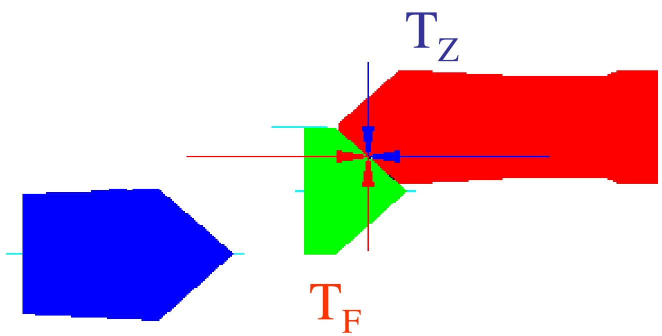
Friction Torque:

$$T_F = \frac{n_c \cdot \mu \cdot d_m \cdot F_a}{2 \cdot \sin\alpha} \quad [\mathrm{Nm}]$$

Blocking Release Torque:

$$T_Z = F_a \cdot \frac{d_D}{2} \cdot \frac{\cos\frac{\beta}{2} - \mu_D \cdot \sin\frac{\beta}{2}}{\sin\frac{\beta}{2} + \mu_D \cdot \cos\frac{\beta}{2}} \quad [\mathrm{Nm}]$$

Blocking Safety: $T_F > T_Z$



α	[°]	cone angle
β	[°]	chamfer angle
μ	[-]	c.o.f. of cone
μ_D	[-]	c.o.f. of chamfers
d_m	[mm]	mean cone diameter
d_D	[mm]	pitch diameter
F_a	[N]	shift force at sleeve
n_c	[-]	number of cones

→ **Blocking safety is given if $T_F > T_Z$**

HOERBIGER

Copyright by HOERBIGER Antriebstechnik GmbH (Germany), 2013. Any kind of use in part or in full provides HOERBIGER Antriebstechnik GmbH's prior written consent.

Calculation of specific friction work q_A

$$q_A = \frac{W}{A} \text{ [J/mm}^2\text{]}$$

$$W = \frac{1}{2}\left(-J \cdot \Delta\omega^2 \pm T_V \cdot \Delta\omega \cdot t_R\right)$$

$$\Delta\omega = \Delta n_{SYN} \times 2\pi / 60$$

t_R	[s]	slipping time
T_V	[Nm]	drag torque
J	[kgm²]	mass moment of inertia
n_{SYN}	[min^{-1}]	speed difference to synchronize
A	[mm²]	total friction surface
W	[J]	friction work

HOERBIGER

Copyright by HOERBIGER Antriebstechnik GmbH (Germany), 2013. Any kind of use in part or in full provides HOERBIGER Antriebstechnik GmbH's prior written consent.

Calculation of mean specific friction power P_{mA}

$$P_{mA} = \frac{q_A}{t_R} \text{[W/mm²]} \quad \text{or} \quad P_{mA} = \frac{P_m}{A} \text{ [W/mm²]}$$

$$P_m = \frac{W}{t_R}$$

t_R	[s]	slipping time
P_m	[W]	mean friction power
q_A	[J/mm²]	specific friction work
A	[mm²]	total friction surface
W	[J]	friction work

HOERBIGER

Copyright by HOERBIGER Antriebstechnik GmbH (Germany), 2013. Any kind of use in part or in full provides HOERBIGER Antriebstechnik GmbH's prior written consent.

Calculation of max. sliding speed v_{max}

$$v_{max} = \Delta n_{SYN} / 60 \times \pi \times d_{max} \quad [\mathrm{m/s}]$$

d_{max}	[mm]	max. cone diameter
n_{SYN}	[min^{-1}]	speed difference to synchronize

HOERBIGER

Copyright by HOERBIGER Antriebstechnik GmbH (Germany), 2013. Any kind of use in part or in full provides HOERBIGER Antriebstechnik GmbH's prior written consent.

Calculation of mean specific pressure p_m

$$p_m = \frac{F_N}{(A / n_c)} \text{ [N/mm}^2\text{]}$$

$$F_N = (T_F / (\mu \times d_m / 2)) / n_c$$

$$T_F = J \times \Delta\omega / t_R$$

t_R	[s]	slipping time
J	[kgm²]	mass moment of inertia
T_F	[Nm]	friction torque
n_c	[-]	number of cones
d_m	[mm]	mean cone diameter
µ	[-]	coefficient of friction c.o.f.
F_N	[N]	normal force on cone
A	[mm²]	total friction surface

HOERBIGER

Copyright by HOERBIGER Antriebstechnik GmbH (Germany), 2013. Any kind of use in part or in full provides HOERBIGER Antriebstechnik GmbH's prior written consent.

Calculation of max. specific friction power P_{max}

$$P_{max} = p_m \times v_{max} \times \mu \quad [W]$$

μ	[-]	coeffiecient of friction c.o.f.
v_{max}	[m/s]	max. sliding speed
p_m	[N/mm²]	mean specific pressure

HOERBIGER

Copyright by HOERBIGER Antriebstechnik GmbH (Germany), 2013. Any kind of use in part or in full provides HOERBIGER Antriebstechnik GmbH's prior written consent.

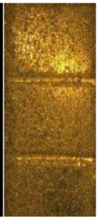
Characteristic values for calculated parameters

HOERBIGER **Synchronizers - Competence in Systems**

HOERBIGER HS90 – Sinter Layer

- Improved c.o.f. characteristic
- Stable c.o.f. at high loads
- Adapted to latest oil developments
- Suitable for *HOERBIGER* Classic and *HOERBIGER* SKS

load parameters standard values!	permanent load	overload
sliding speed (m/s)	10	20
surface pressure (N/mm²)	8	10
friction work (J/mm²)	1	2
friction power (W/mm²)	4.5	10
c.o.f. values	$0.09 < \mu < 0.120$	



load parameters are dependent on type of oil and lubrication

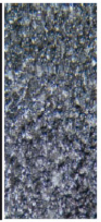
Product Information
Friction Linings

HOERBIGER **Synchronizers - Competence in Systems**

HOERBIGER HC300 – Carbon Dual Layer

- A friction lining for all high-end applications
- Benchmark for comfort and robustness
- Suitable for *HOERBIGER* Classic

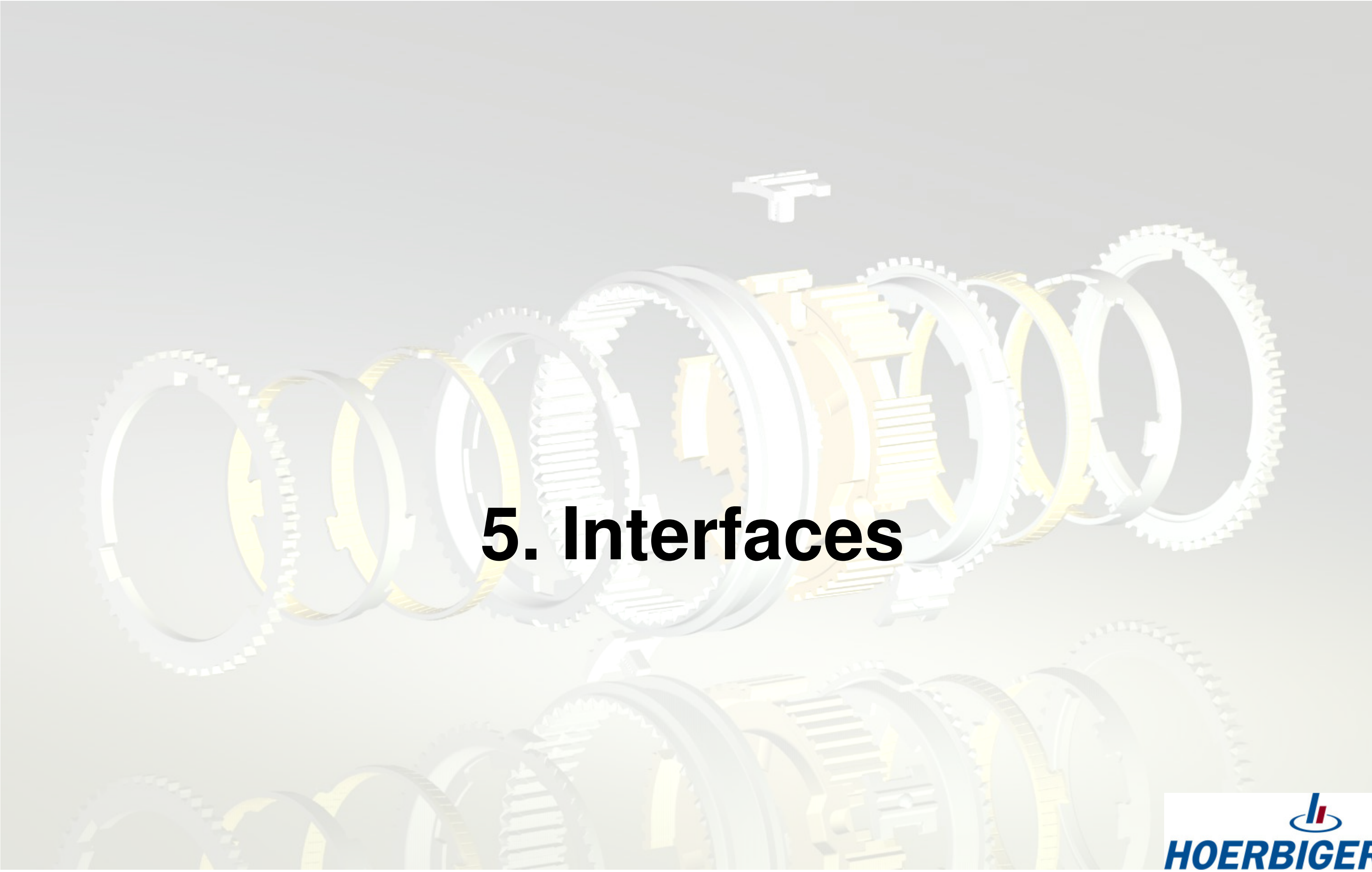
load parameters standard values!	permanent load	overload
sliding speed (m/s)	14	20
surface pressure (N/mm²)	10	16
friction work (J/mm²)	1.5	4
friction power (W/mm²)	10	14
c.o.f. values	$0.1 < \mu < 0.140$	



load parameters are dependent on type of oil and lubrication

Product Information
Friction Linings

Copyright by HOERBIGER Antriebstechnik GmbH (Germany), 2013. Any kind of use in part or in full provides HOERBIGER Antriebstechnik GmbH's prior written consent.



5. Interfaces

Copyright by HOERBIGER Antriebstechnik GmbH (Germany), 2013. Any kind of use in part or in full provides HOERBIGER Antriebstechnik GmbH's prior written consent.

5. Interfaces

The definition of interfaces between the synchronizer system and the transmission is essential for a proper function and durability.

- **The neutral position of the shift fork determines the clearance of the synchronizer rings. Low clearance will cause drag torque and in extreme cases overheat and destroy the friction lining.**

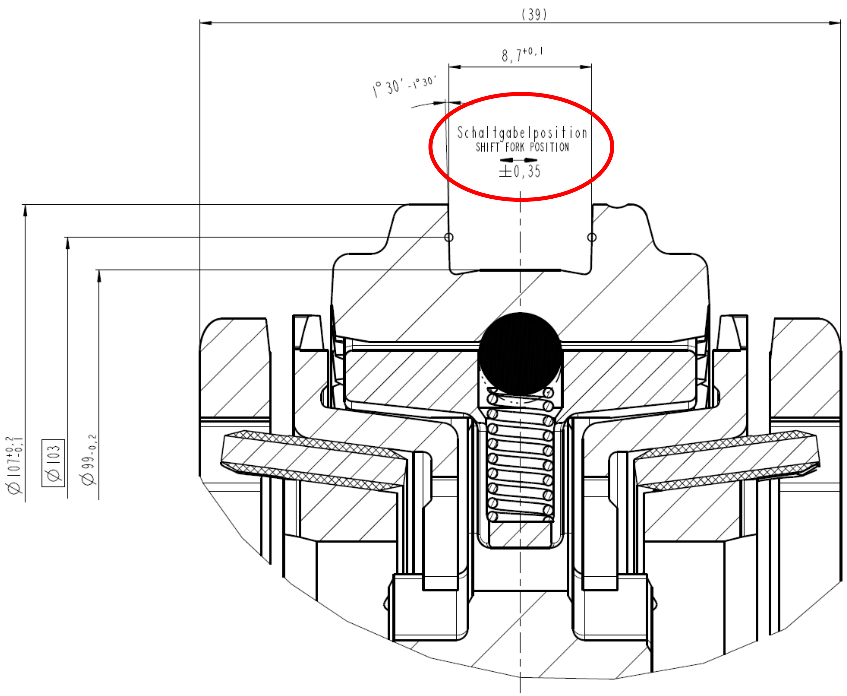
- **The clearance of the gear wheels determine the maximum possible axial space for the synchro rings. Too much clearance can cause a decoupling of blocker rings from the hub or what is more likely from blocker rings and inner rings in multi-cone synchronizers.**

HOERBIGER

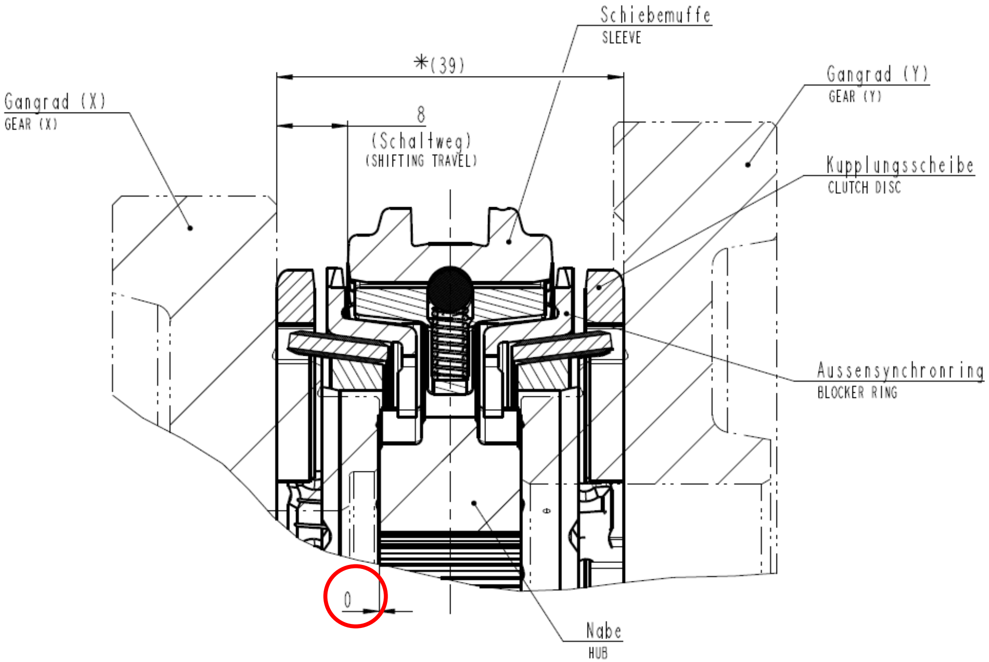
Copyright by HOERBIGER Antriebstechnik GmbH (Germany), 2013. Any kind of use in part or in full provides HOERBIGER Antriebstechnik GmbH's prior written consent.

Shift Fork / Gear Wheel

The neutral position of the shift fork should not exceed +/- 0,35 mm.



The clearance between hub and gear wheel should not exceed 0,4 mm.



Drawing shows gear wheels touching the hub

Copyright by HOERBIGER Antriebstechnik GmbH (Germany), 2013. Any kind of use in part or in full provides HOERBIGER Antriebstechnik GmbH's prior written consent.

6. Functional Problems and Solutions

Copyright by HOERBIGER Antriebstechnik GmbH (Germany), 2013. Any kind of use in part or in full provides HOERBIGER Antriebstechnik GmbH's prior written consent.

6. Functional Problems and Solutions

During development and testing functional problems have to be detected and solutions have to be fixed.

Typical problems and possible solutions are summarized on the next pages.

- **To avoid functional problems already in the design phase it is necessary to combine long-time experience and high level of data quality.**

- **To solve occuring problems a detailed analysis has to be carried out in advance by recording shift curves in the vehicle or transmission test rig.**

- **Solutions can be developed and tested first in a simulation model before manufacturing prototypes for validation in the vehicle.**

HOERBIGER

Copyright by HOERBIGER Antriebstechnik GmbH (Germany), 2013. Any kind of use in part or in full provides HOERBIGER Antriebstechnik GmbH's prior written consent.

Shift Force F_a too high

$$F_a = \frac{2 \cdot \sin\alpha \cdot J \cdot \Delta\varpi}{n_c \cdot \mu \cdot d_m \cdot t_F}$$

To reduce the shift force following measures can be taken:

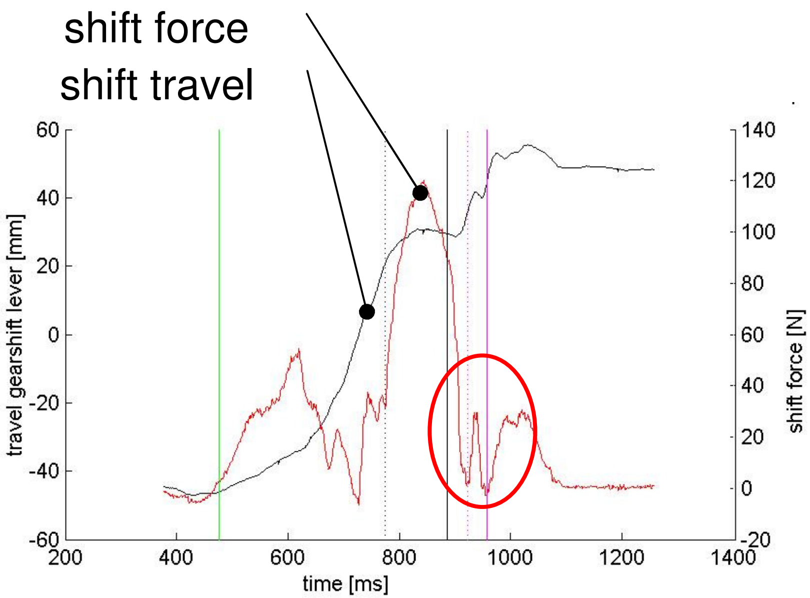
- increase diameter d_m
- increase number of cones n_c
- increase c.o.f. (friction lining, oil)
- reduce cone angle α

! to avoid self-locking $\mu < \tan\alpha$

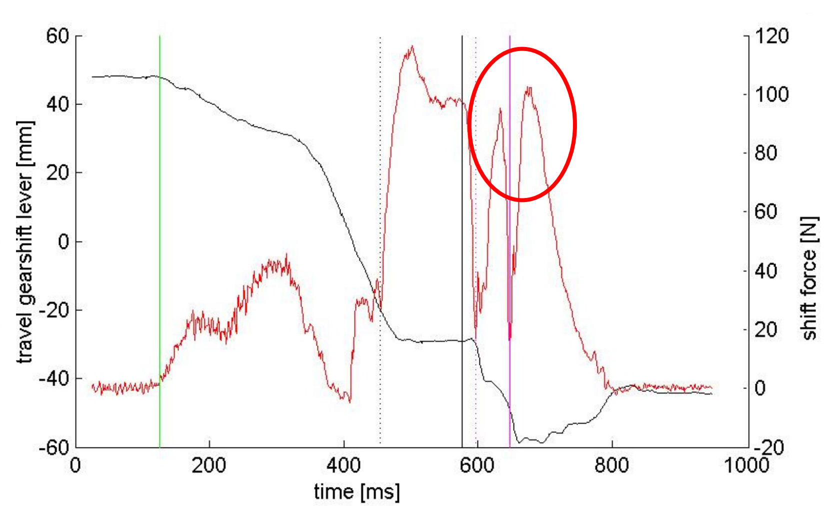
Copyright by HOERBIGER Antriebstechnik GmbH (Germany), 2013. Any kind of use in part or in full provides HOERBIGER Antriebstechnik GmbH's prior written consent.

Shift Quality - 2nd load bump

The 2nd load bump occurs when the sleeve enters into the engagement ring. If the resistance is too high, it can be felt at the shift knob.



Low 2nd load bump



High 2nd load bump

HOERBIGER

Copyright by HOERBIGER Antriebstechnik GmbH (Germany), 2013. Any kind of use in part or in full provides HOERBIGER Antriebstechnik GmbH's prior written consent.

Shift Quality - 2nd load bump

The 2nd load bump occurs when the sleeve enters into the engagement ring. If the resistance is too high it can be felt at the shift knob.

Reasons for 2nd load bumps can be:

- high drag torque, esp. in cold transmission > reduces input speed in free flight phase
- high friction torque T_F, > oscillation of driveline
- losses in shift system > high friction in cable shift
- clutch not 100% open

Possible measures:

- low viscosity oil, low friction bearings
- reduced chamfer angle (blocking safety must be respected)
- reduced losses in shift system (low friction cable shift)

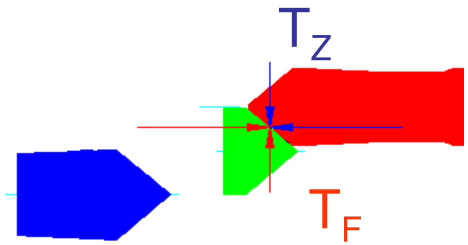
HOERBIGER

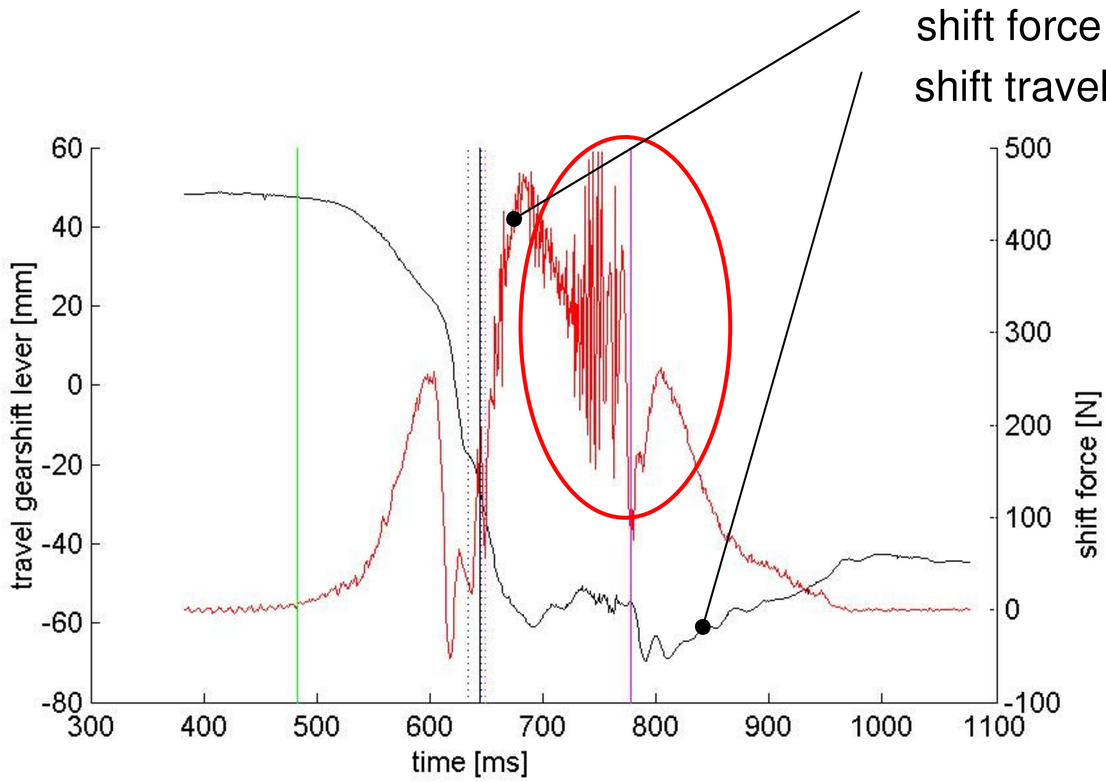
Copyright by HOERBIGER Antriebstechnik GmbH (Germany), 2013. Any kind of use in part or in full provides HOERBIGER Antriebstechnik GmbH's prior written consent.

Shift Quality - clash

Clash occurs when the blocking safety is not given. In this case the sleeve moves towards the engagement ring before the speed difference has been synchronized.

blocking safety: $T_F > T_Z$





clash event

Copyright by HOERBIGER Antriebstechnik GmbH (Germany), 2013. Any kind of use in part or in full provides HOERBIGER Antriebstechnik GmbH's prior written consent.

Shift Quality - clash

Clash occurs when the blocking safety is not given. In this case the sleeve moves towards the engagement ring before the speed difference has been synchronized.

Reasons for clash can be:

- c.o.f. too low for design layout
- c.o.f. changes over lifetime > degradation of lining or oil
- oil viscosity too high at low temperature > cold clash
- high wear > loss of wear gap

Possible measures:

- increase blocking safety (chamfer angle, cone angle, friction lining)
- improve groove geometry (cold clash)
- improve c.o.f. increase in presynchronization (detent force)
- increase wear gap

HOERBIGER

Copyright by HOERBIGER Antriebstechnik GmbH (Germany), 2013. Any kind of use in part or in full provides HOERBIGER Antriebstechnik GmbH's prior written consent.

Shift Quality - clash

A specific reason for clash can also be extreme wear and/or drop of c.o.f. due to an overheating of the friction rings

Reasons for overheating can be:

- misuse (shifting against closed clutch, ...)
- insufficient design (e.g. too small clearance, ...)
- shift fork position decentralized

Possible measures:

- instruction of drivers
- reduce tolerances for gear clearance
- install detent to center the sleeve to the hub

Copyright by HOERBIGER Antriebstechnik GmbH (Germany), 2013. Any kind of use in part or in full provides HOERBIGER Antriebstechnik GmbH's prior written consent.

Shift Quality - gear jump out

After the gear has been shifted the sleeve decouples from the engagement ring.

Reasons for gear jump out can be:

- back taper angle too small
- tumbling of the sleeve due to run out failures at the connected parts

HOERBIGER

Copyright by HOERBIGER Antriebstechnik GmbH (Germany), 2013. Any kind of use in part or in full provides HOERBIGER Antriebstechnik GmbH's prior written consent.

Shift Quality - blocking of 1^{st}- or R-gear

Gear can‘t be engaged when the vehicle is not moving

Reasons for blocking of 1^{st}- and R-gear:

- self-locking ($\mu > \tan\alpha$)
- double engagement
- detent not released
- clutch not 100% open

HOERBIGER

Copyright by HOERBIGER Antriebstechnik GmbH (Germany), 2013. Any kind of use in part or in full provides HOERBIGER Antriebstechnik GmbH's prior written consent.

7. HOERBIGER Capabilities

7.1. Design & Development

Copyright by HOERBIGER Antriebstechnik GmbH (Germany), 2013. Any kind of use in part or in full provides HOERBIGER Antriebstechnik GmbH's prior written consent.

7.1. Design & Development

Strategic Target of HOERBIGER Product Development is

‚Technological Cost Leadership‘.

Under Technological Cost Leadership we assume the capability to simplify the overall synchronizer system to generate functional high-value synchronizer systems at costs below those of todays state of the art synchronizers

The Technological Cost Leadership enables us to offer to our customers taylored system design with the best price-performance ratio.

To achieve this ambitious target it is essential

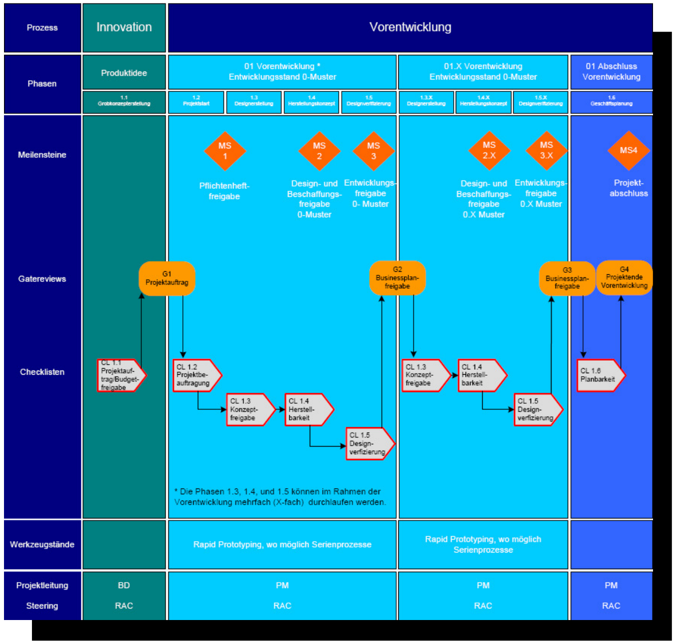
- to posses fundamental knowledge on tribology, materials and production processes and
- to fully understand the requirements for function and durability of synchronizer components and systems,
- to apply suitable tools for calculations, simulations and design,
- to make use of relevant test rigs for validation of function and durability and
- to be able to assess shift quality by measurement and subjective evaluation.

HOERBIGER

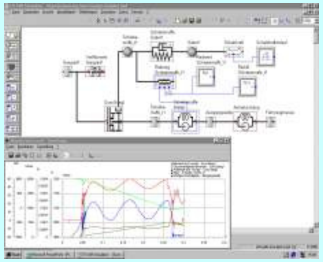
Copyright by HOERBIGER Antriebstechnik GmbH (Germany), 2013. Any kind of use in part or in full provides HOERBIGER Antriebstechnik GmbH's prior written consent.

Development Tools

Development follows Stage-Gate Pocess

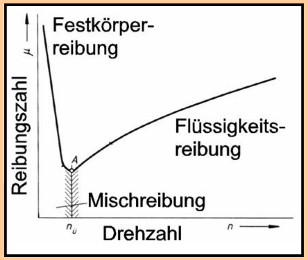


Simulation

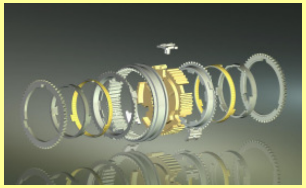


Testing

Tribology



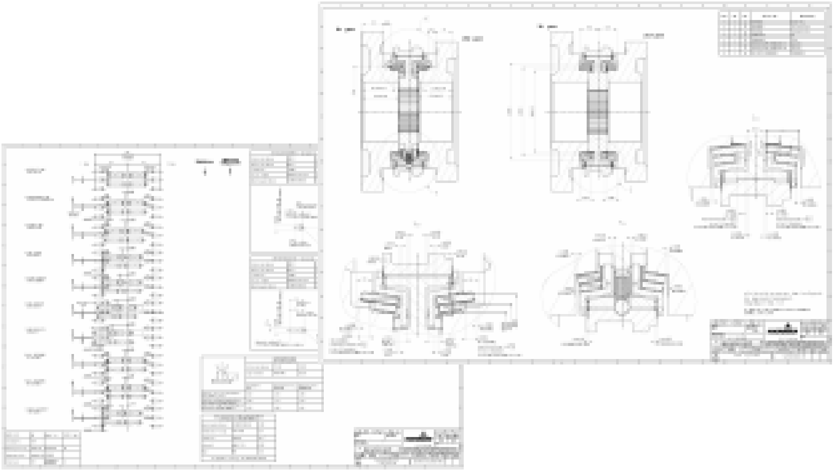
Design



Copyright by HOERBIGER Antriebstechnik GmbH (Germany), 2013. Any kind of use in part or in full provides HOERBIGER Antriebstechnik GmbH's prior written consent.

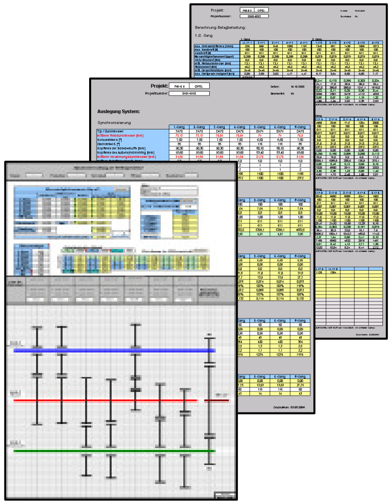
7.1. Design & Development

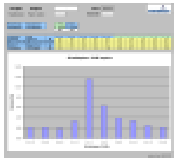
Development Tools

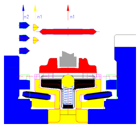


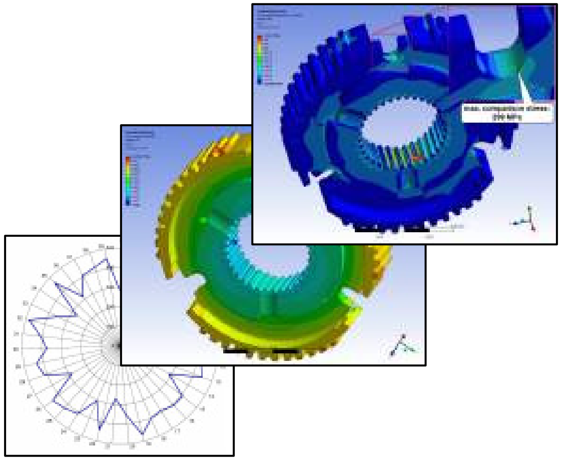
<u>Concept Layout / Design</u>

- System Layout
- Concept Definition
- Design Engineering
- Analysis of Functionality
- Optimization of existing Systems









Copyright by HOERBIGER Antriebstechnik GmbH (Germany), 2013. Any kind of use in part or in full provides HOERBIGER Antriebstechnik GmbH's prior written consent.

Development Tools

Modeling

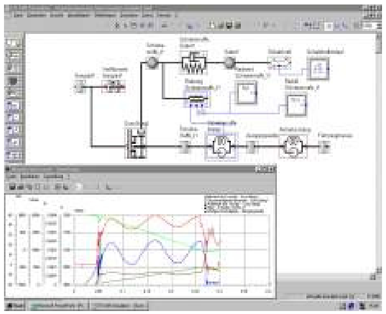
- modular model design
- efficient modeling
- adapted to vehicle environment
- dynamic 3-dimensional visualization

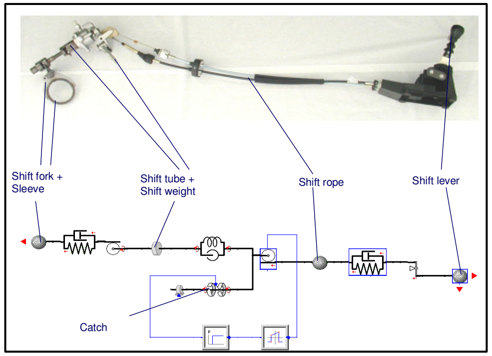
Simulation

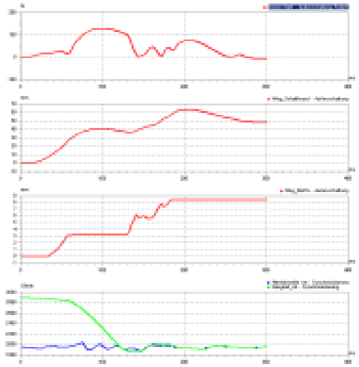
- statistical parameter variation
- parameter variation with DoE
- analysis of complex interactions and optimization of subsystems

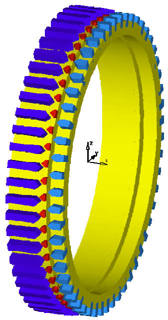
Validation

- check of characteristic values at components
- system validation by rig and vehicle measurements





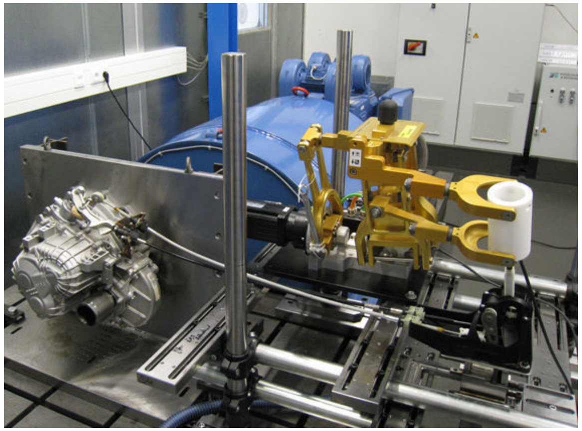




Copyright by HOERBIGER Antriebstechnik GmbH (Germany), 2013. Any kind of use in part or in full provides HOERBIGER Antriebstechnik GmbH's prior written consent.

Development Tools

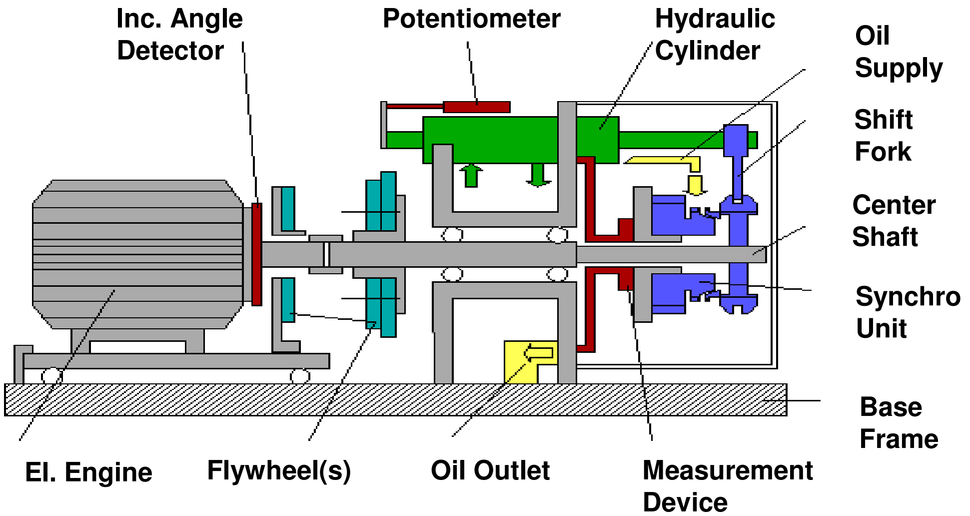
- tribometer
- synchronizer test rig HOERBIGER µ-comp
- synchronizer test rig ZF SSP180
- torsional and linear pulser
- transmission test rig
- drive train test rig
- in vehicle shift quality measurement



HOERBIGER

Copyright by HOERBIGER Antriebstechnik GmbH (Germany), 2013. Any kind of use in part or in full provides HOERBIGER Antriebstechnik GmbH's prior written consent.

HOERBIGER µcomp Synchronizer Test Rig



HOERBIGER

Copyright by HOERBIGER Antriebstechnik GmbH (Germany), 2013. Any kind of use in part or in full provides HOERBIGER Antriebstechnik GmbH's prior written consent.

HOERBIGER Shift Simulator

Copyright by HOERBIGER Antriebstechnik GmbH (Germany), 2013. Any kind of use in part or in full provides HOERBIGER Antriebstechnik GmbH's prior written consent.

7.2. Manufacturing

Copyright by HOERBIGER Antriebstechnik GmbH (Germany), 2013. Any kind of use in part or in full provides HOERBIGER Antriebstechnik GmbH's prior written consent.

7.2. Manufacturing

As a result of the efficient and flexible use of metal forming technology, machining, heat treatment, and friction lining production, HOERBIGER has efficient manufacturing technologies at its disposal - with sustainable cost advantages for the customer.

- **Metal-forming and Machining**
  HOERBIGER employs powerful metal-forming presses and modern machining equipment to produce ready-to-install synchronizer components and systems. In-house tool & die design as well as automated production lines assure high quality standards. This consistently allows HOERBIGER to offer products with excellent features at an excellent cost-benefit ratio.

- **Heat treatment**
  Modern heat treating equipment assures high-quality as well as careful finishing of HOERBIGER synchronizer components.

- **Friction lining production (sintered and carbon linings)**
  HOERBIGER manufactures all sintered friction linings in-house. Moreover, HOERBIGER offers a wide range of specially developed carbon friction linings. Sintered and carbon friction linings are applied to the synchronizer rings in automated equipment.

From highly complex components to complete ready-to-install systems:

HOERBIGER always offers customers outstanding products in the best quality at a balanced cost-benefit ratio.

HOERBIGER

Copyright by HOERBIGER Antriebstechnik GmbH (Germany), 2013. Any kind of use in part or in full provides HOERBIGER Antriebstechnik GmbH's prior written consent.

Production Technologies - overview



Innovative products and systems through excellence in production and technology

- machining
- metal forming technology
- heat treatment
- friction material production and friction material bonding
- assembly
- testing technology

We set standards through top quality and state-of-the-art technology.

Copyright by HOERBIGER Antriebstechnik GmbH (Germany), 2013. Any kind of use in part or in full provides HOERBIGER Antriebstechnik GmbH's prior written consent.

Production Technologies for Sleeves + Engagment Rings

… a unique combination of processes

- turning
- milling
- broaching
- chamfering
- back taper milling
- heat treatment
- washing

HOERBIGER

Copyright by HOERBIGER Antriebstechnik GmbH (Germany), 2013. Any kind of use in part or in full provides HOERBIGER Antriebstechnik GmbH's prior written consent.

Production Technologies for Synchro Rings

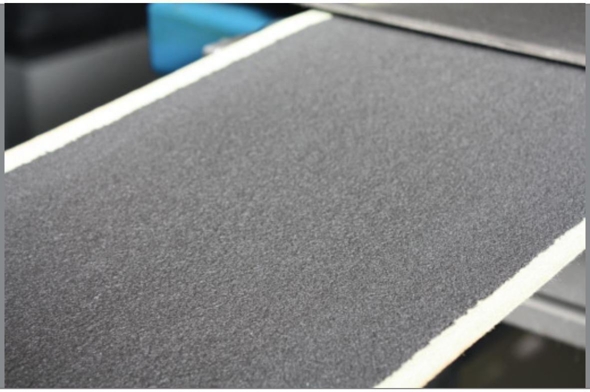



… complex components are produced in their final shape (net shape)

- deep drawing
- stamping
- fine blanking
- cold forming
- bending
- heat treatment

Copyright by HOERBIGER Antriebstechnik GmbH (Germany), 2013. Any kind of use in part or in full provides HOERBIGER Antriebstechnik GmbH's prior written consent.

Production Technologies for Friction Linings



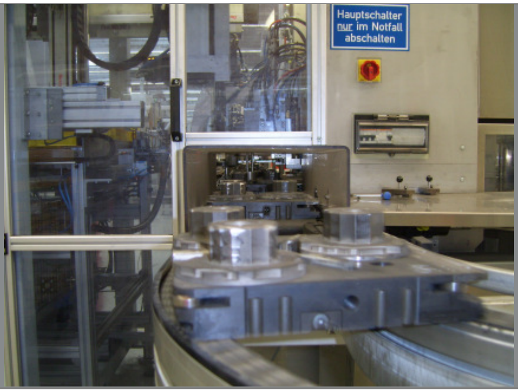
… unique product portfolio

- manufacturing of sintered metallic linings
- manufacturing of carbon linings
- bonding of sintered and carbon linings

Copyright by HOERBIGER Antriebstechnik GmbH (Germany), 2013. Any kind of use in part or in full provides HOERBIGER Antriebstechnik GmbH's prior written consent.

7.2. Manufacturing

Assembly and Testing



… pre-finished and fully-automatic for ready-to-install systems

- friction systems
- sleeve/hub systems
- complete synchronizer groups
- running-in
- functional testing

HOERBIGER

Copyright by HOERBIGER Antriebstechnik GmbH (Germany), 2013. Any kind of use in part or in full provides HOERBIGER Antriebstechnik GmbH's prior written consent.

8. HOERBIGER Product Portfolio

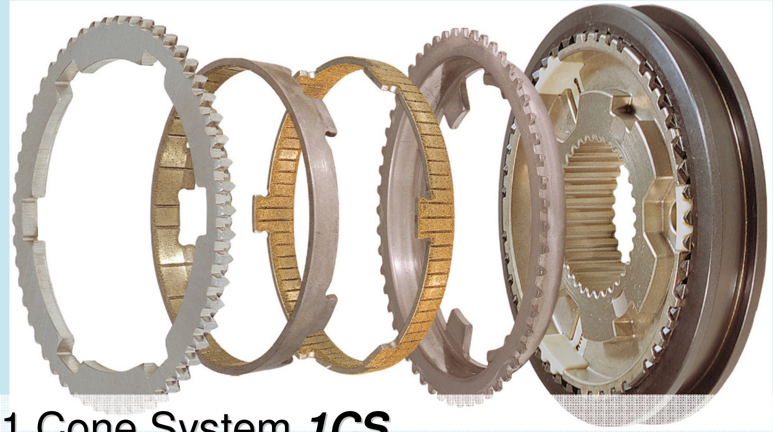
Copyright by HOERBIGER Antriebstechnik GmbH (Germany), 2013. Any kind of use in part or in full provides HOERBIGER Antriebstechnik GmbH's prior written consent.

Synchronizer Systems

- Most innovative and competent partner for synchronizer development
- Unique portfolio of development tools for simulation, testing & assessment
- First adress for solving of problems regarding shift comfort and reliability

HOERBIGER - Classic Line

The proven synchronizer for all applications



- 1 Cone System ***1CS***
  - 2 Cone System ***2CS***
    - 3 Cone System ***3CS***

HOERBIGER - SKS Line

The synchronizer without blocking teeth

- 1 Cone System ***1CS***
  - 2 Cone System ***2CS***

HOERBIGER

Copyright by HOERBIGER Antriebstechnik GmbH (Germany), 2013. Any kind of use in part or in full provides HOERBIGER Antriebstechnik GmbH's prior written consent.

Friction Systems

HOERBIGER **-** Classic Line

The proven synchronizer for all applications

- 2 Cone System ***2CS***
- 3 Cone System ***3CS***
- with **HS** Sinter or **HC** Carbon Lining

- First in market with sheet metal formed friction systems
- In high volume series production since 1999
- Best reliabilty for wide range of applications
- Problem solver in terms of shift quality, efficiency and durability

HOERBIGER

Copyright by HOERBIGER Antriebstechnik GmbH (Germany), 2013. Any kind of use in part or in full provides HOERBIGER Antriebstechnik GmbH's prior written consent.

Blocker Rings

***HOERBIGER* - Classic Line**

The proven synchronizer for all applications

- **BRC** with **HC** Carbon Lining
  - **BRC** with **HS** Sinter Lining
    - **BRE** with **HS** Sinter Lining

- Only HOERBIGER can offer Sinter **and** Carbon friction linings in sheet metal rings
- In high volume series production for MT and DCT applications for successful OEMS and gearbox manufacturers
- Excellent quality records due to fully automated manufacturing lines
- Due to better wear resistance also as replacement for brass rings with molybdenum coating

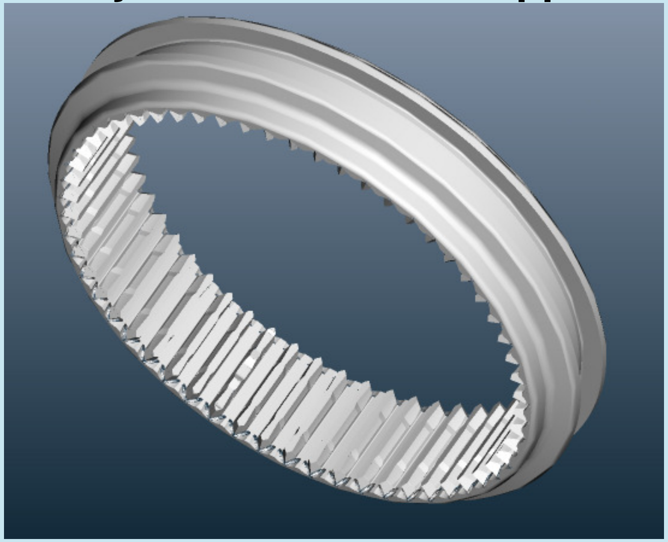
HOERBIGER

Copyright by HOERBIGER Antriebstechnik GmbH (Germany), 2013. Any kind of use in part or in full provides HOERBIGER Antriebstechnik GmbH's prior written consent.

Synchronizer Sleeves

HOERBIGER - Classic Line

The proven synchronizer for all applications



- **Sliding Sleeves** from rolled blanks

- HOERBIGER produces sleeves with an experience of more than 75 years
- Most modern production equipment has been developed exclusively with leading machine suppliers like Präwema
- In-house process chain including production of rolled blanks ensures optimal quality control
- High volume production in place at two production sites in Germany and one in China
- Quality in regards of spline error and chamfer angles as well as safety against cracks and breakage superior compared to sheet metal or powder metal sleeves

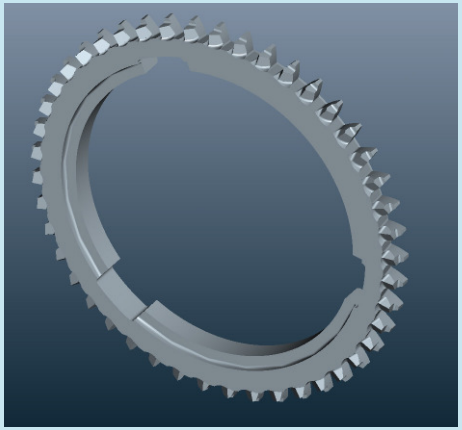
HOERBIGER

Copyright by HOERBIGER Antriebstechnik GmbH (Germany), 2013. Any kind of use in part or in full provides HOERBIGER Antriebstechnik GmbH's prior written consent.

Engagement Rings

***HOERBIGER* - Classic Line**

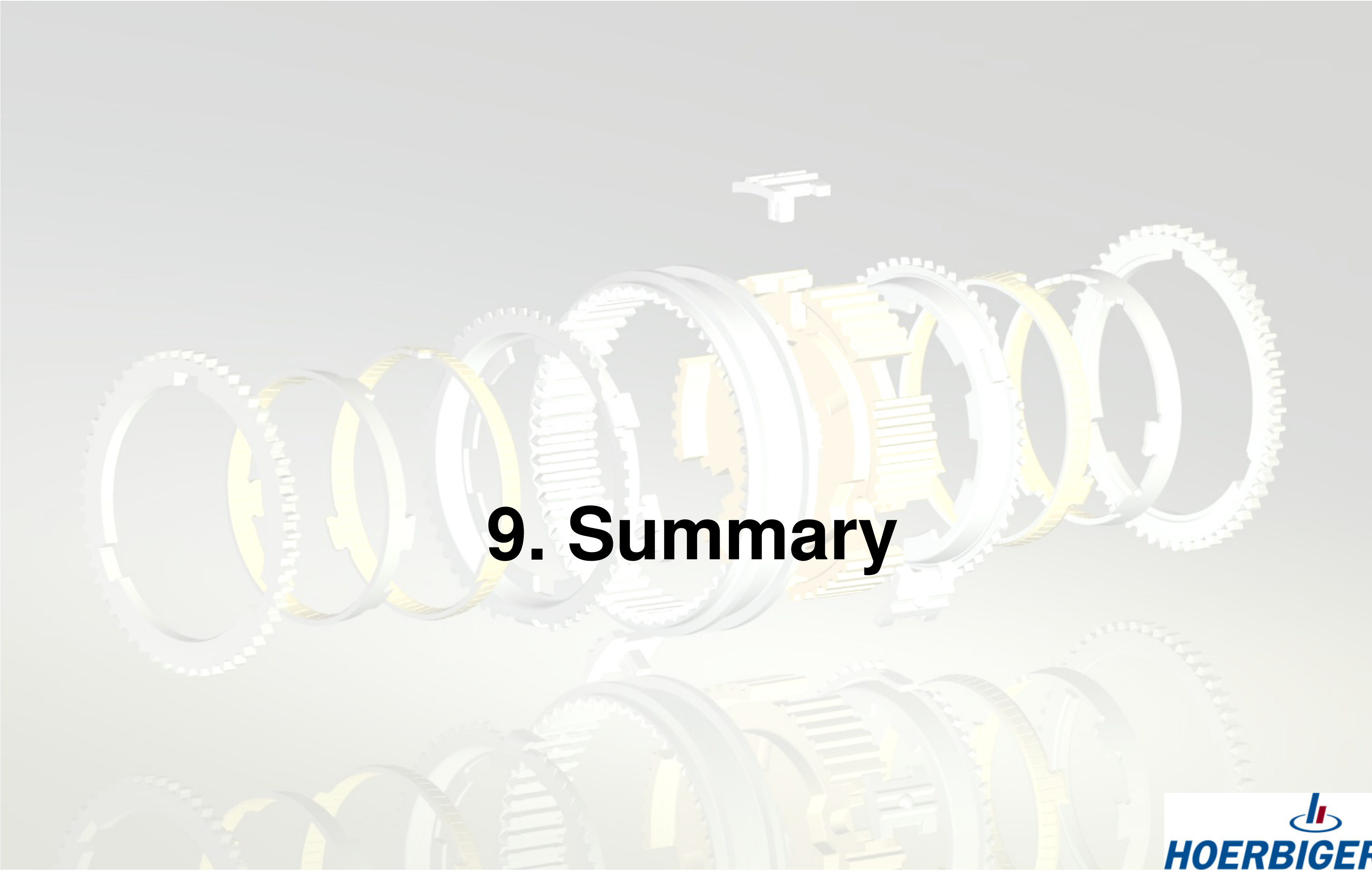
The proven synchronizer for all applications



- **Engagement Rings** from stamped blanks

- HOERBIGER combines in-house know how on stamping and machining
- High volume production since decades
- Highest quality in regards of spline error and chamfer angles

Copyright by HOERBIGER Antriebstechnik GmbH (Germany), 2013. Any kind of use in part or in full provides HOERBIGER Antriebstechnik GmbH's prior written consent.



9. Summary

Copyright by HOERBIGER Antriebstechnik GmbH (Germany), 2013. Any kind of use in part or in full provides HOERBIGER Antriebstechnik GmbH's prior written consent.

9. Summary

By supplying the synchronizer, HOERBIGER provides the central component of the transmission featuring interfaces to the output, the clutch and, by way of the gear shift, to the driver.

The layout and design of the synchronizers play an essential role in how the driver experiences the gear shift.

Long lasting experience is needed for the development of synchronizer components and systems. The vertical integration of all production steps ensures highest quality and cost effectivness.

Close cooperation between HOERBIGER and its customers is required to achieve reliable and comfortable sychronizer solutions.

Copyright by HOERBIGER Antriebstechnik GmbH (Germany), 2013. Any kind of use in part or in full provides HOERBIGER Antriebstechnik GmbH's prior written consent.

HOERBIGER

because performance counts

HOERBIGER

Copyright by HOERBIGER Antriebstechnik GmbH (Germany), 2013. Any kind of use in part or in full provides HOERBIGER Antriebstechnik GmbH's prior written consent.