



SCHAEFFLER  
Symposium  
2018

- ▶ Industry’s VCR Motivation
- ▶ VCR Concepts
- ▶ Closer Look: Multi-link VCR
- ▶ Schaeffler’s Multi-link VCR Actuation System



Variabilities of the ICE

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### Variabilities of the ICE

Injection



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### Variabilities of the ICE

Injection

Ignition



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### Variabilities of the ICE

- ✓ Injection
- ✓ Ignition
- ✓ Oil pump



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The image shows a 3D model of a multi-cylinder internal combustion engine. A green component, likely the variable compression ratio actuator, is highlighted at the bottom of the engine block. The background is dark with a pattern of green circles of varying sizes.

### Variabilities of the ICE

- ✓ Injection
- ✓ Ignition
- ✓ Oil pump
- ✓ Air path – turbo charger



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This image is similar to the one above, showing a 3D model of an internal combustion engine. In addition to the green actuator at the bottom, a turbocharger is also highlighted in green on the right side of the engine. The background features the same dark green circle pattern.

### Variabilities of the ICE

- Injection
- Ignition
- Oil pump
- Air path – turbo charger
- Air path – valve train



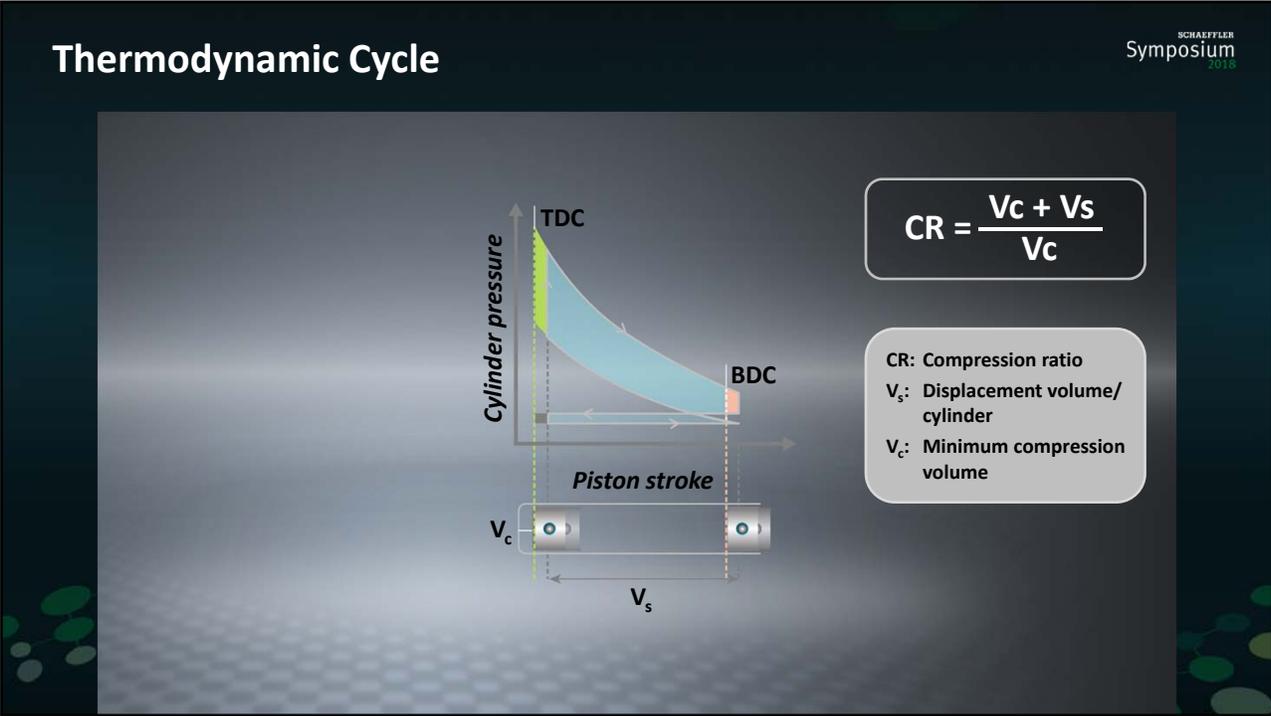
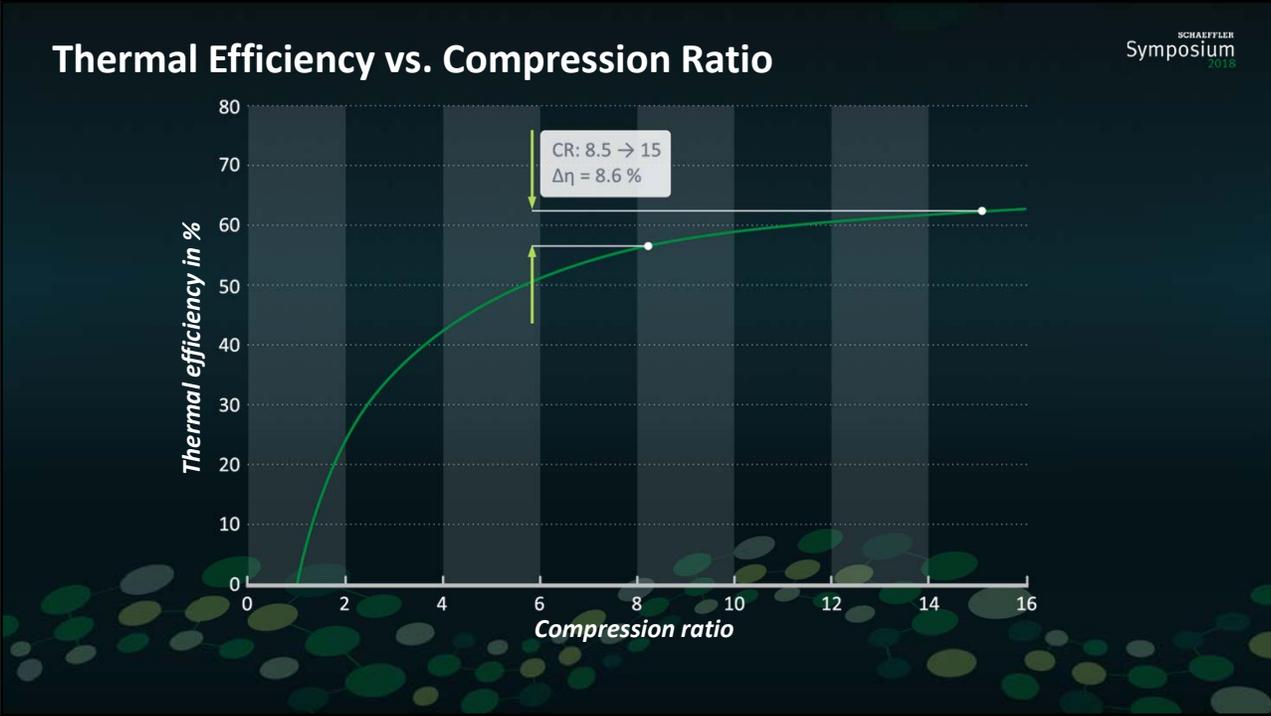
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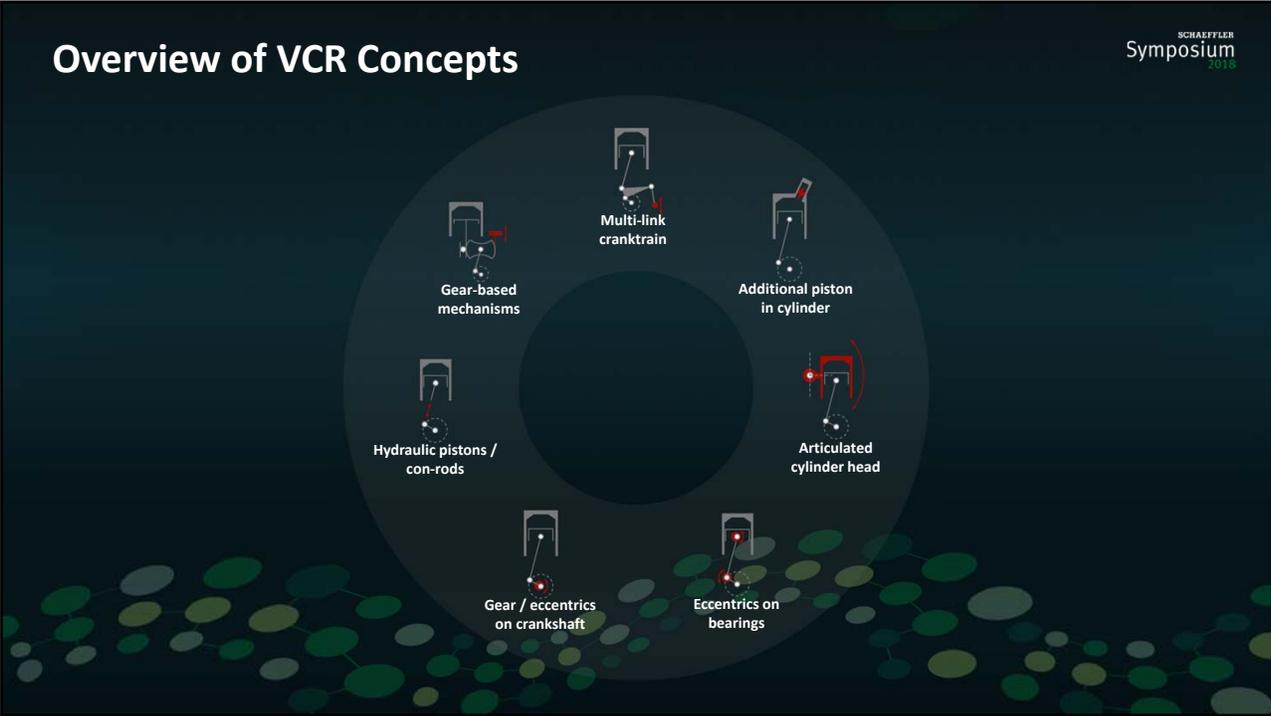
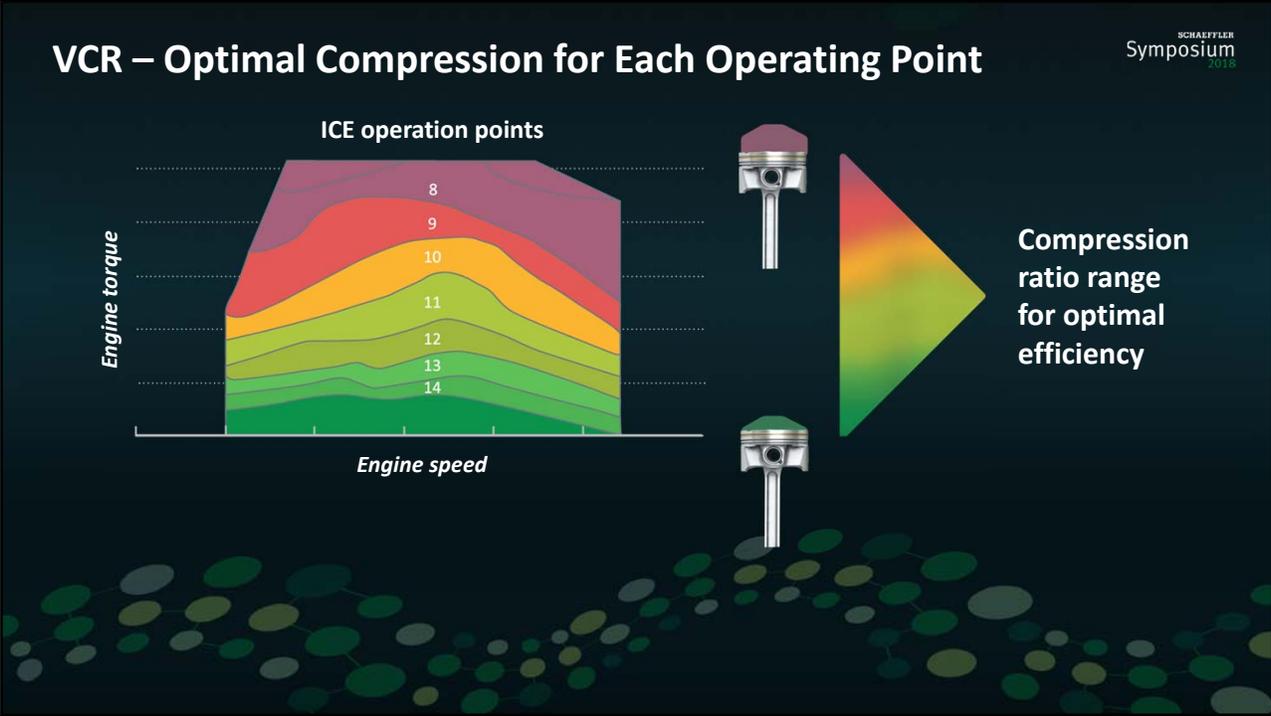
### Variabilities of the ICE

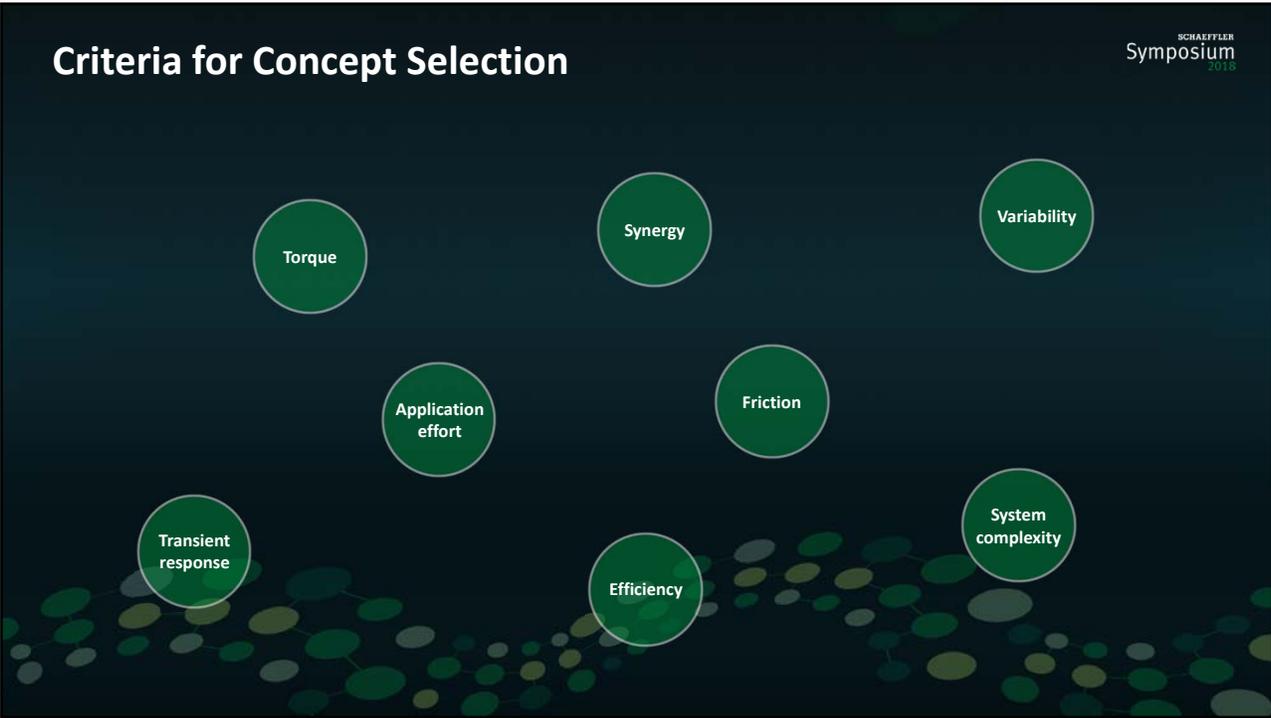
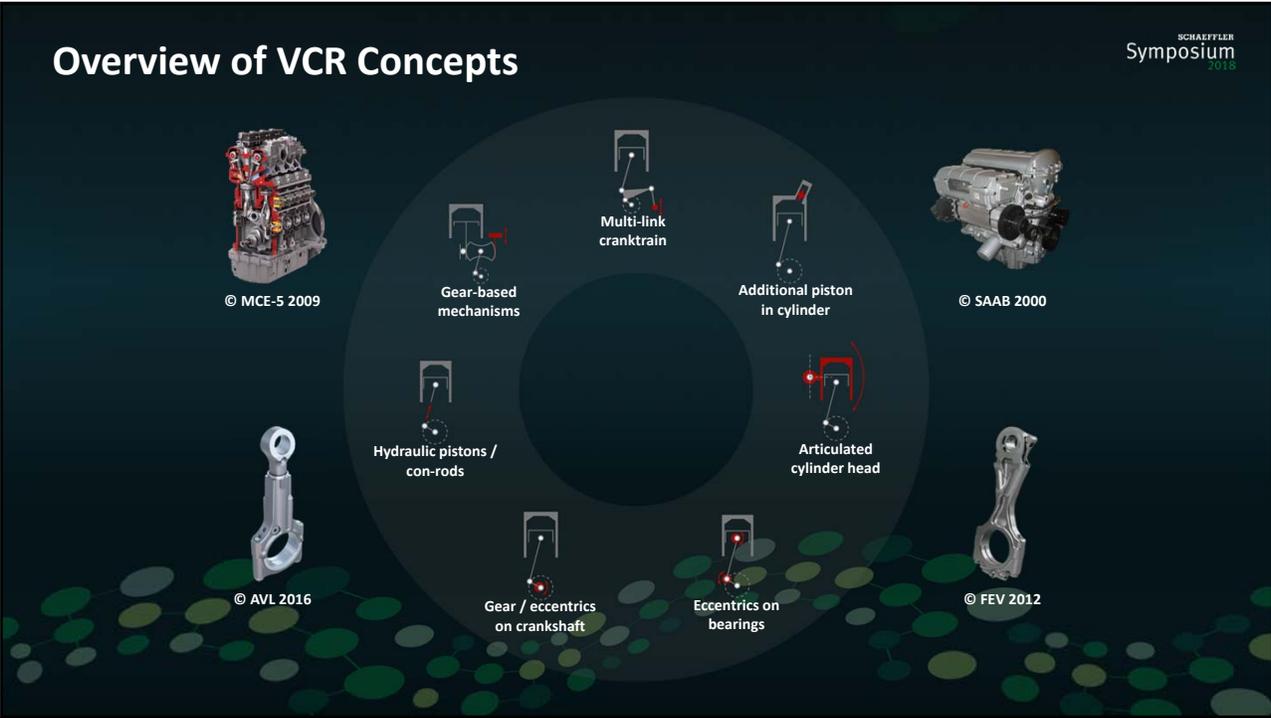
- Injection
- Ignition
- Oil pump
- Air path – turbo charger
- Air path – valve train
- Geometric compression ratio



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### Overview of VCR Concepts

© MCE-5 2009

© SAAB 2000

© AVL 2016

© FEV 2012

Multi-link cranktrain

Gear-based mechanisms

Additional piston in cylinder

Articulated cylinder head

Eccentrics on bearings

Gear / eccentrics on crankshaft

Hydraulic pistons / con-rods

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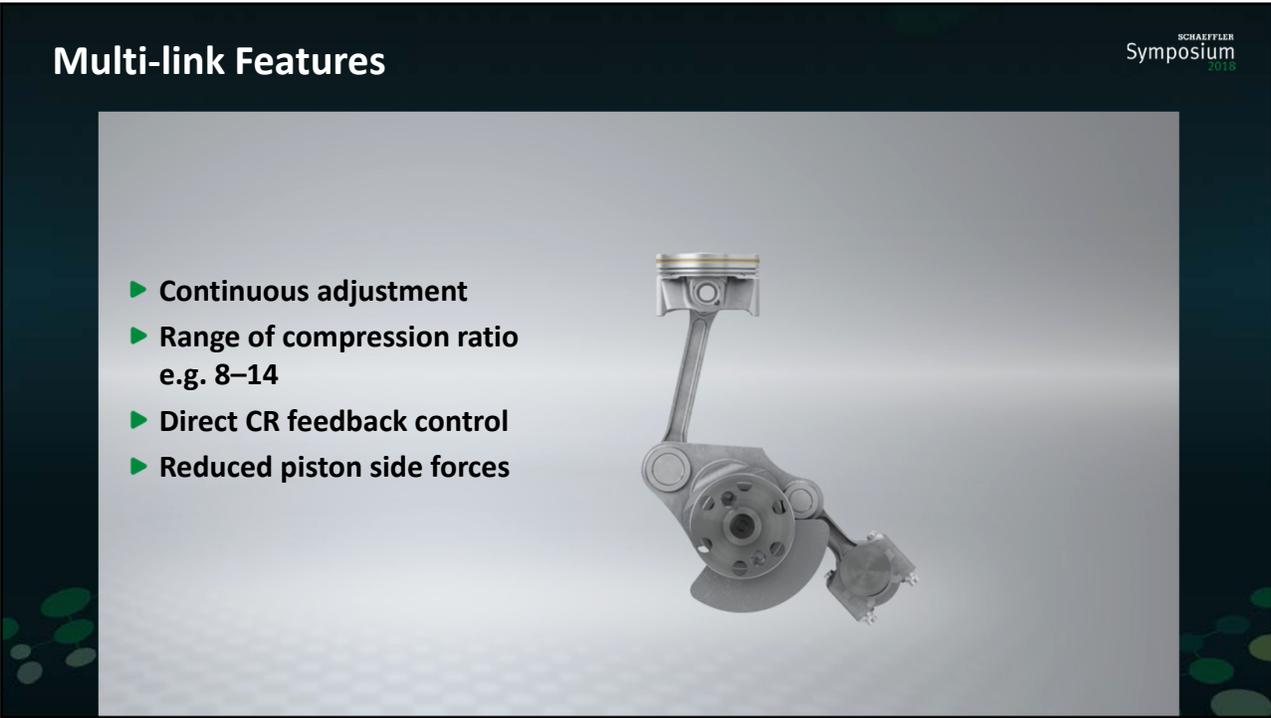
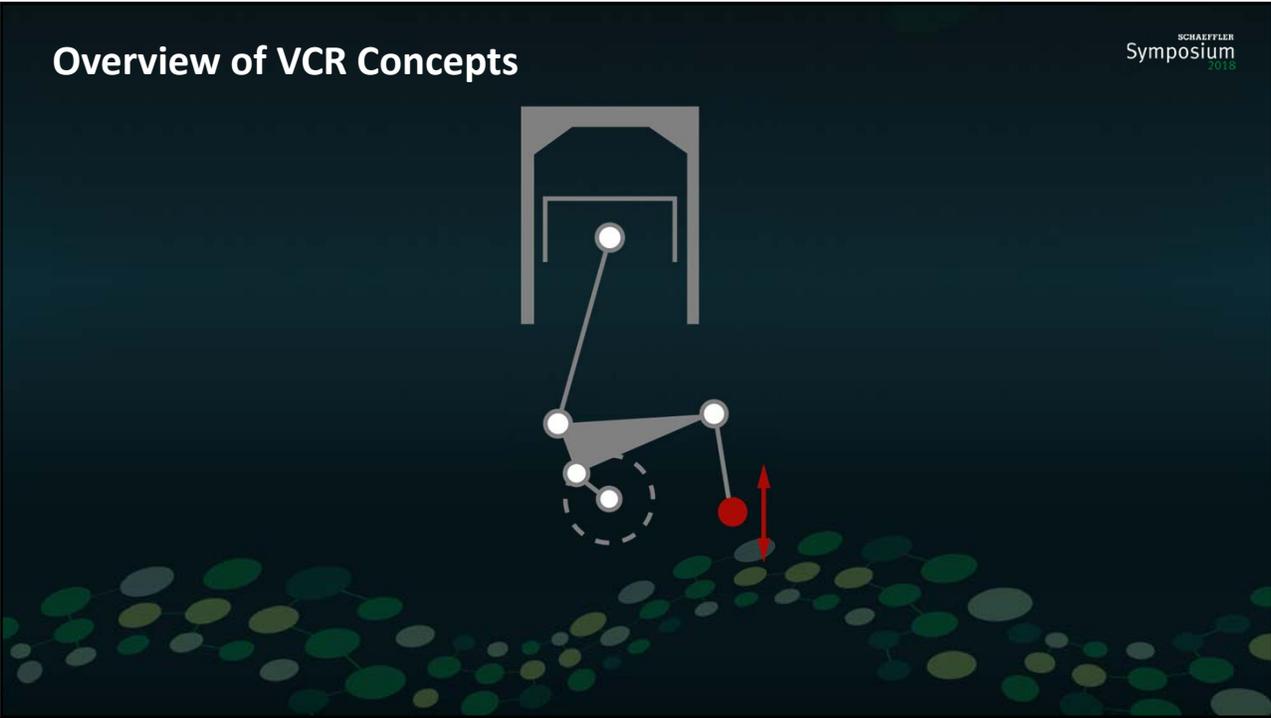
Articulated cylinder head

Eccentrics on bearings

Gear / eccentrics on crank shaft

Hydraulic pistons / con-rods

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### Multi-link Features

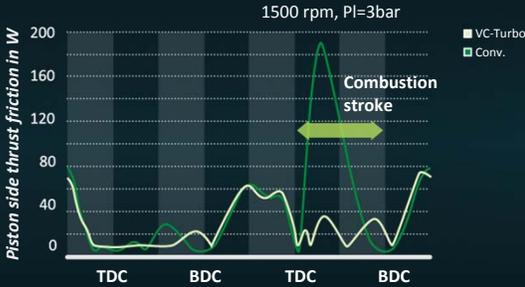
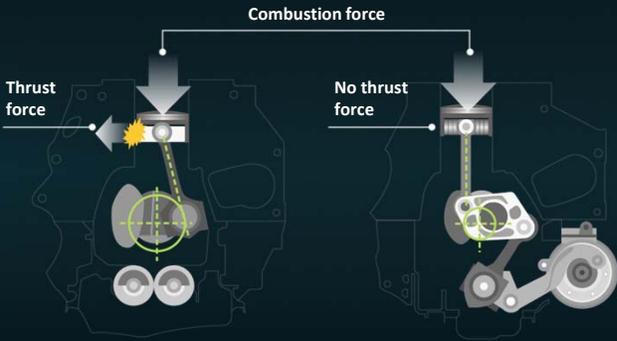
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- ▶ Continuous adjustment
- ▶ Range of compression ratio e.g. 8–14
- ▶ Direct CR feedback control
- ▶ Reduced piston side forces
- ▶ Elimination of balance-shaft-system possible



### Mass Production Example

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© Nissan, Aachen 2017

#### Nissan Layout

- ▶ Friction benefit
- ▶ Low-power consumption in end positions
- ▶ Compact packaging

### The Idea

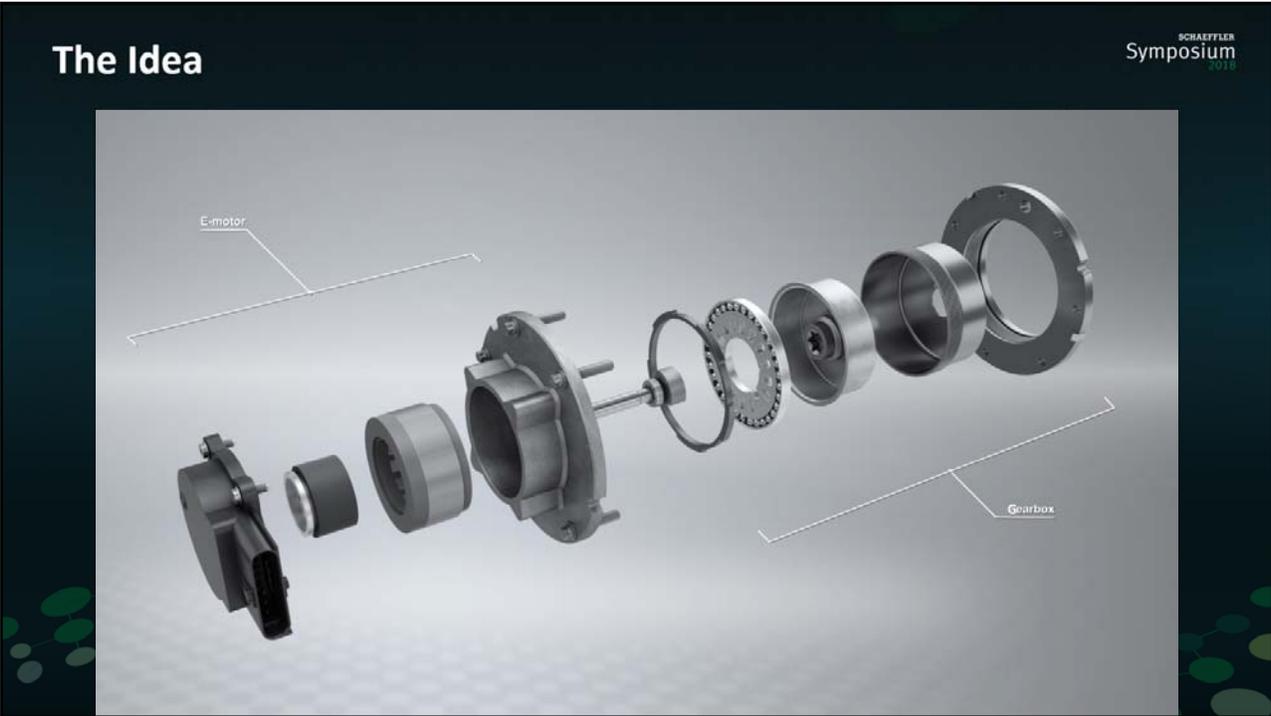
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### The Idea

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### The Idea

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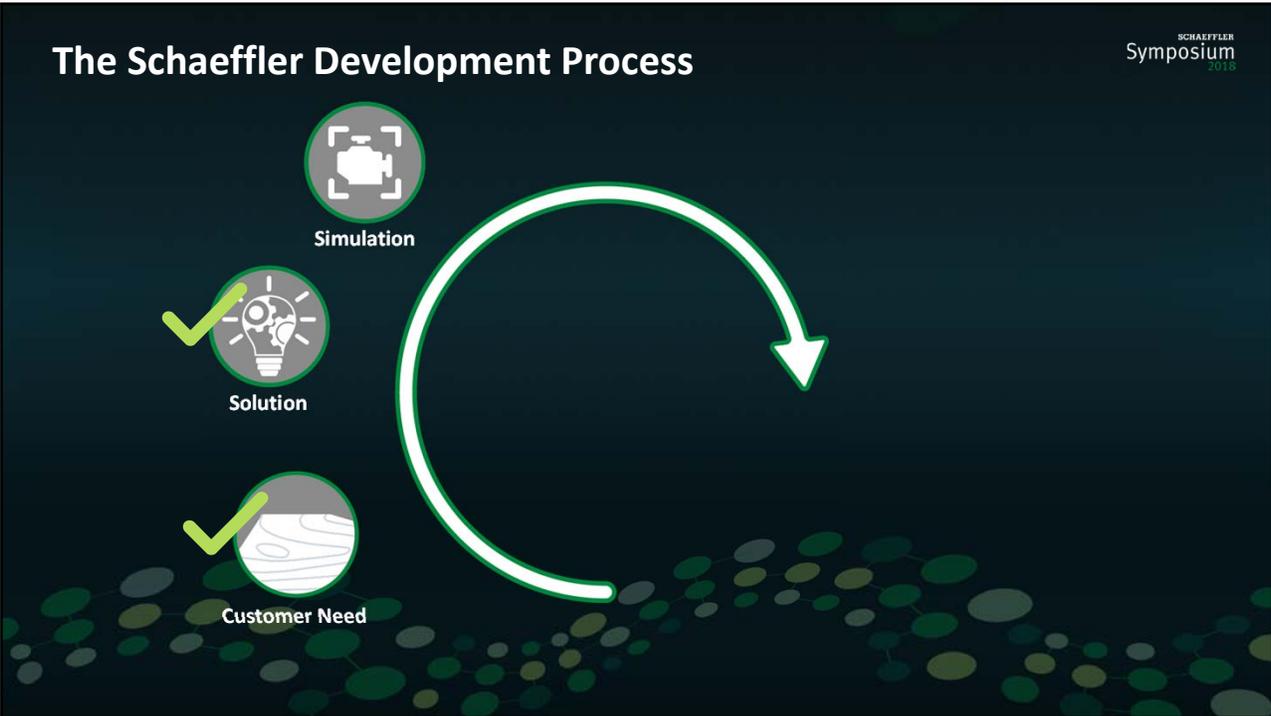
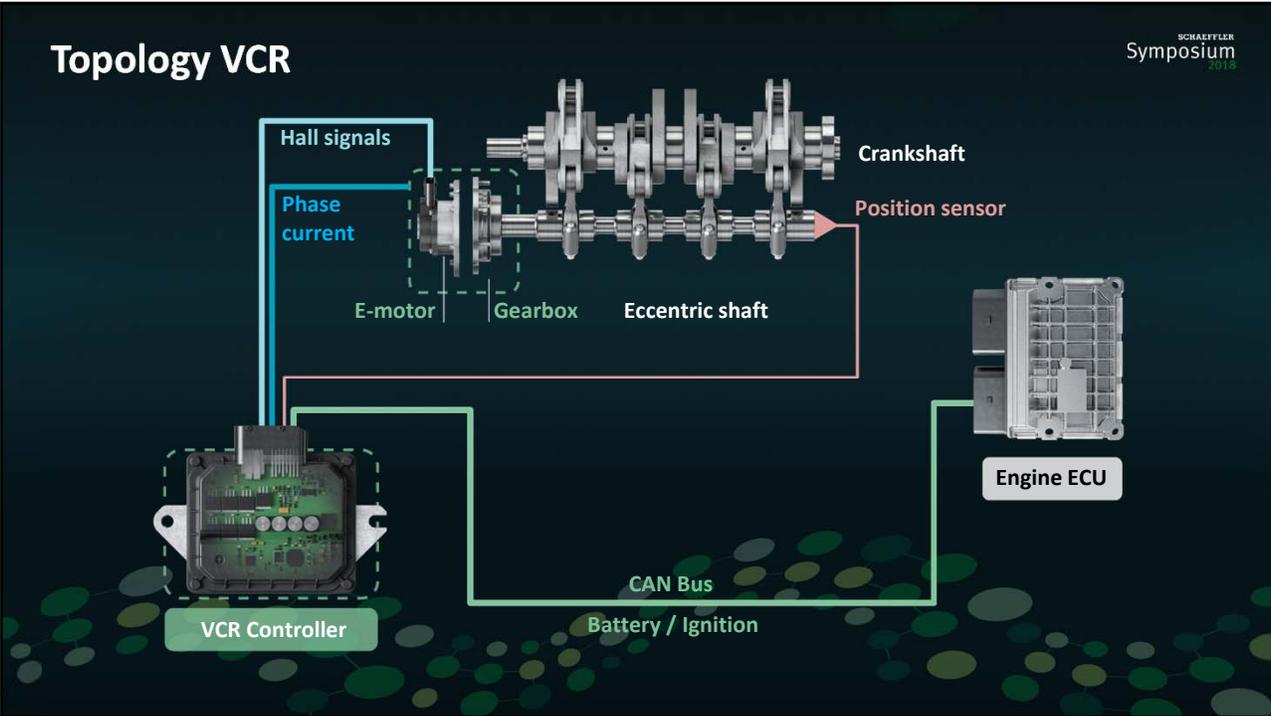


### The Idea

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Features	Camphaser	VCR
Brushless DC E-motor	✓	✓
Strainwave gearbox	✓	✓
Control unit	Hardware, software and calibration data set	
Specifications	Camphaser	VCR
Gearbox ratio	1:66	1:80-1:300
Nom. max. torque	35 Nm	> 300 Nm





# The Schaeffler Development Process



Simulation

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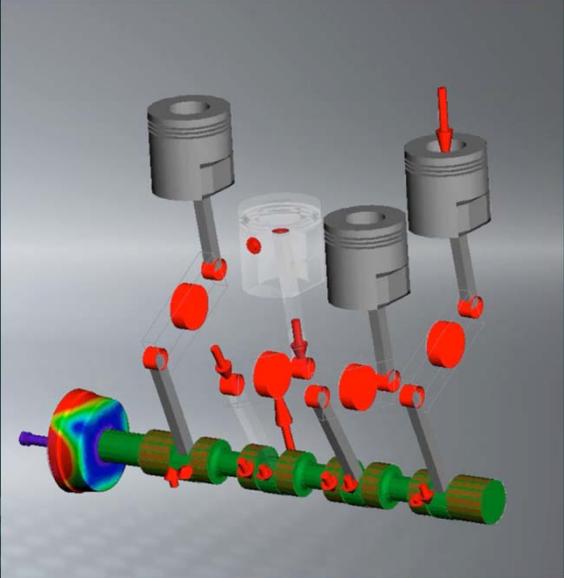
# Multi-Body Simulation

**Multi-Body System Model**

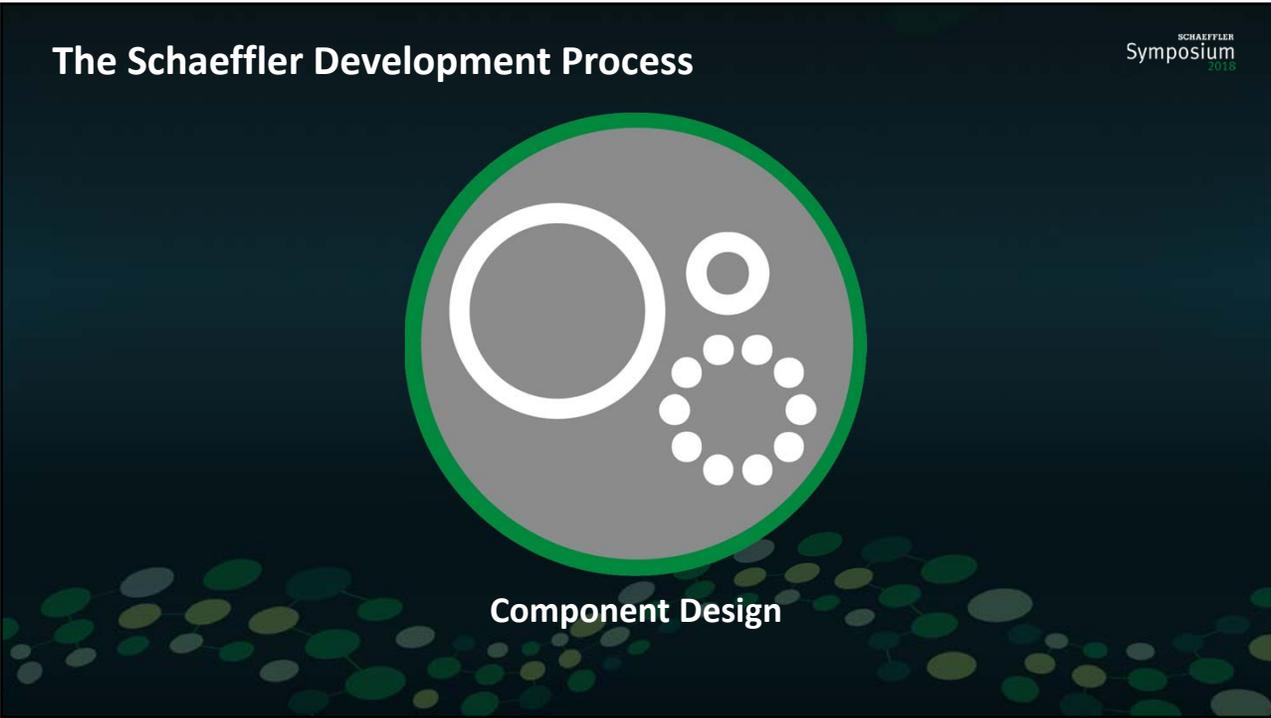
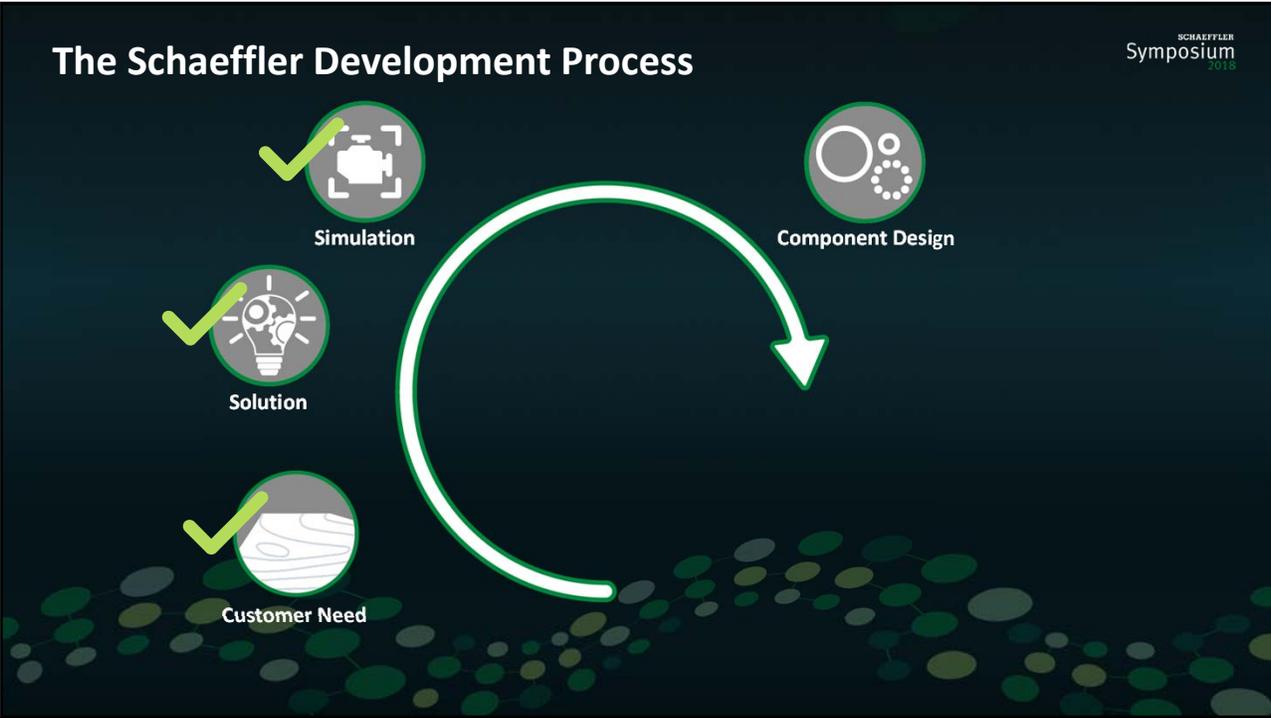
- ▶ Representation of complete engine cranktrain
- ▶ Dynamic combustion loads
- ▶ Constant flywheel rotation
- ▶ Various engine operating conditions

**Results**

- ▶ Full dynamic loads upon actuator
- ▶ Resonance phenomena
- ▶ Critical operating conditions



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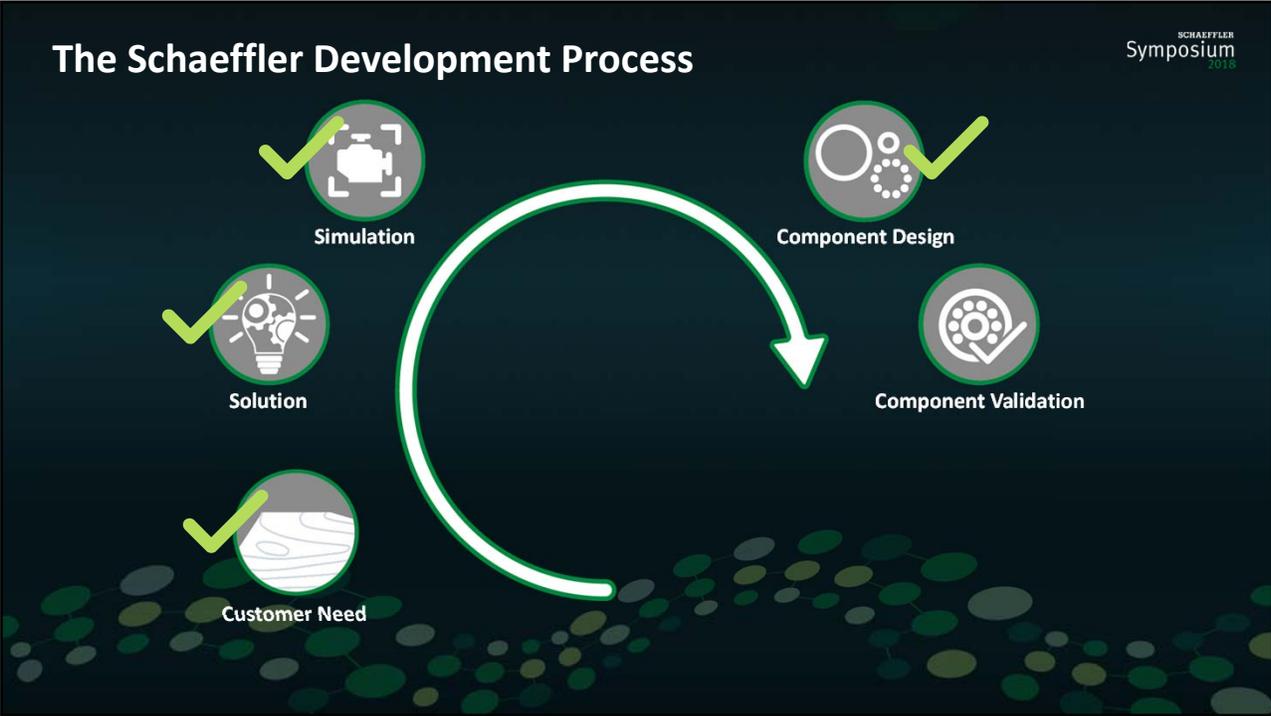
## Actuator System Simulation

**Customer requirements**

- ▶ High-shifting speed
- ▶ Minimal power consumption in shifting / holding operation
- ▶ Torque capacity
- ▶ Failsafe and diagnosis functions

**Optimization strategies**

- ▶ Investigation of sensitivities
- ▶ Adjustment of gearing ratio / dimensions
- ▶ Definition of E-motor characteristics
  - ▶ Axial vs. radial dimensions
  - ▶ Torque vs. speed capability



# The Schaeffler Development Process

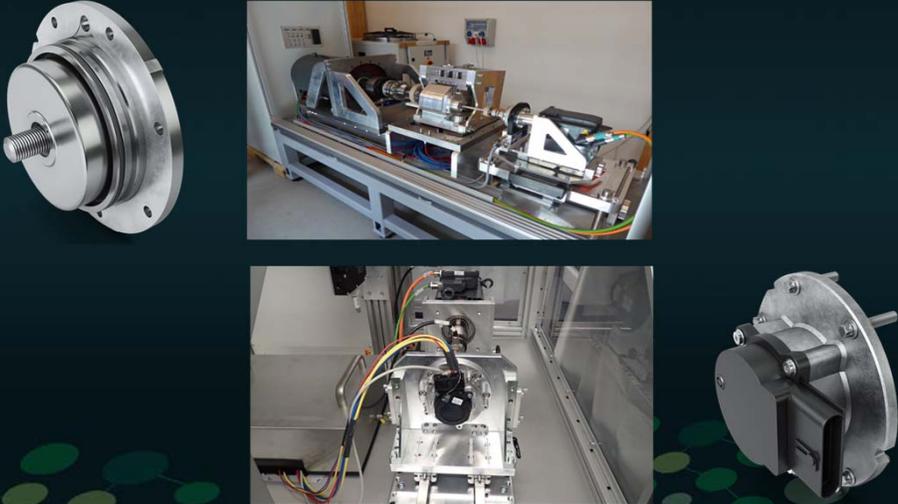
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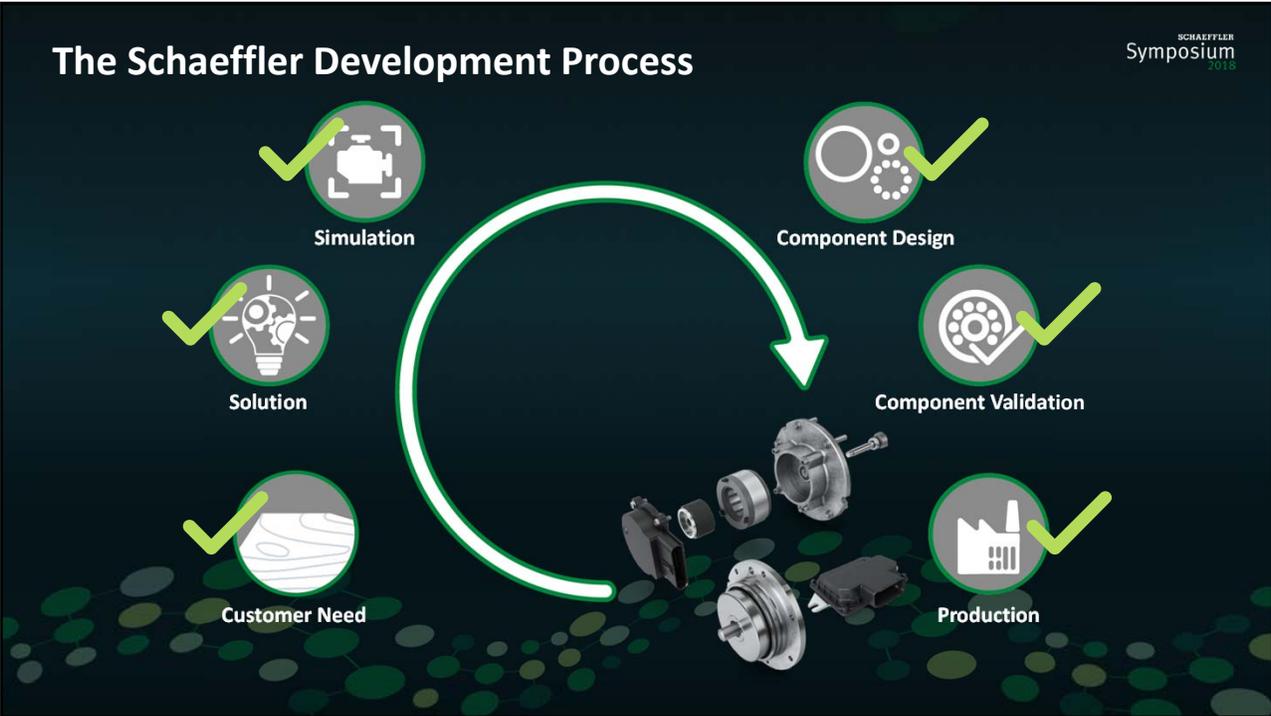


Component Validation

# Component Validation

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# VCR Actuator in Summary



**Mass production readiness**

**Benefit for our customer**

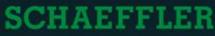
**Results of system evolution**

**Calculation / validation experience**

**Experience in Mechatronic Systems**

**Highly skilled simulation team**

**Experience in ECP control unit**

Schaeffler Symposium September 6, 2018

# Mobility for tomorrow

