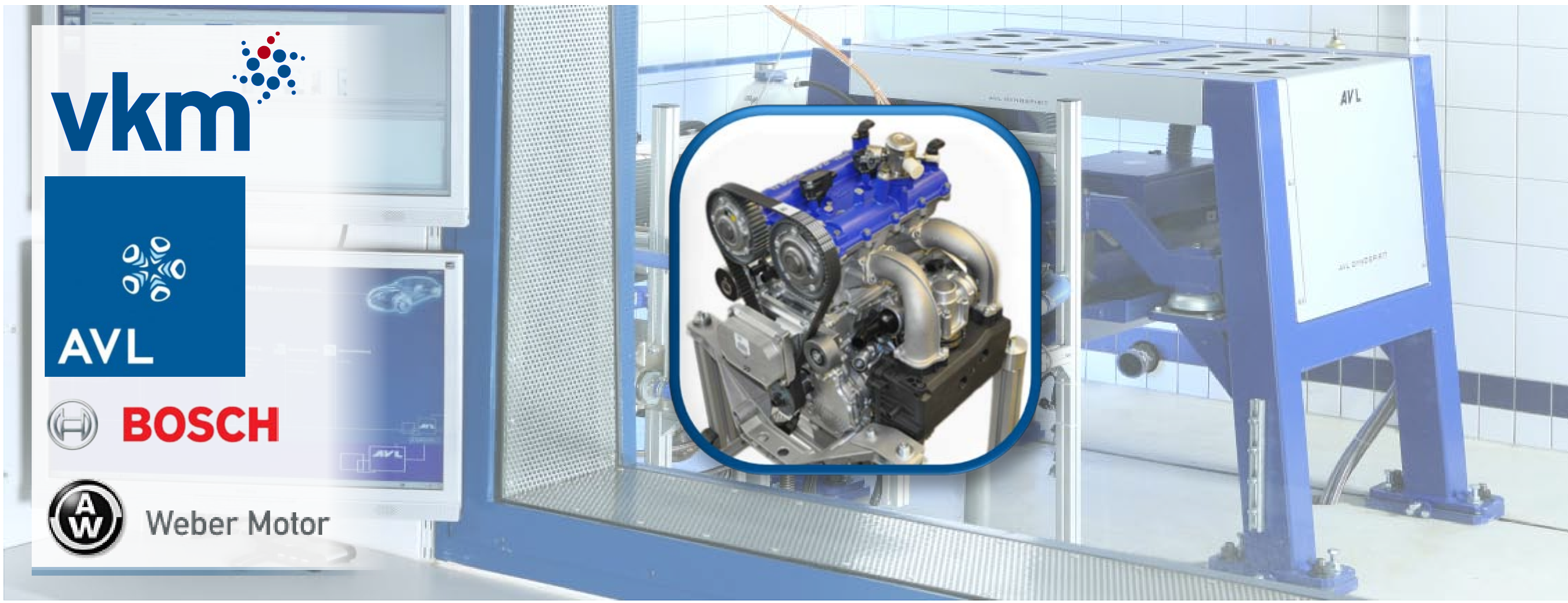
Two-Cylinder Engine for Hybrid Powertrain on a Highly Dynamic Testbed

Engine Expo 2012, 12th June



Speaker: D. Buch, **Co-Authors:** T. Weber, G. Hochmann, C. Beidl

Agenda

Challenges of Two-Cylinder Engines in Powertrains

Challenges of Testing Two-Cylinders

Introduction of Virtual Vehicle Engine Testbed (VVETB)

Testing of a Two-Cylinder on VVETB

Outlook: Simulation of Hybrid Electric Vehicle on VVETB

Summary

Challenges of Two-Cylinder Engines in Powertrains

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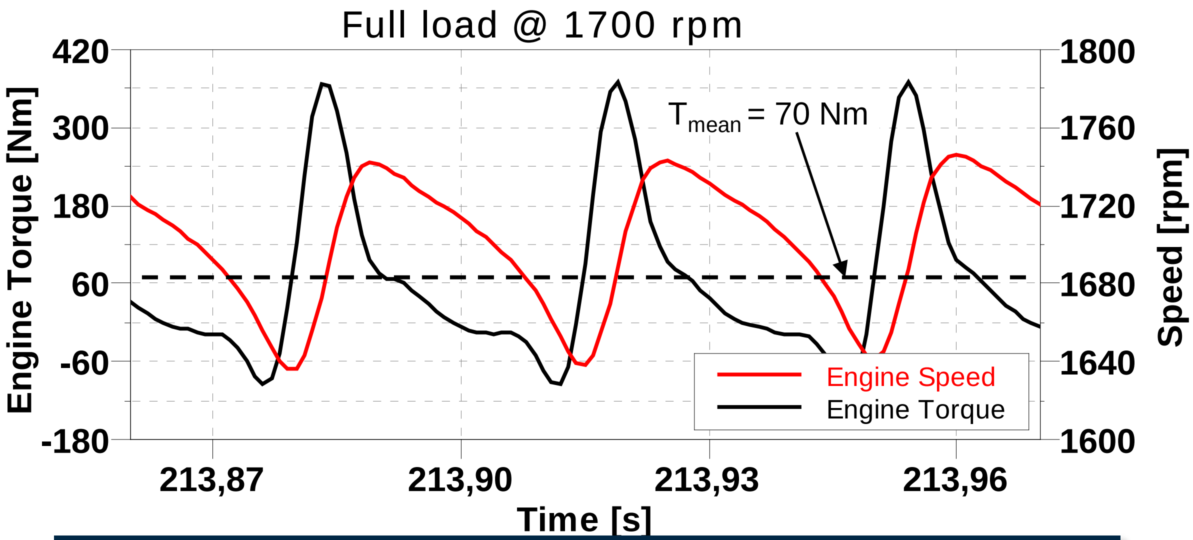

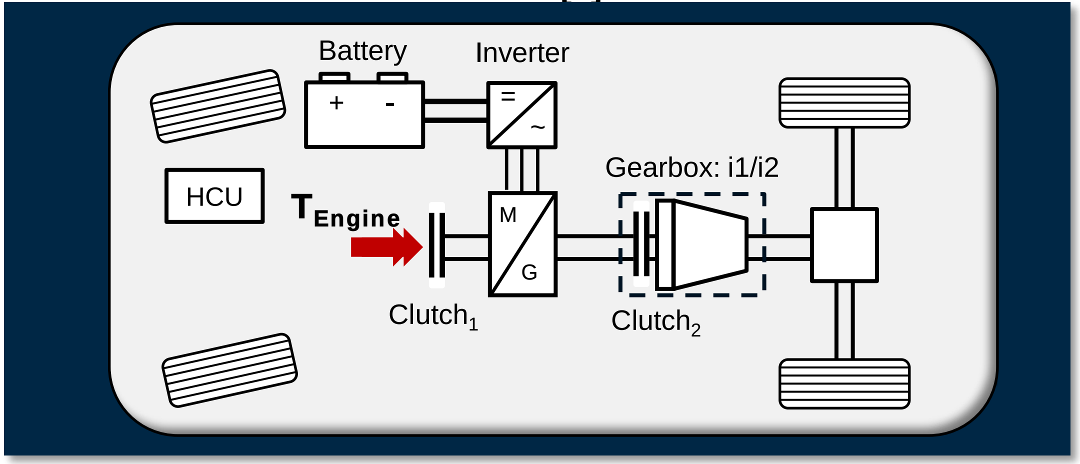

Powertrain Dynamics:

- High torque amplitude
- High torsional vibrations
- Low frequency (in relation to 4-Cylinders)

NVH-behaviour has to be optimized!

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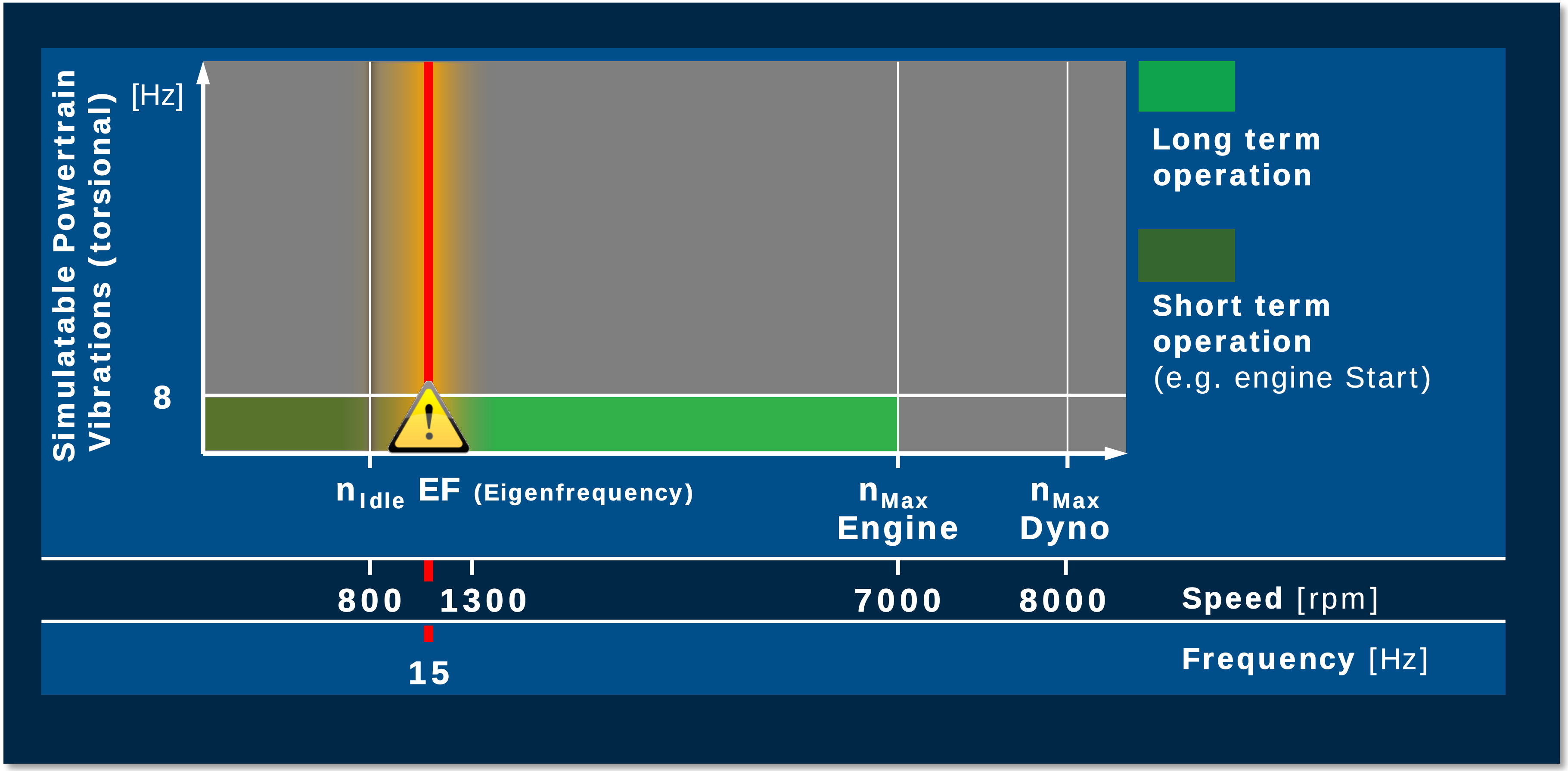
Two-Cylinder Engine on Conventional Testbed



Two-Cylinder Engine on Conventional Testbed

Simulatable Powertrain Vibrations (torsional)

Analysis of Powertrain Dynamics

Situation:

- No realistic in-vehicle behaviour
  - Start/stop, idle
  - Acceleration
  - Rotational irregularities
- Limited operation range

Needs:

- Realistic in-vehicle behaviour at the testbed:

  → Detailed analysis in early phases of development

  → Optimization of (real & virtual) components

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VVETB
→ Key Features and Possibilities

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***V**irtual **V**ehicle **E**ngine **T**est **B**ed*

Highly Dynamic Engine Test Bed: VVETB

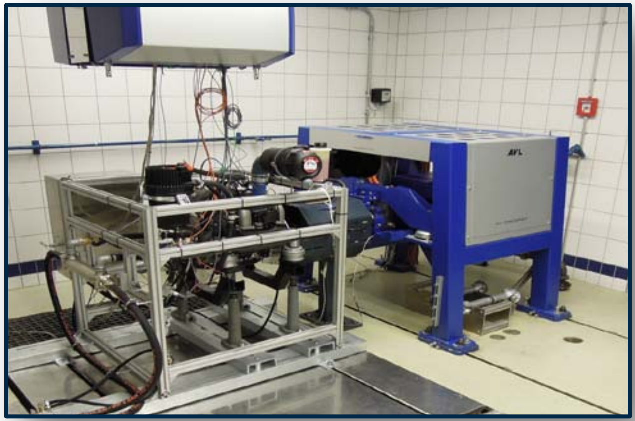
Properties:

Stiff shaft & adaptive feedforward control

Advantages:

- Powertrain simulation up to 40 Hz
- (Zero) inertia simulation
- Realistic in-vehicle behaviour
- ...

AVL



2 Cyl. Engine @ VVETB

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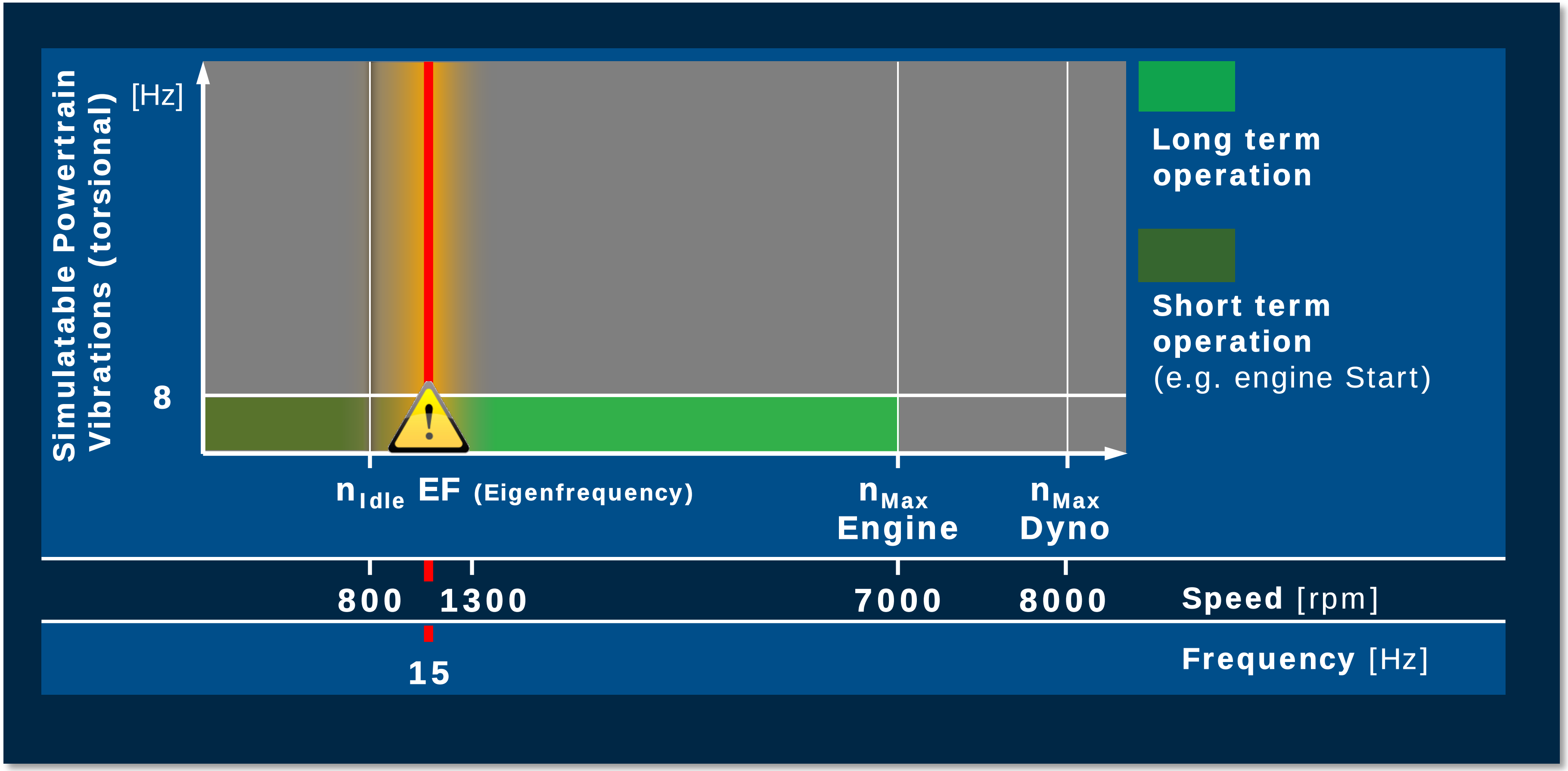
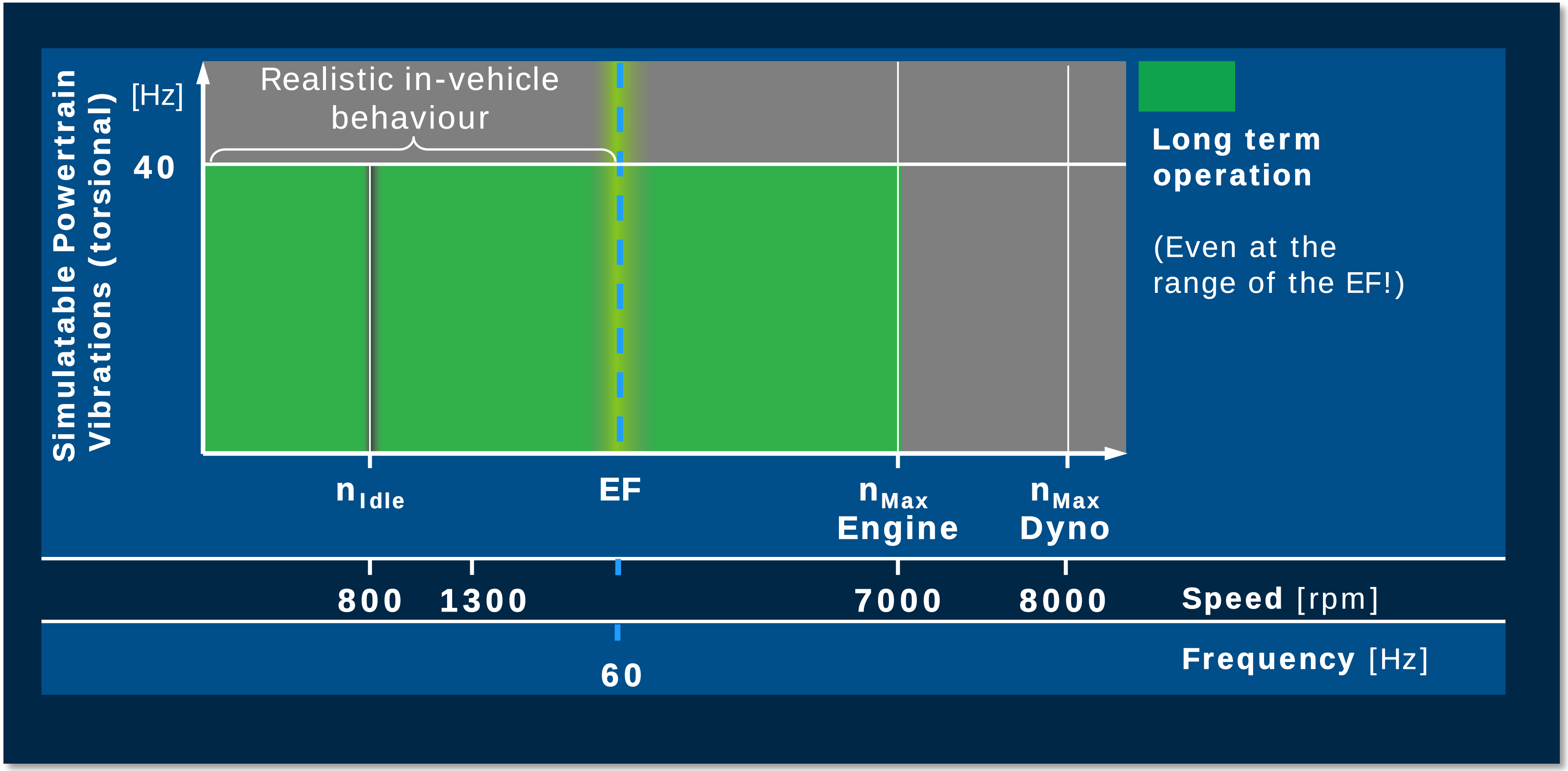
Two-Cylinder Engine on Conventional Testbed

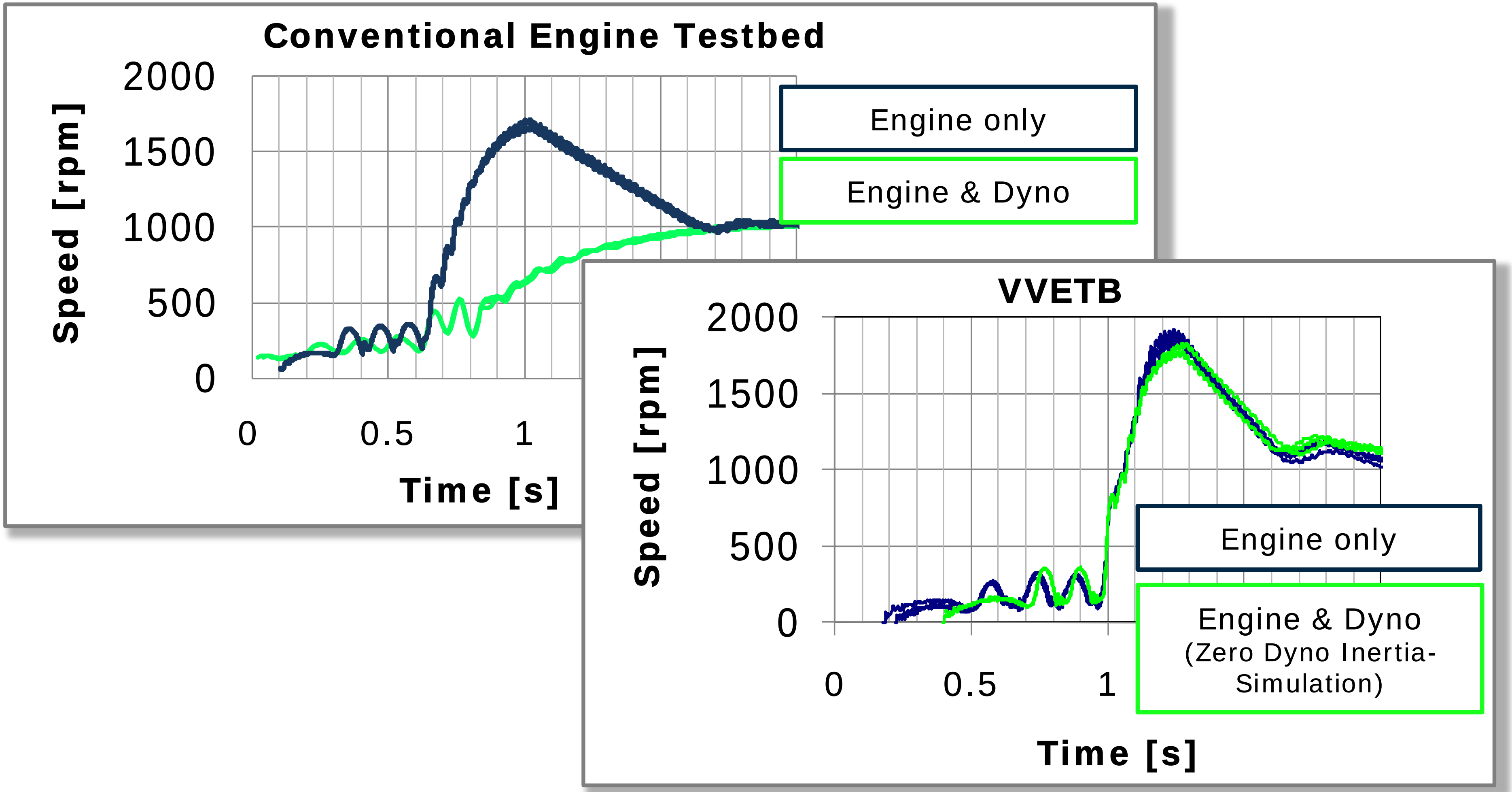


Two-Cylinder Engine on Highly Dynamic Engine Testbed



Comparison of the VVETB with a Standard Dynamic Engine Testbed

→ Four-Cyl. Engine Start w/ and w/o Dynamometer



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Two-Cylinder: MPE 850 from Weber Motor with a Optimization by Robert Bosch

BOSCH

Weber Motor

MPE 850 DOHC NA	
Design	2 Cylinder inline, four stroke MPFI
Displacement	850 ccm
Torque	>65 Nm between 1500 – 6000 rpm
Power	41 kW @ 6000 rpm
Compression Ratio	12,8:1
Ignition Spacing	360 °CA
Bore x Stroke	89 mm x 68mm
Valve Control	Four valves, DOHC with roller type rocker arm and hydraulic valve clearance adjustment
Motormanagement	Bosch MED 17.9
Weight	50 kg (dry)
Balance Shaft	Yes
Best BSFC	242 g/kWh

Source:
„Effizienter E-Fahrzeugantrieb mit dem kompakten CEA-Konzept – Combustion Engine Assist“, 7th MTZ-Conference, Wolfsburg 2012

Testing MPE850 on VVETB

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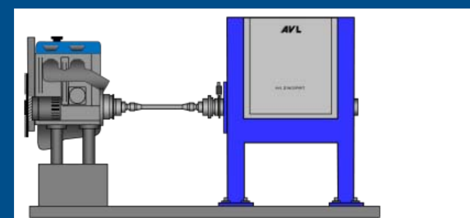
Testbed Configurations:

Config 1: Engine only

Config 2: Engine & Dyno



Operation Modes:

- T/Alpha (Acc. Pedal)
- N/Alpha (Acc. Pedal)

→ Dyno Inertia = 0!

Tested Scenarios:

- Operation in EF → Stable in total operation range?
- Start /Stop
- Free Acceleration

$\left.\begin{array}{l}\text{Start /Stop}\\ \text{Free Acceleration}\end{array}\right\}$ Influence on real engine behaviour?

- Simulation of Different Flywheel Inertias → Quality of inertia simulation?

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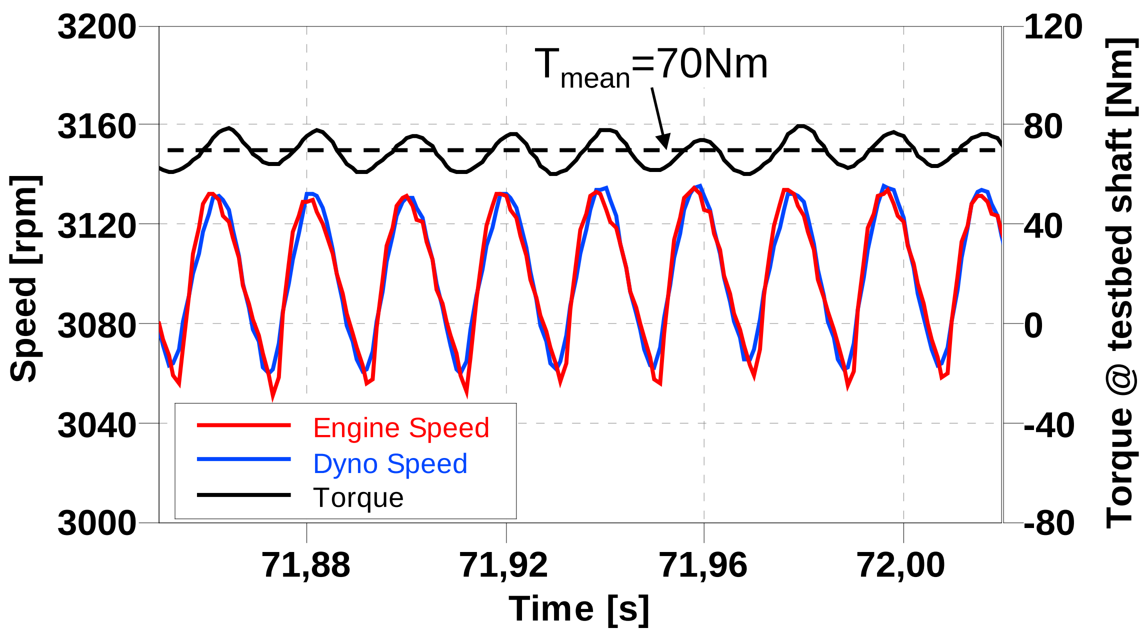
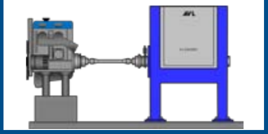
Operation in Eigenfrequency

→ Full Load @ 3100 rpm → 52Hz



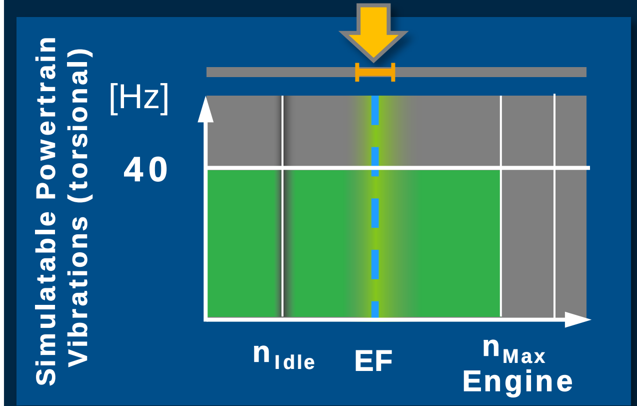
- Stable long term operation
- Dyno follows engine speed
- High torque oscillations suppressed

Config 2: Engine & Dyno



Operation Mode N/Alpha

N=3100rpm / Alpha=100%



Start

→ Starts with Starter w/ and w/o Dynamometer

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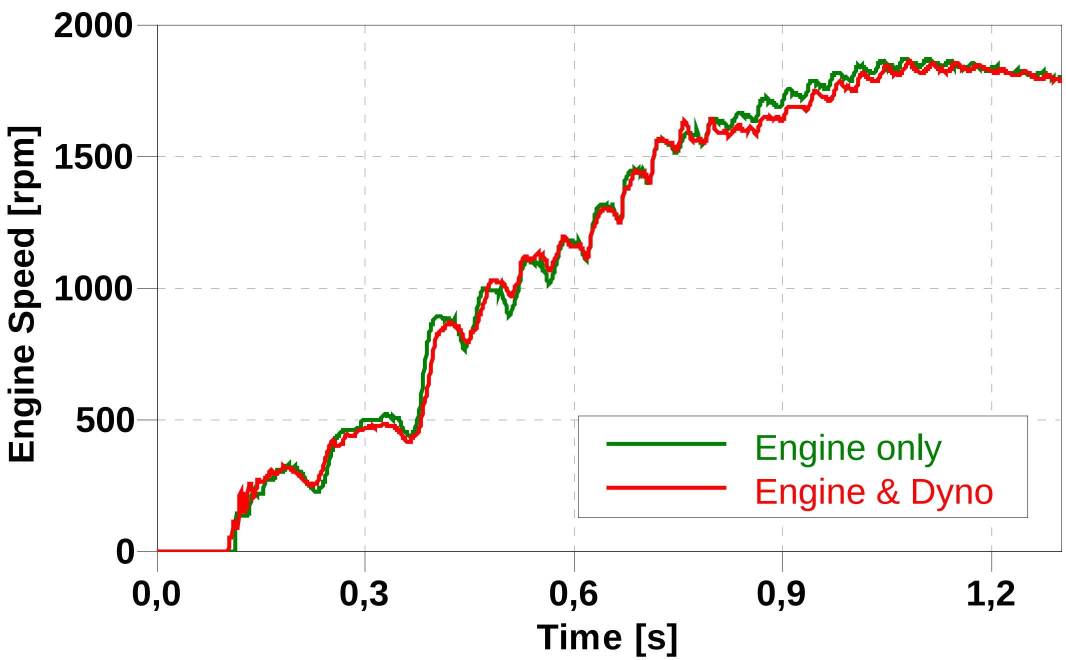
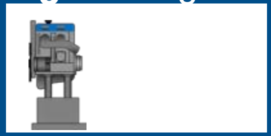
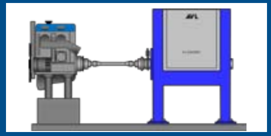


Config 1: Engine only

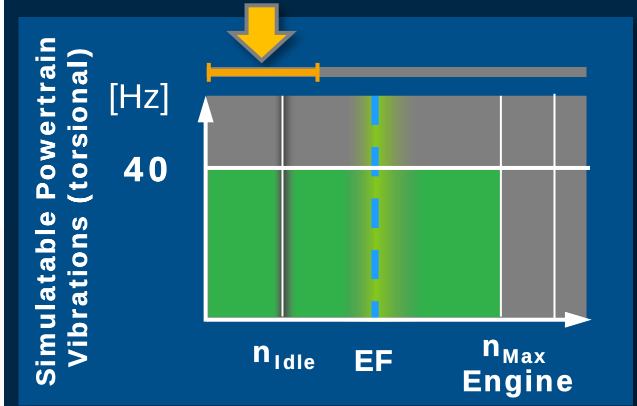


Config 2: Engine & Dyno



Operation Mode T/alpha

Target Torque 0 Nm



- No Influence on engine behaviour
- Dyno regulates its inertia to zero

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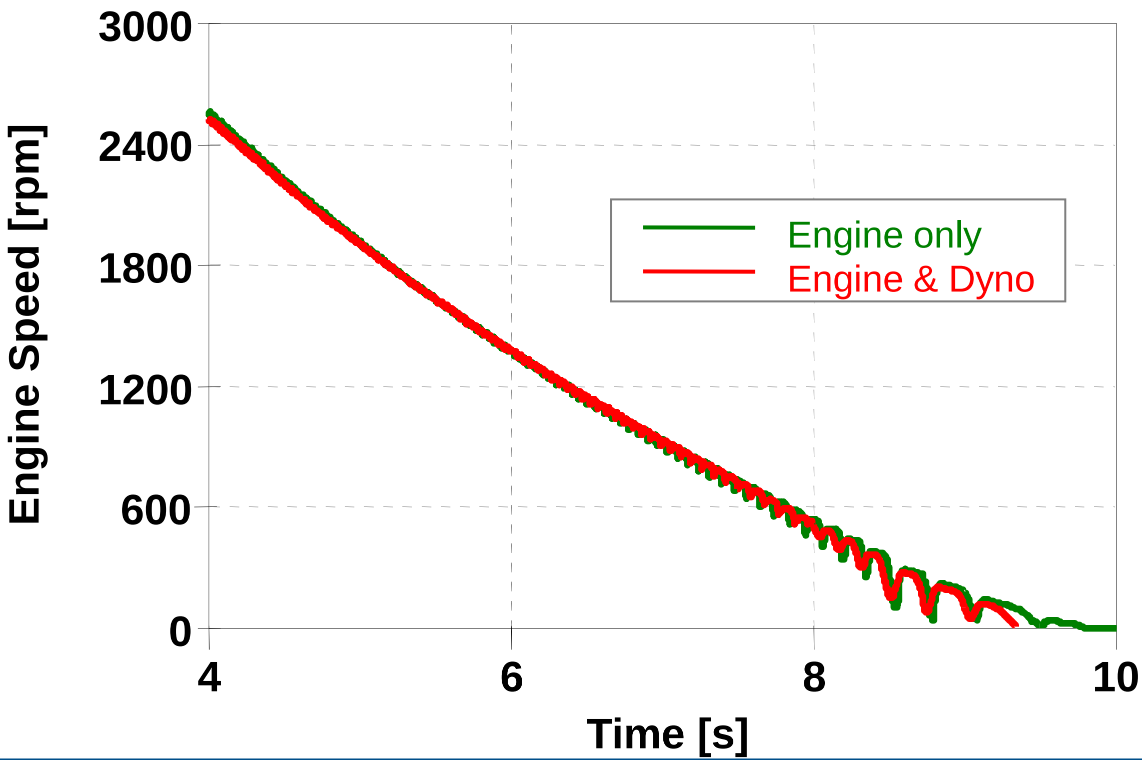
Stop
→ Coast Down to 0 rpm



- No Influence on engine behaviour
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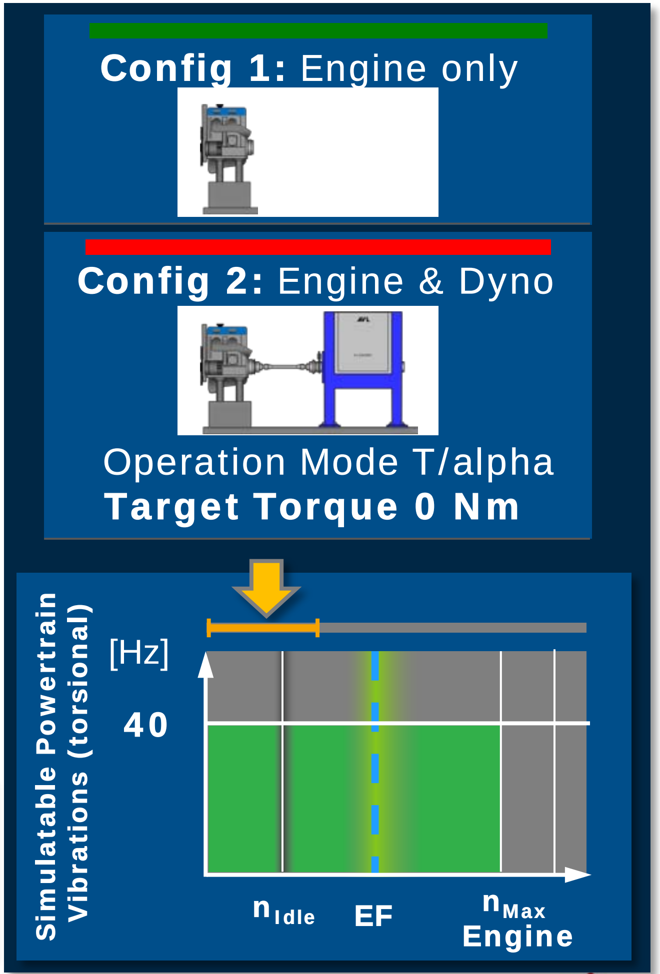
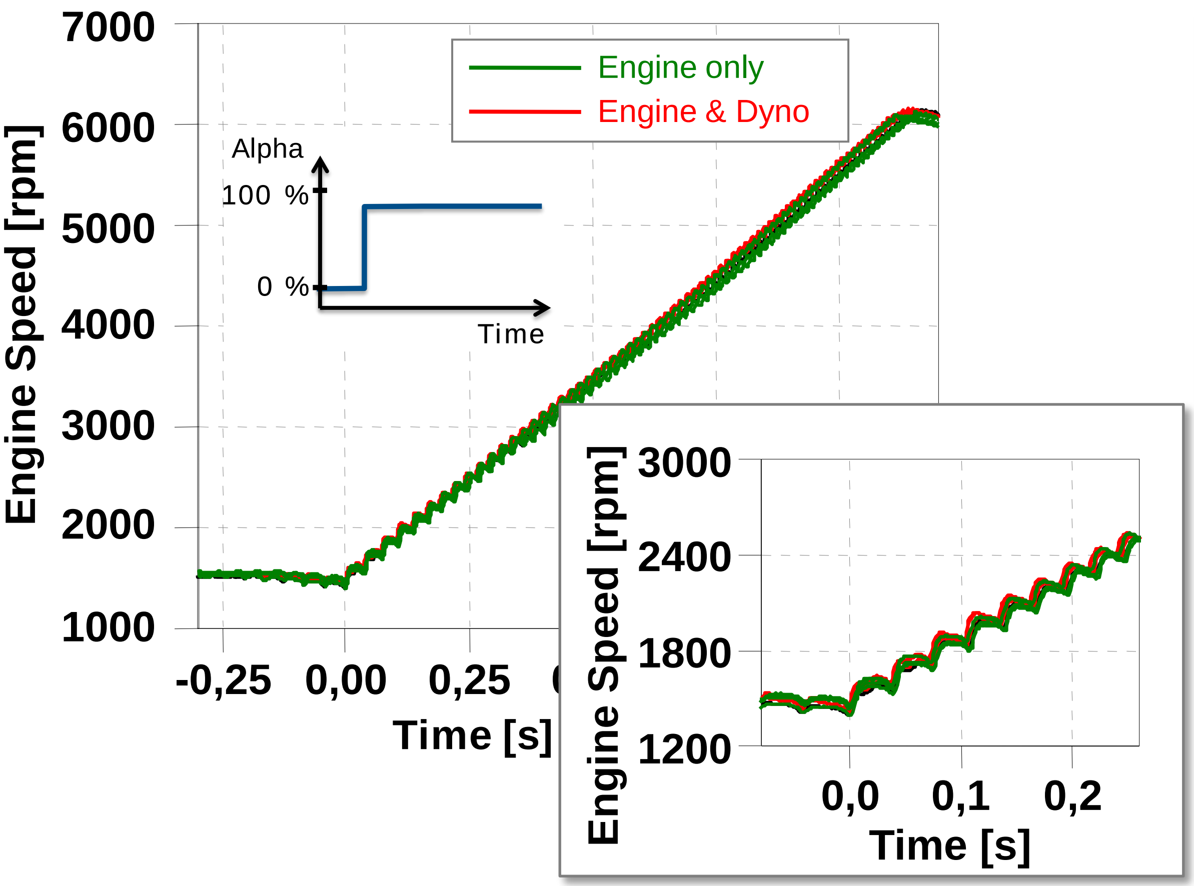


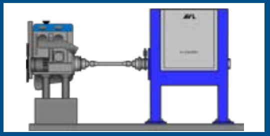
Tip-In
→ Free Acceleration of the Engine w/ and w/o Dyno



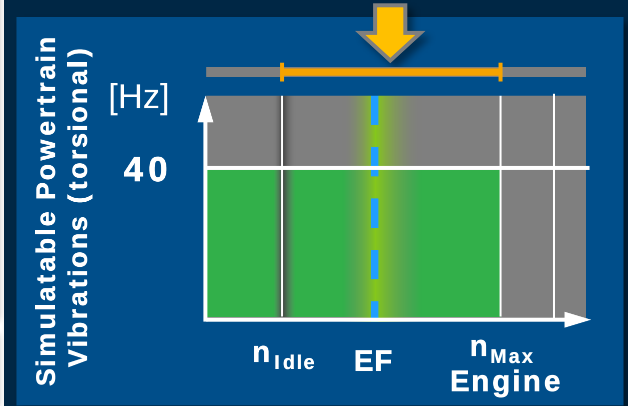
- No influence on engine behaviour

Config 1: Engine only

Config 2: Engine & Dyno

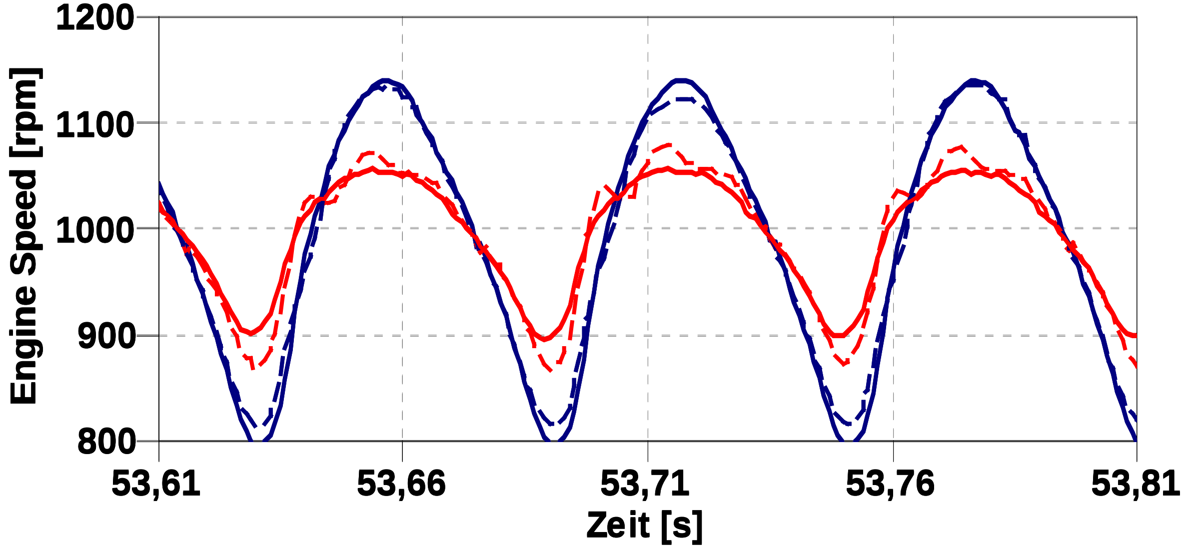


Operation Mode T/alpha
Target Torque 0 Nm



Simulation of Different Flywheel Inertias

→ Comparison Between Two Real Flywheels and Flywheel-Simulation by the Dyno



Config A: $\theta_{Flywheel} = 0{,}17\ kgm^2$

REAL

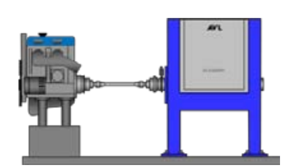
SIMULATED

Config B: $\theta_{Flywheel} = 0{,}10\ kgm^2$

REAL

SIMULATED

Config: Engine & Dyno



Operation Mode N/Alpha

N=1000rpm/Alpha=100%

- Increased / reduced inertia of real flywheels

→ Same rotational irregularities with real and simulated flywheels

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Simulation of Torque Influencing Components at the Engine Testbed

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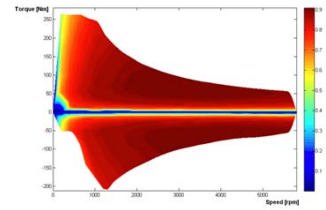
Simulation of torque influencing components with the simulation environment AVL INtime/ ArteLab™ Embedded in the automation system (Real Time, 1kHz)

- Hybrid components
- Starter simulation
- Simulation of auxiliaries
  - Generator
  - Air conditioning compressor
  - ...
- Dual mass flywheel

Source: Bosch

Source: LuK

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Simulation of Torque Influencing Components at the Engine Testbed

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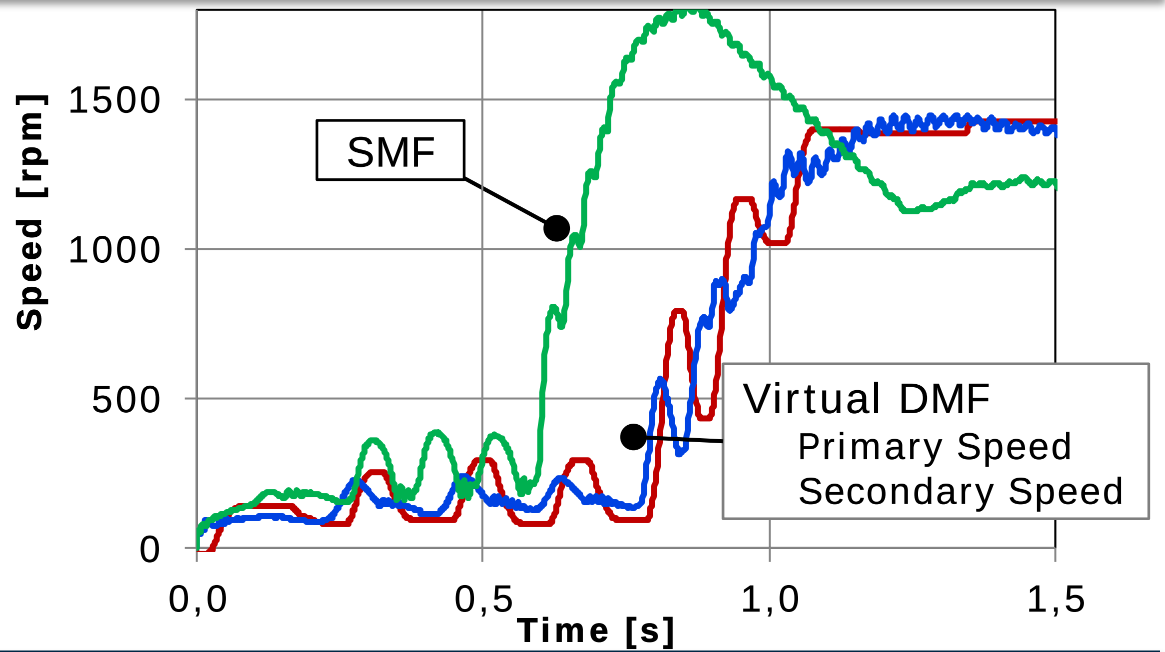
Engine Starts with Different Virtual Flywheels
Same Testbed Setup



source: LuK

DMF Simulation:
Primary-Speed = Engine Speed
Secondary Speed → Powertrain-Simulation

Hardware:
- ICE & SMF

Scenarios:
- Engine start
- Idle
- Engine stop
- Low speed Operation
- Change of mind

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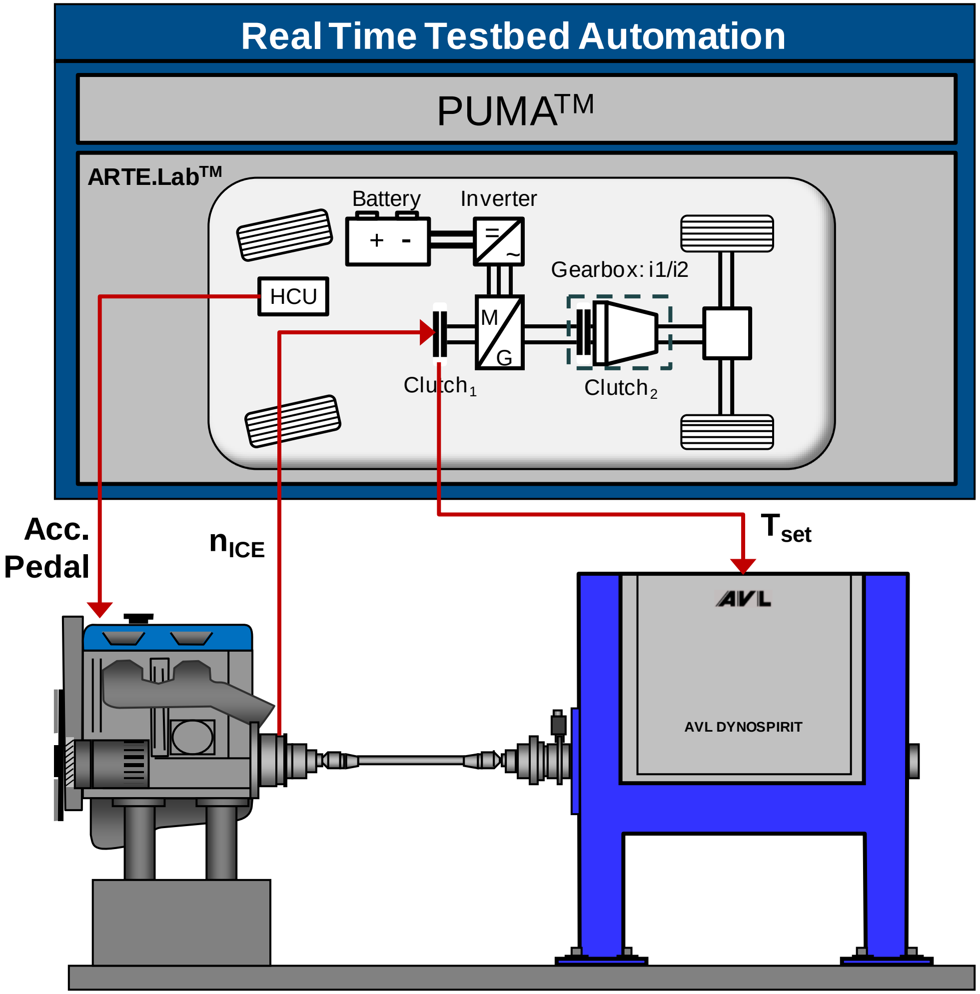
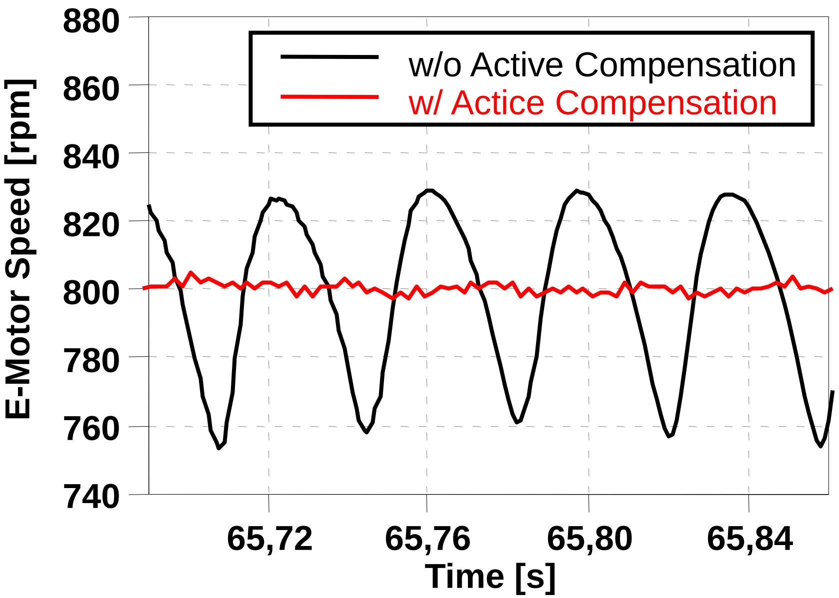
Simulation of Hybrid Electric Vehicle on VVETB



- Active oscillation damping by a virtual E-Motor
- Feedback of the real engine behaviour



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Keep in Mind…

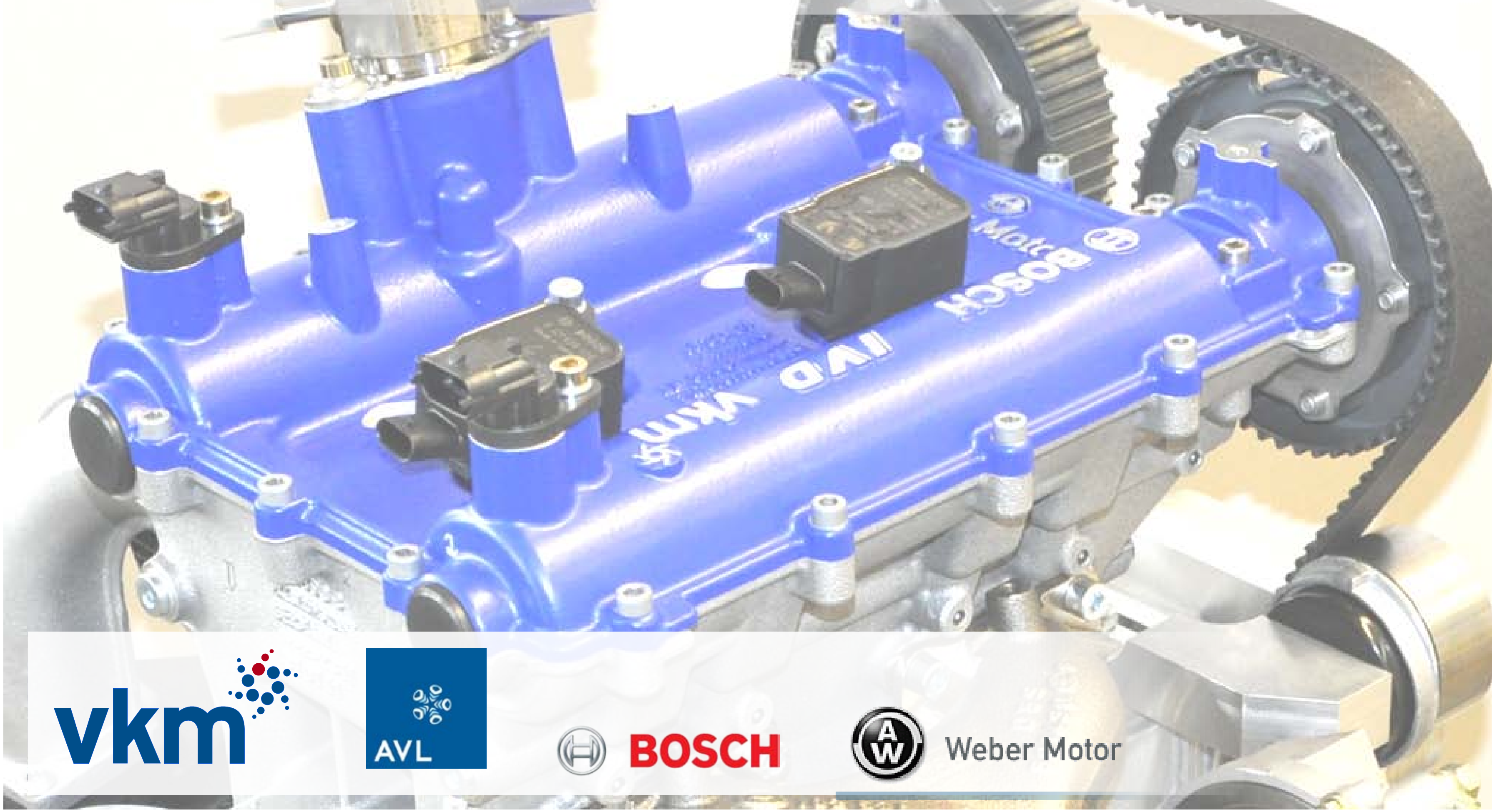
Advantages of a highly dynamic engine testbed like VVETB:

- Testing of two- and three-cylinders in total speed range without awareness of Eigenfrequency
- Realistic in-vehicle behaviour
- Simulation of:
  - Flywheel with different inertias
  - Vehicle and powertrain components

Usage for engine and powertrain development:

- Engine NVH application
- Realistic feedback of the engine when:
  - Varying virtual powertrain components or its characteristics
  - Implementing special control strategies e.g. an active damping control of a virtual e-motor

Vielen Dank für Ihre Aufmerksamkeit
Thank You for Your Attention



vkm AVL BOSCH Weber Motor