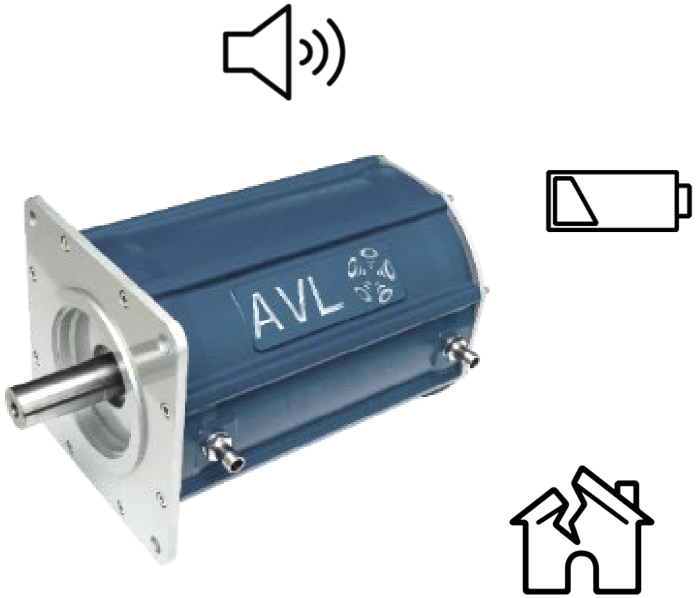
Toxic Torque / Dynamic Torque & Force Measurement

Toxic torque

Toxic torque is the part of torque, which influences the e-drive in a negative way.
In most cases those components are high frequent, can’t be detected directly and do not contribute to motion.



Toxic Torque is responsible for:

- Generation of noise and vibrations
- Reduction of efficiency
- Reduction of lifetime
- Limitation of rotation speed

Consider…

Have you ever thought about a clear differentiation between torsional oscillations and vibrations?

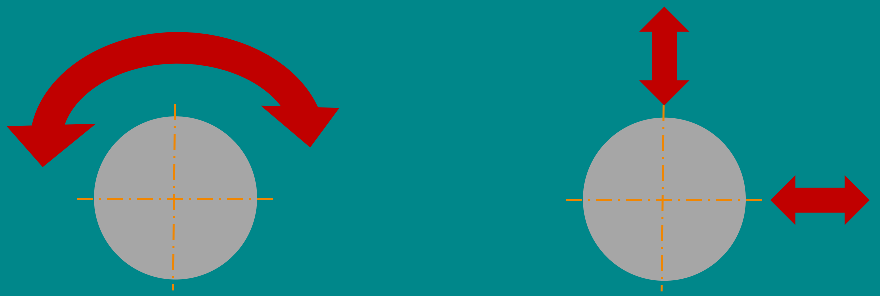
Can you trust the results by using different accelerometers on slightly different positions, by using different mounting methods for the same e-motor?

Aren‘t the repeatability and reproducibility crucial for a time-saving and efficient development of your e-motor?

Don‘t you want to use results in [N] and [Nm], instead of calculating or interpreting data which originally are measured in a different unit like [mm/s²] ?

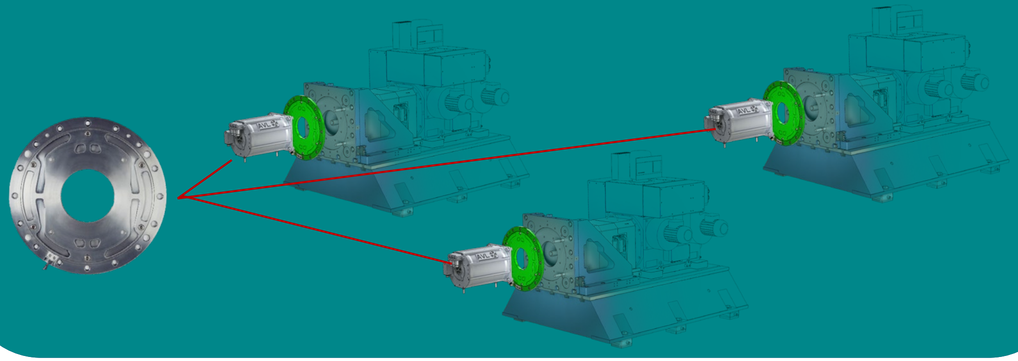
Future-proof and reliable e-motor testing

Torsional oscillations vs. vibrations

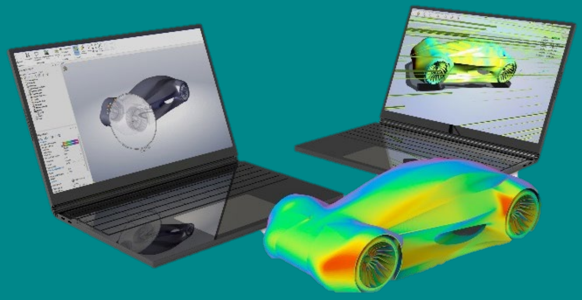


Rely on your measurement results

Repeatable and reproducible



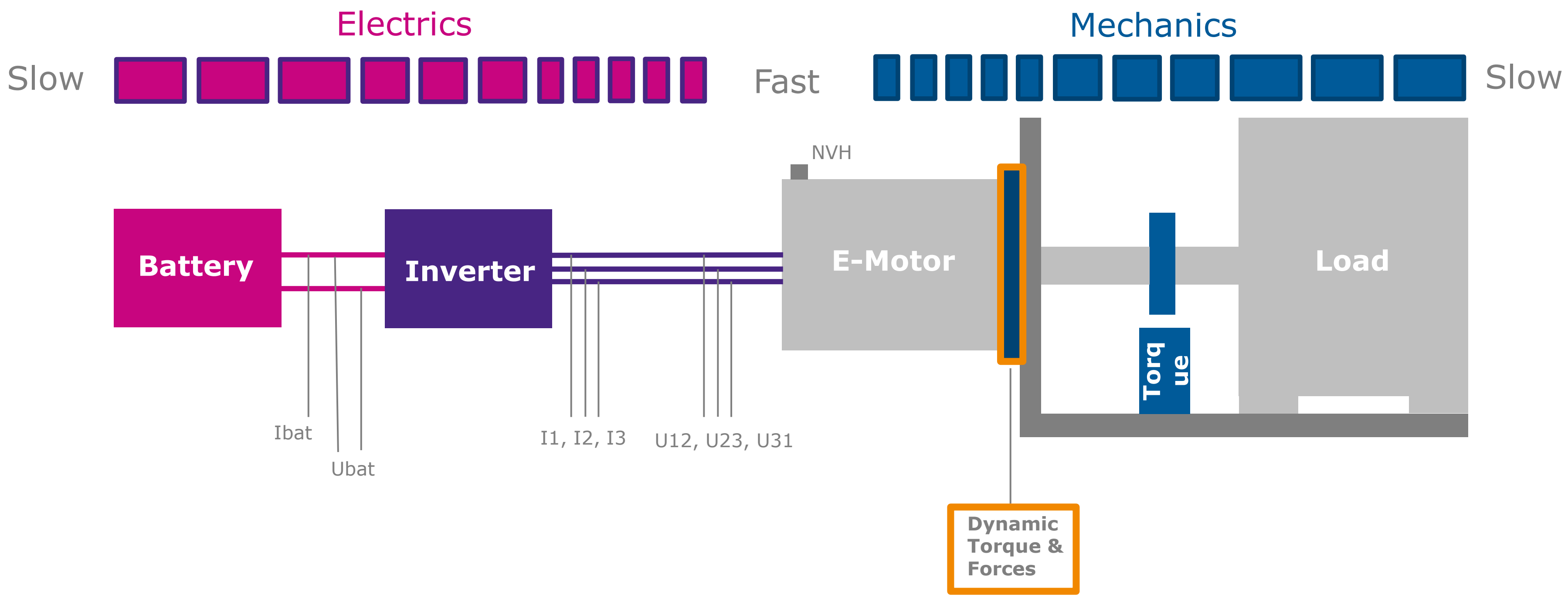
Results in [N] and [Nm]



Closing the gap of the test setup

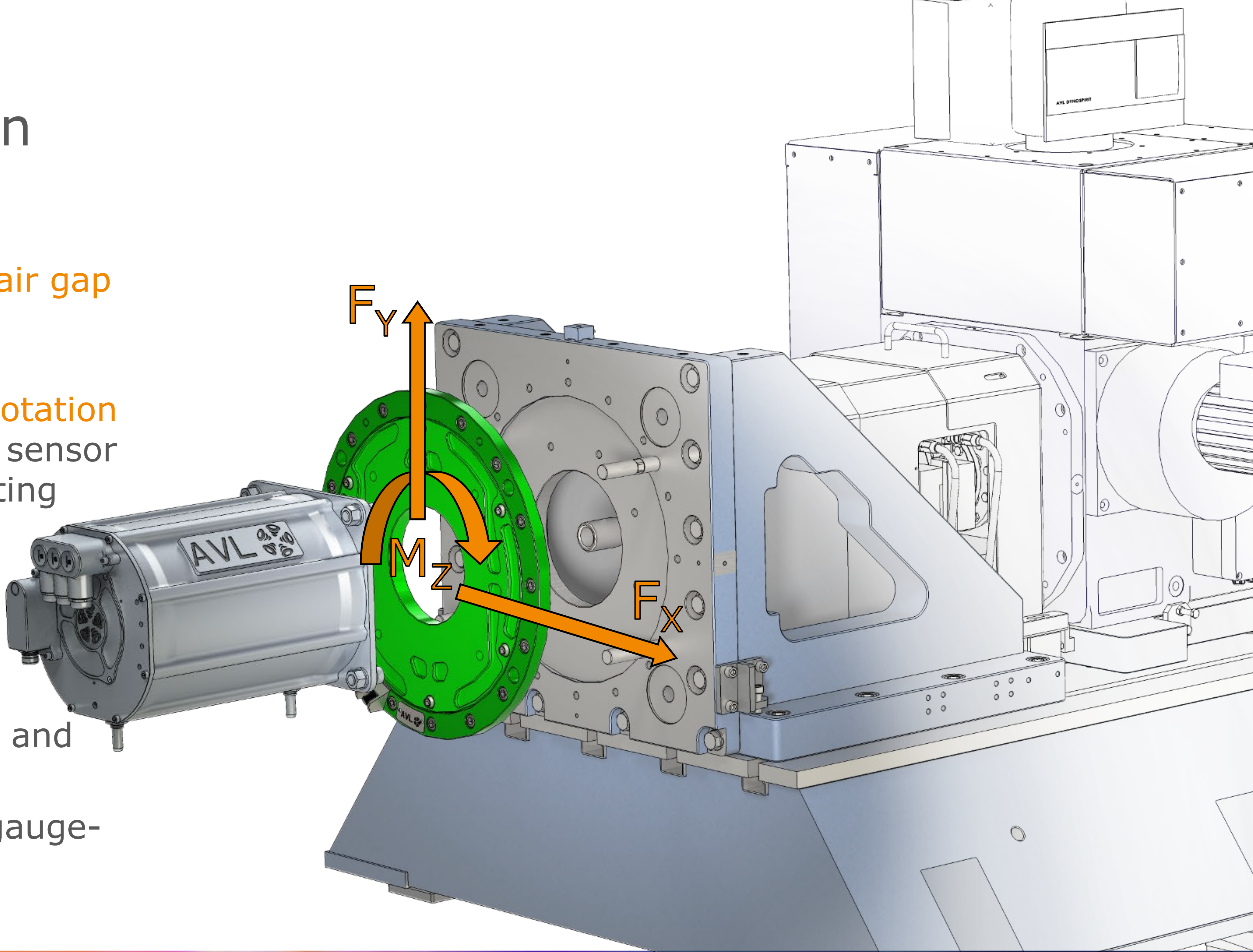
We are excellent in measuring electric and mechanic values in an accurate way on the slow sides of a testbed setup. The challenges appear on the fast side of it – where electric energy is transformed to rotation. But even there, with focus on high frequent e-power measurements, we are well experienced.

The Dynamic Torque Transducer closes the gab on the fast mechanic side, by resolving high frequent torque and forces on the closest position to the motors air gap moment.



Mounting situation

- Closest position to the air gap moment
- No limitation onto the rotation speed, because of high sensor stiffness and the mounting position.



- Measuring of torque M_Z and lateral forces F_X, F_Y
- In addition to a strain gauge-based torque sensor

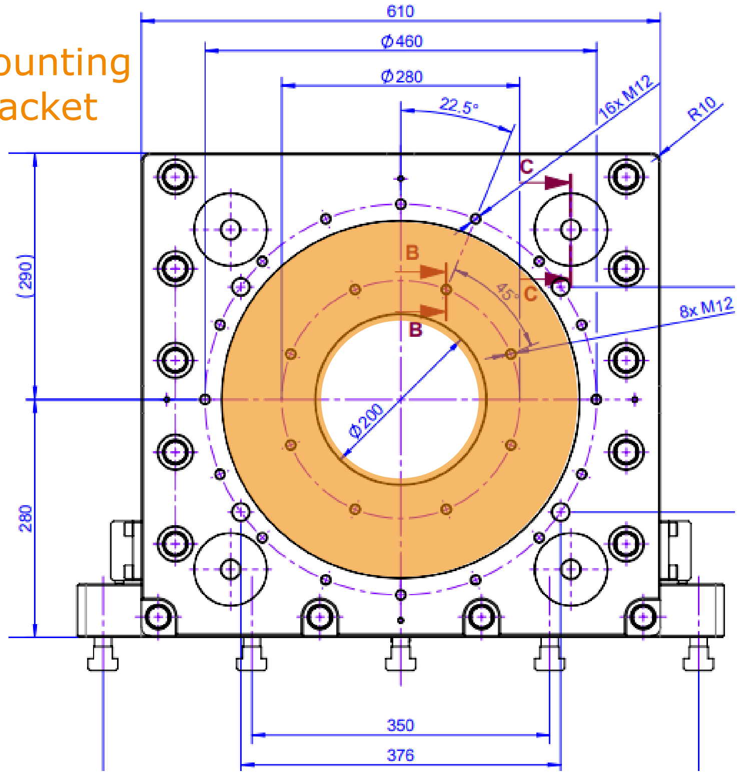
Dynamic Torque Transducer

- On the basis of piezoelectric technology
- Torque range: 3500 Nm
- Lateral forces: 28.5 kN
- Very dynamic: 150 Nm/ms (up to 25kHz)
- Torque ripple accuracy: ± 0.5 % (RE… relative error)

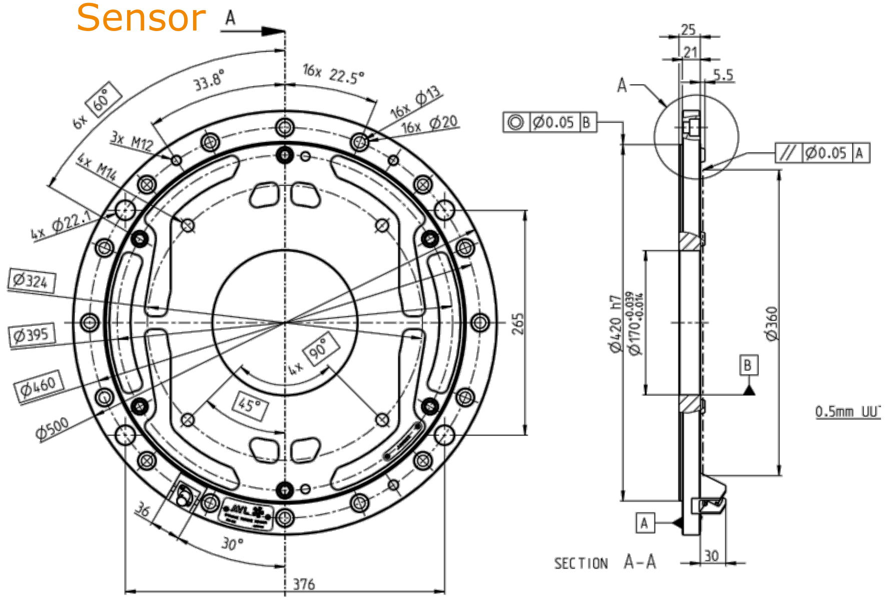
Sensor mounting

- Exact fitting of the sensor onto to AVL's mounting bracket
  - Centering pins, clearance fit Ø420mm (h7/H7)
- Sensor outside diameter Ø500mm
- The flange to the e-motor will be customized
- New Adapter solution
- A customization of the complete sensor hardware is possible

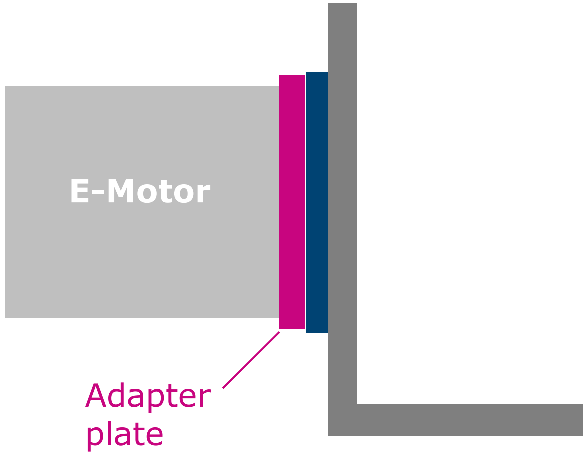
Mounting bracket



Sensor



Adapter solution



Measurement chain

Dynamic
Torque
Transducer

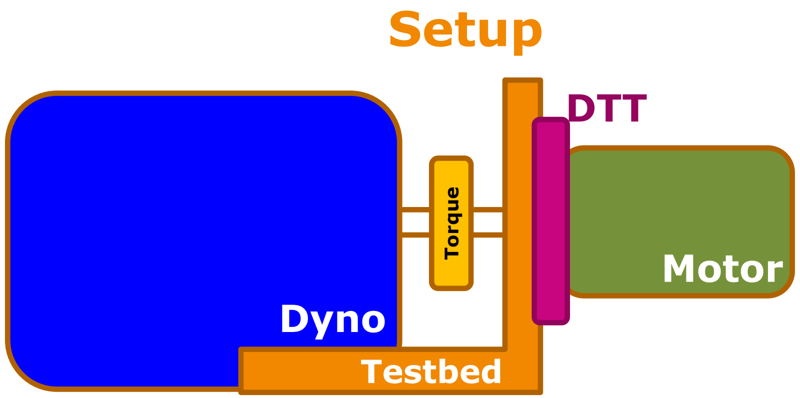
IndiCom
Dynamic
Torque Toolbox

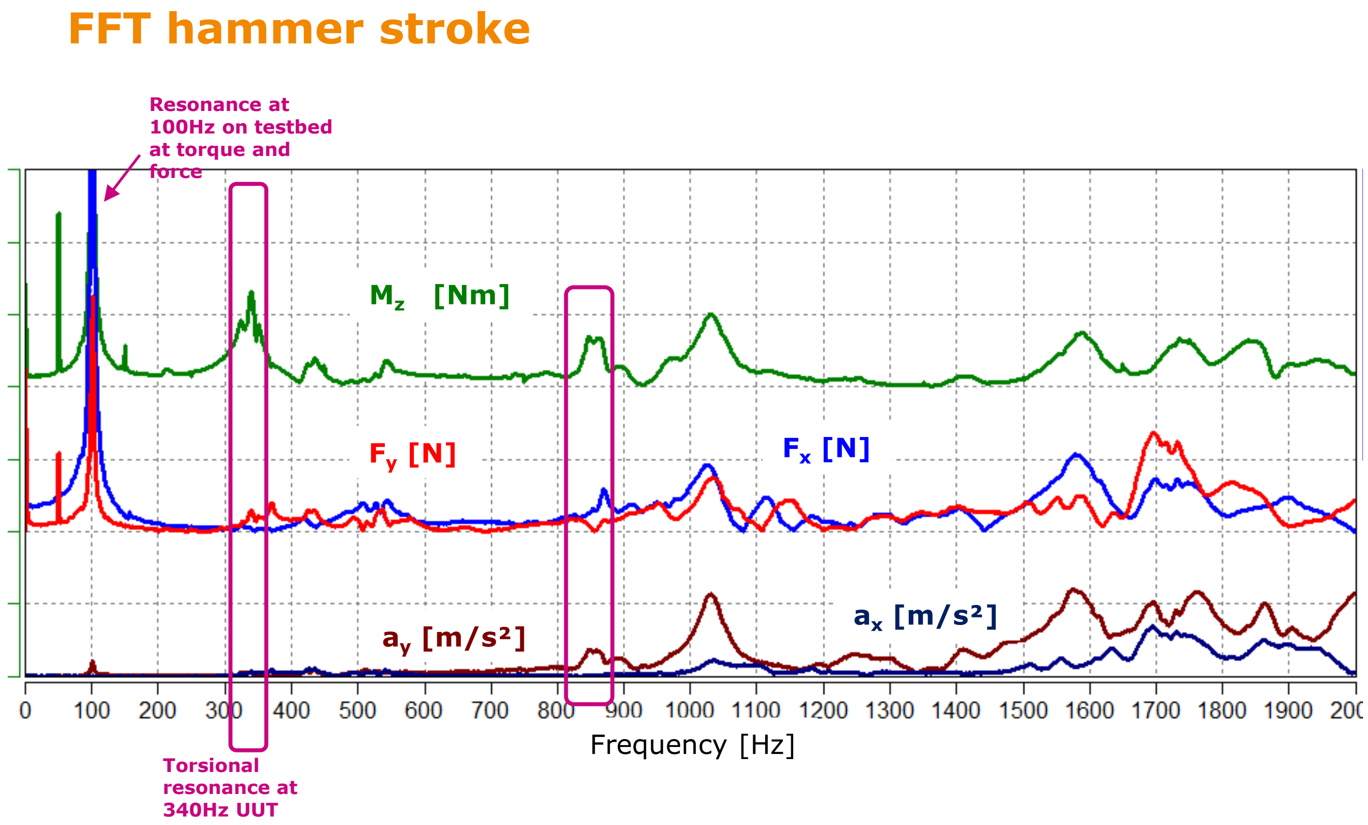
Charge

DAQ, charge amplifier

- RTP calculation (M_Z, F_X, F_Y)
- I/O on backside: for strain gauge sensors, EtherCat etc.

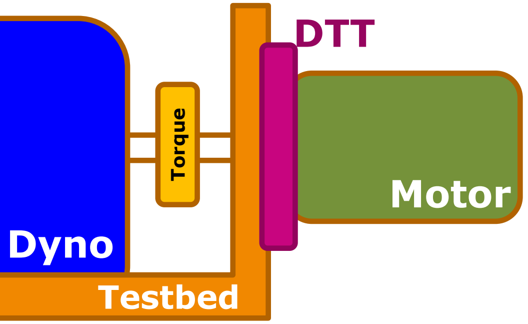
Testbed Behavior





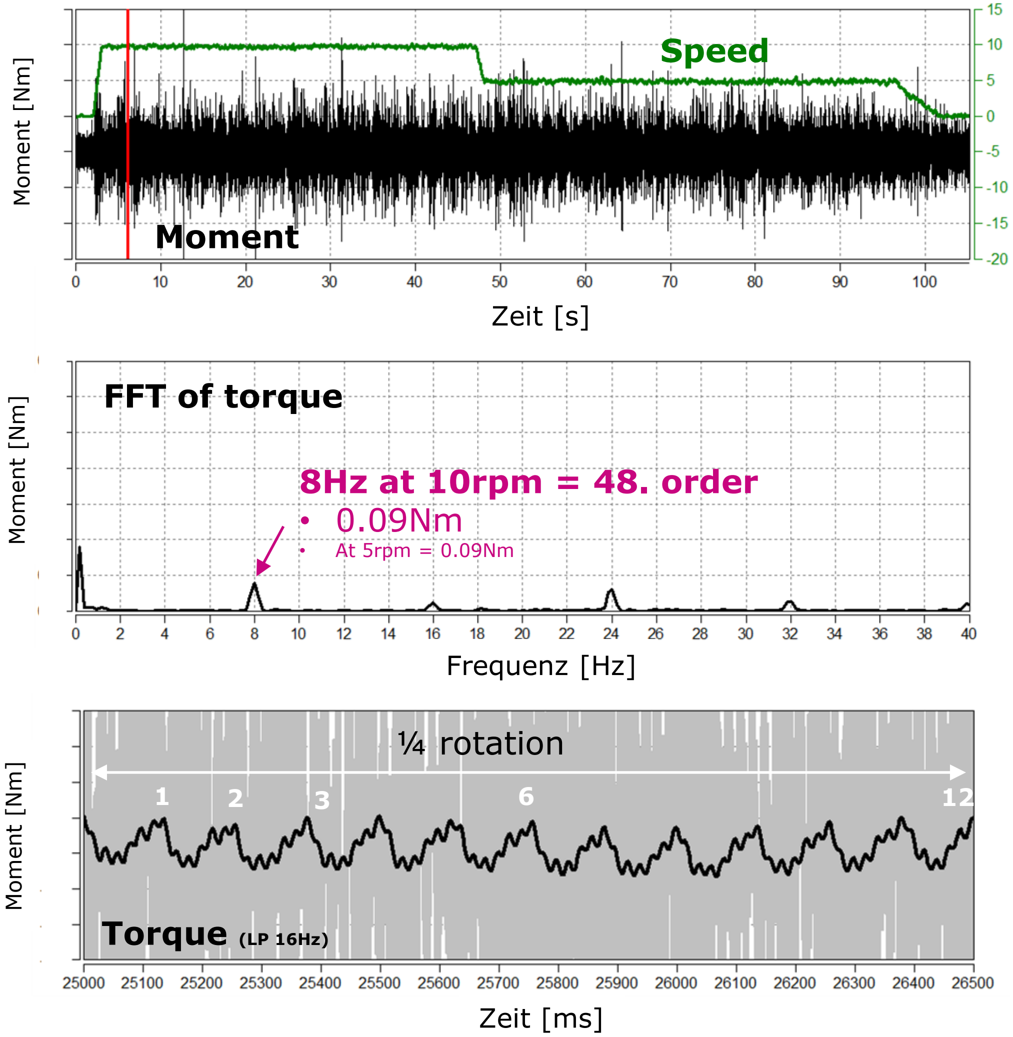
Cogging Torque

Setup



Method (related to norm)

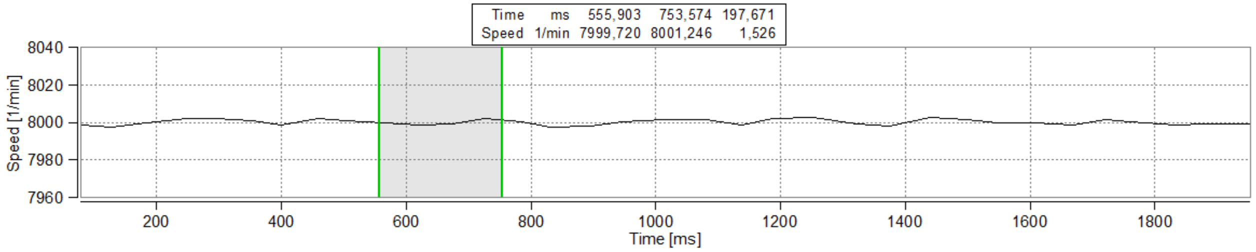
1. Ramp down at low speed
   2min
2. Evaluate Cogging Torque orders **<1min**

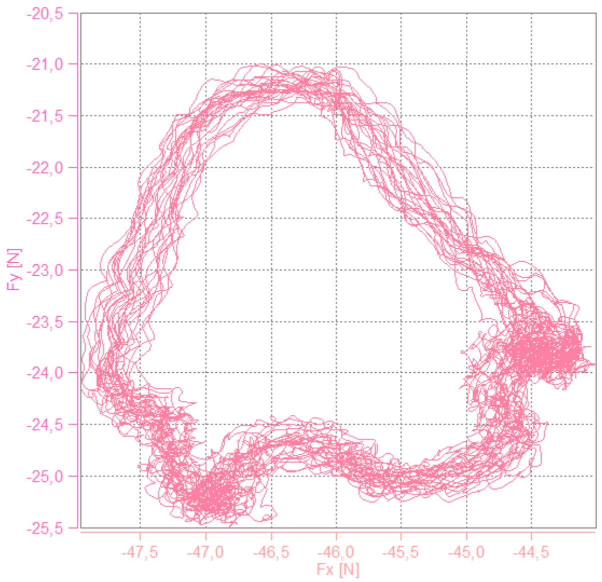


Summary

- Result
  - 0.09Nm
  - Cogging Torque in Nm in relation to ISO21782-3
- Effort
  - ca. 3min
- Savings
  - Special torque sensor for low torque ranges <1Nm
  - ⌛ for commissioning

Lateral forces





Further applications

- Rotor balancing
- Rotor centering

- Friction
- Durability tests (state of bearings)

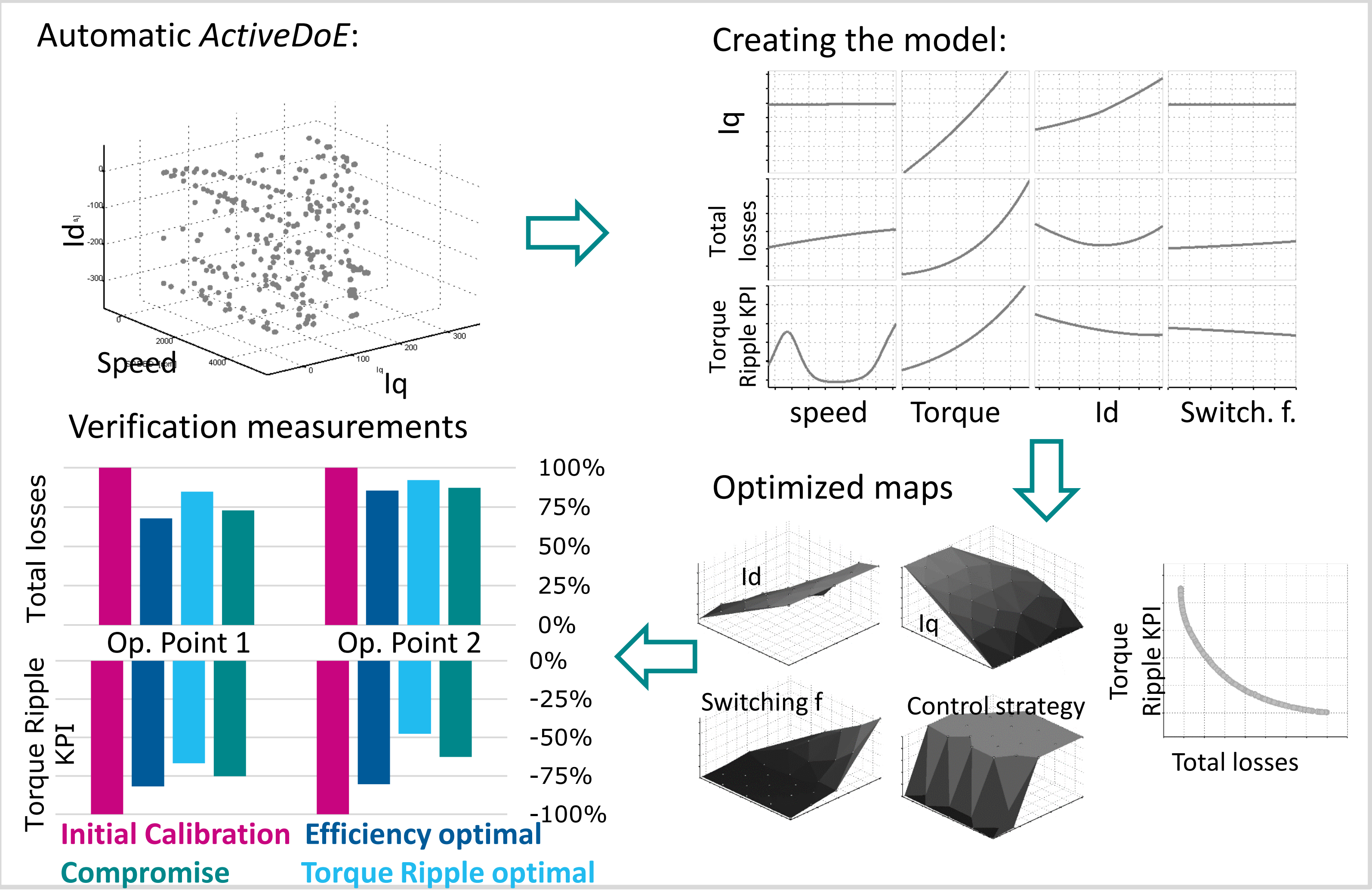
Sensor comparison in terms of measurement capability

	Today's standard		AVL Dynamic Torque Transducer
🟩	Measurement of static torque	🟨	Static torque under defined conditions
🟨	Measurement of dynamic torque is limited Torque up to 5 kHz or even less due to elasticity of the shaft ~50-200Hz	🟩	Measurement of dynamic torque up to 25 kHz Independent Resolution <10 mNm
🟨	Vibrations up to 20 kHz	🟩	High dynamic torque and lateral forces Direct at gearbox connection point
🟥	Measurement of forces not possible	🟩	Measurement of lateral forces in x,y,z direction
🟨	Different sensors for different torque ranges	🟩	One sensor for the whole range! Adjustable amplifier → from friction measurement to full torque with same resolution!
🟥	Speed range is limited Torque sensor is part of the shaftsystem	🟩	No speed limit

Sensor comparison on application's perspective

Today's standard	AVL Dynamic Torque Transducer
Cogging Torque Elastic shaft and slackness	Cogging Torque Measurement direct at e-Motor
Torque ripple Elastic shaft and slackness	Torque ripple Measurement direct at e-Motor
Unbalance	Unbalance Measurement of lateral forces
Bearing forces	Bearing forces Measurement of forces in all 3 dimensions
Friction Additional friction of intermediate bearing or dyno	Friction Just e-Motor friction will be measured
NVH Just vibration measurement	NVH Vibration and torsional forces of motor and attached gearboxes

Publication in upcoming ATZ magazine

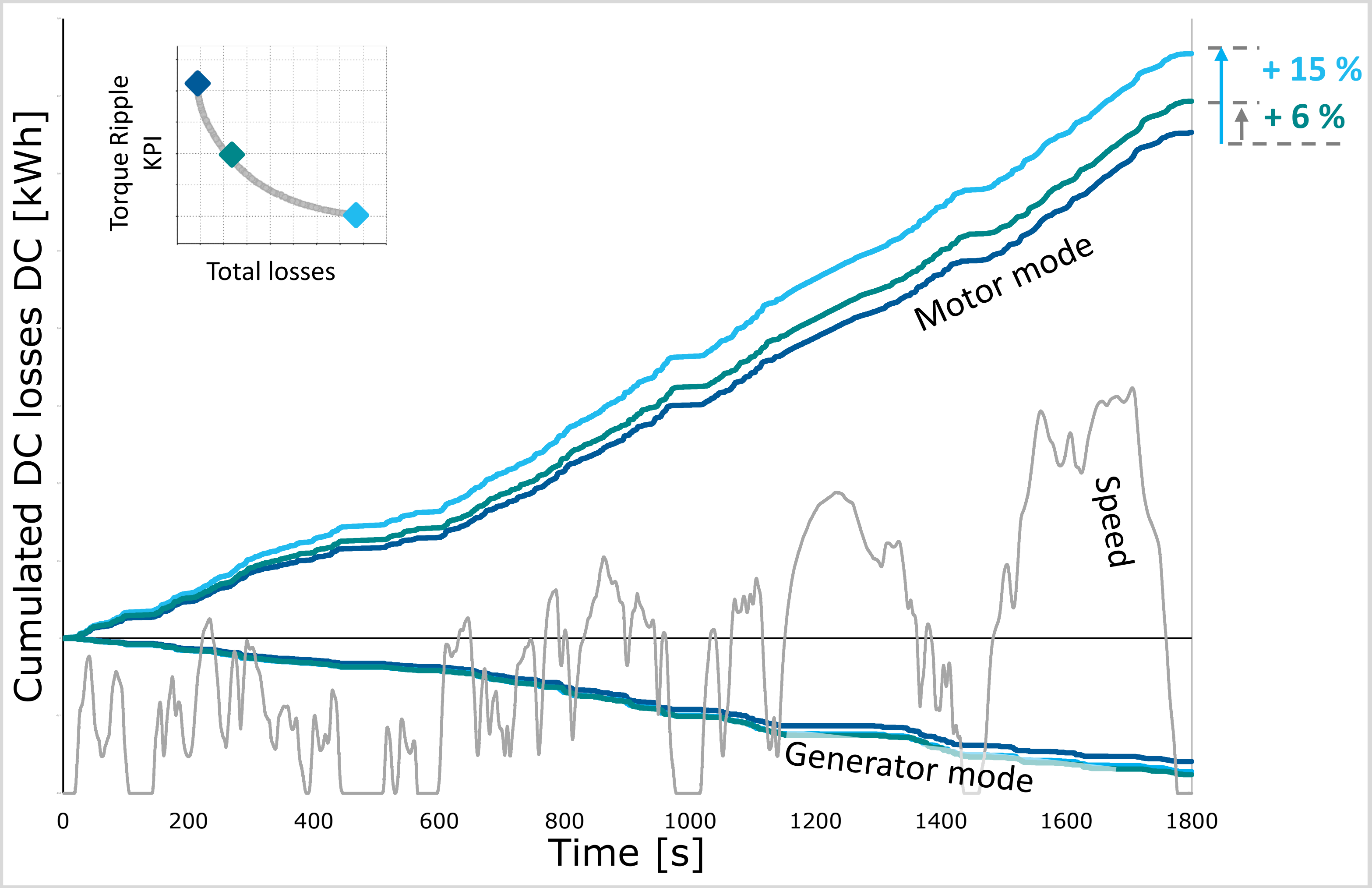


In a model-based way by using active-DOE an e-drive was optimized on a testbed

Variation parameter:
- Id
- Iq
- Switching frequency
- Control strategy

Optimization of:
- Efficiency
- Torque Ripple

WLTP cycle



Comparison of three optimized variations

- **Efficiency optimal**
- **Compromise**
- **Torque Ripple optimal**

Along the pareto front to optimum efficiency, the lowest torque ripples, or any compromise in between can be chosen.

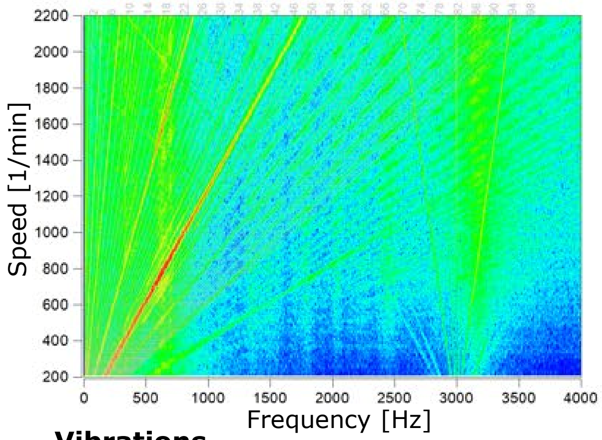
We chose +6% losses for a fundamental reduction of torque ripples.

The effect on NVH (48th order)

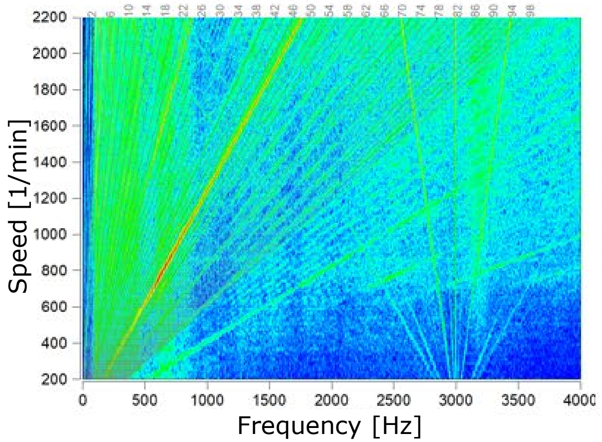
Outcome

- 50% reduction of torque ripples
- 8 dB less vibration

Torque

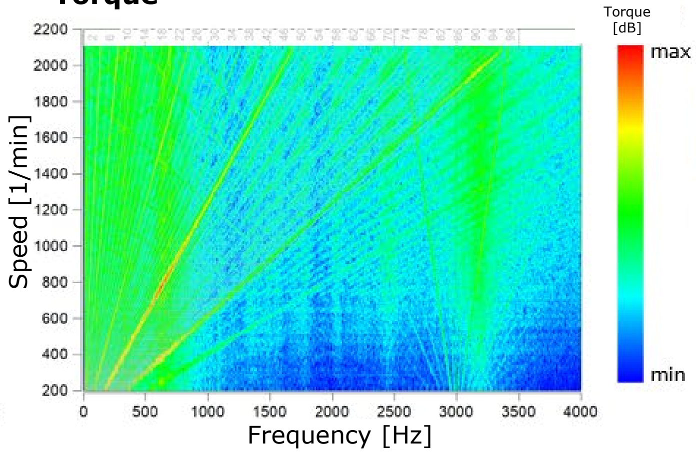


Vibrations

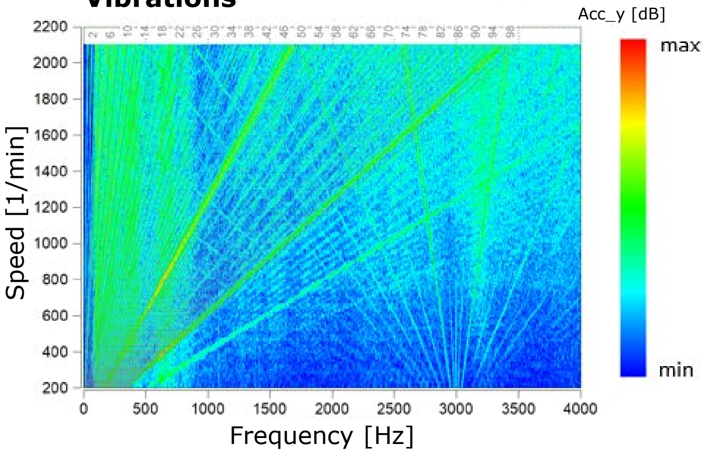


Inital calibration

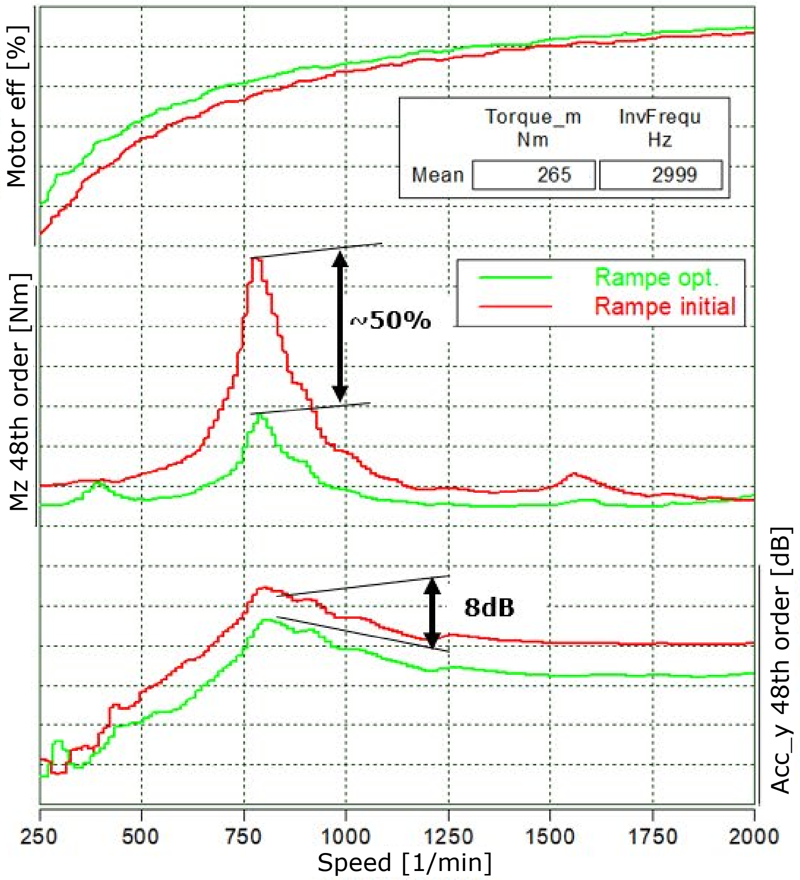
Torque



Vibrations



Torque Ripple optimal



Speed ramp

Kontakt

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Vielen Dank

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