Welcome to the webinar “Higher RPM and Dynamics in Torque Measurements: A Trend?“

Markus Haller

- **International Product Management**
- Diploma in Engineering
- Over 15 years of experience in sensor technology
- Product and Application Manager Torque Transducer
- **E-Mail:** markus.haller@hbm.com

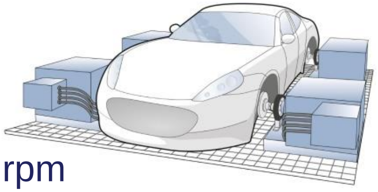
Markus Haller

Agenda

- RPM landscape
- Dynamic torque
- HBM solutions
- Summary

RPM landscape

Automotive



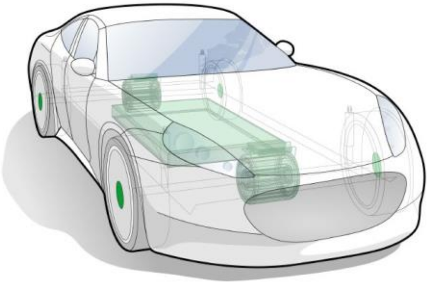
- Diesel: 3.500…5.000 rpm
- Gasoline: 6.000…6.500 rpm
- Sport cars even higher…9.000 rpm
- Racing Formula 1: Depending on Reglement up to 18.000 rpm or even higher
- Turbo charger: >100.000 rpm

Aerospace

- Turbine testing: 22.000 rpm…..plus
- High speed gear box: 30.000 rpm…plus

Electrical Drives

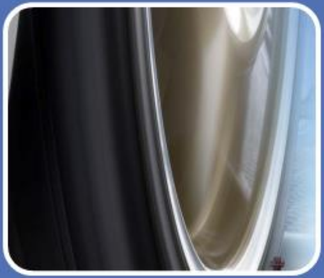
- 20.000 rpm standard
- Synchronous machines up to 25.000 rpm and more are available today
- New concepts => E-axle drives
- Smaller size



Application fields

Aerospace:

- Compressors & Turbines turbo shaft testing
- Helicopter transmissions testing
- Aero engine auxilliaries, Alternators, Starters,
- Fuel pumps, Gears, Seals, bearings



Automotive:

- Turbocharger
- Engine friction testing, Single Cylinder
- High performance engine e.g. F1
- Driveline, transmission, component test
- Electrical motor R&D

Industrial:

- Electric motor
- Compressor & Turbine R&D
- Seal testing
- Power transmission, component test

Electrification – a challenge?

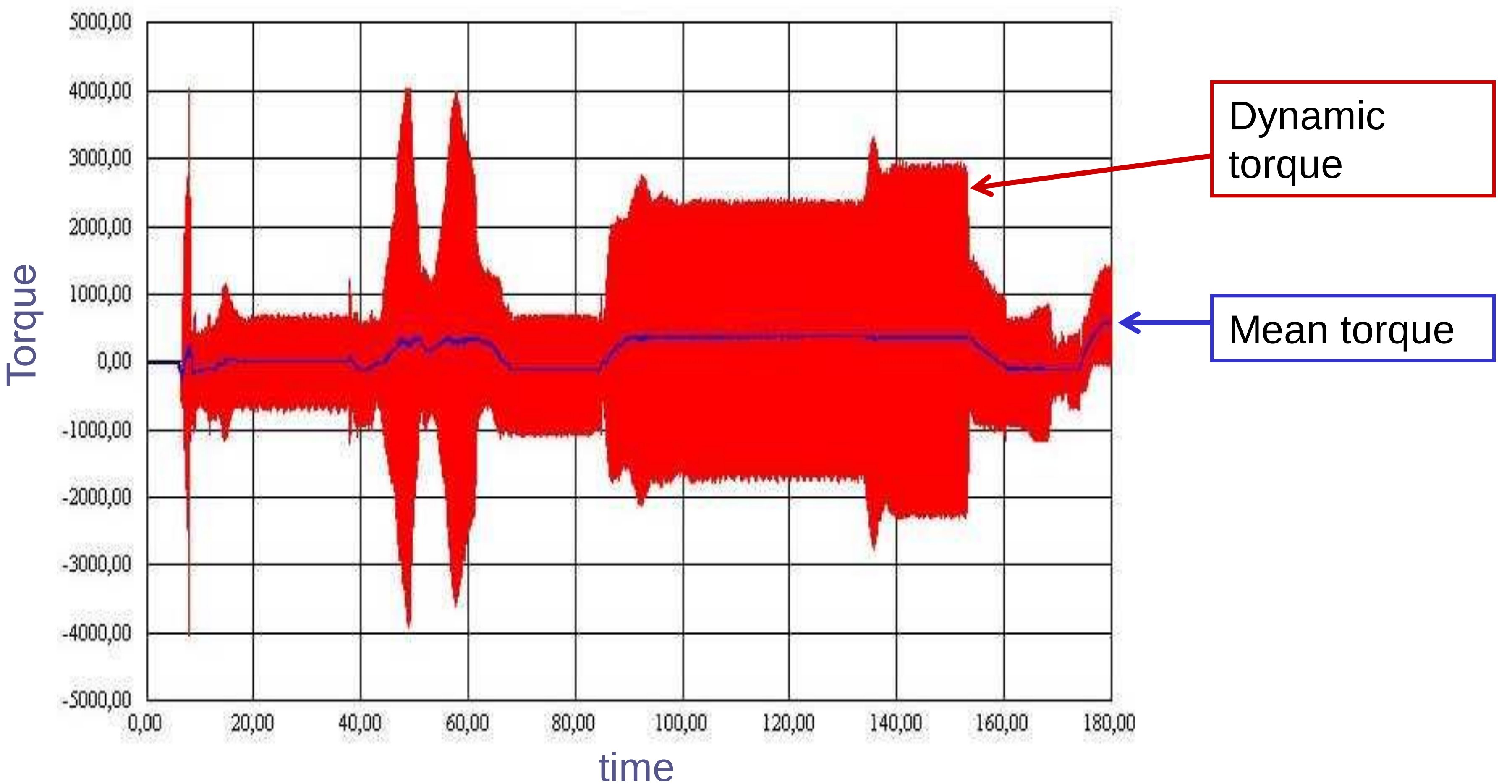
What is the driving factor for constantly increasing rpm capability?

$$P = M \cdot 2 \cdot \pi \cdot n$$

- To achieve a high power density the power generated is realized by increasing the speed while keeping the size small
- Electrical drives lead also to higher dynamics

Dynamic torque measurement

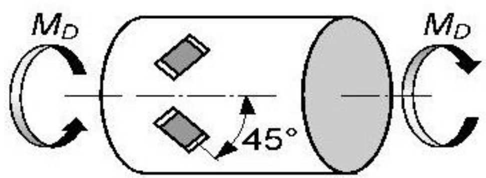
Torque sequence: 5,3-l-Diesel, n_{max} 1200 rpm



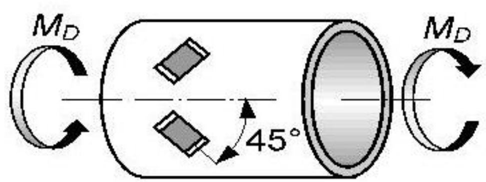
Measuring body shapes

Shaft-Type

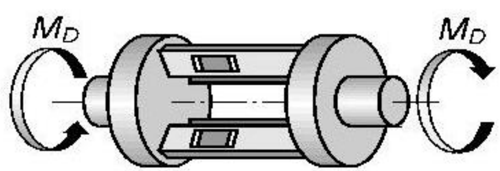
Solid shaft



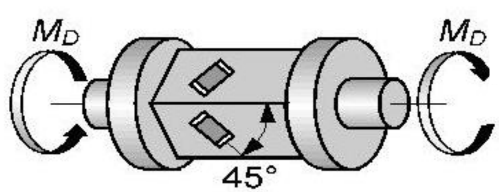
Hollow shaft



Cage shaped

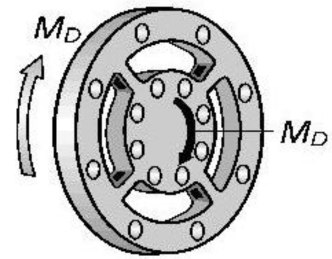


Square drive

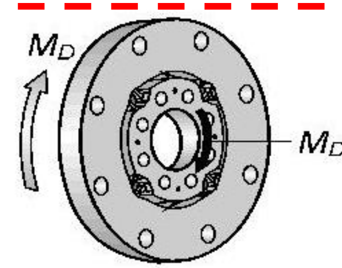


Flange-Type

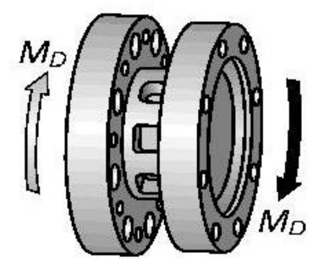
Spoked wheel



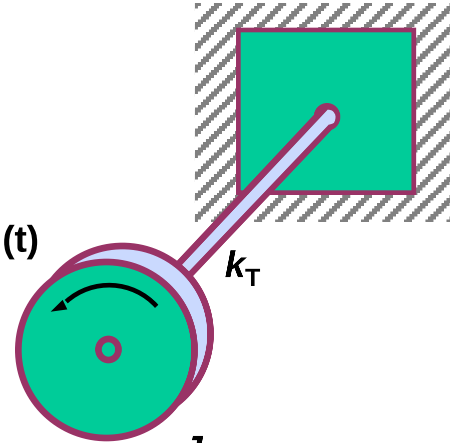
Radial share principle



Axial share principle



Natural frequency – Most simple model



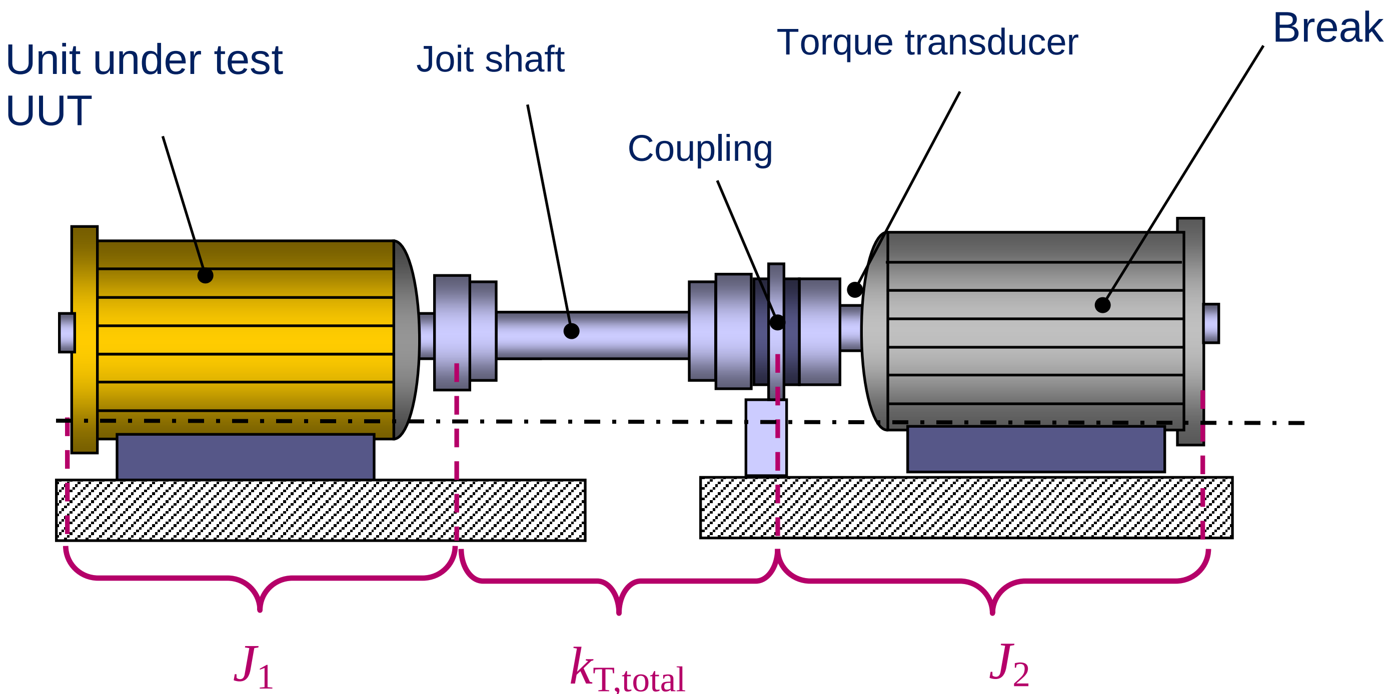
Cantilevered shaft with one disc

Equation of motion: $$J\ddot{\varphi} + k_T\varphi = M_{Dexc}$$

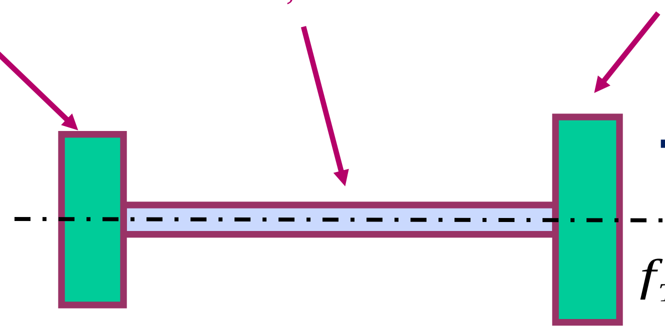
Natural frequency f_{T0}: $$f_{T0} = \frac{1}{2\pi}\sqrt{\frac{k_T}{J}}$$

k_T	Torsional stiffness of shaft / spring constant
J	Mass moment of inertia of the Transducer

Torsional natural frequency of a test bench



Two disc torsional vibrator as replacement model:



➔ Torsional natural frequency:

$$f_{T0} = \frac{1}{2\pi}\sqrt{k_{T,total}\left(\frac{1}{J_1}+\frac{1}{J_2}\right)}$$

Combine stiffness and inertia moments:

k_T Total torsional stiffness

from series connection of springs :

➔ **the smallest stiffness is crucial**

$$\frac{1}{k_{T,total}} = \frac{1}{k_{T1}} + \frac{1}{k_{T2}} + \dots$$

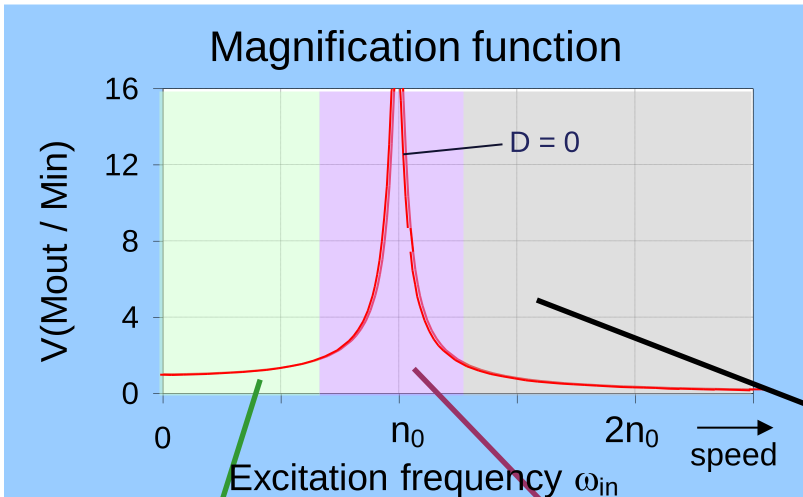
J_{total} Total mass moment of inertia

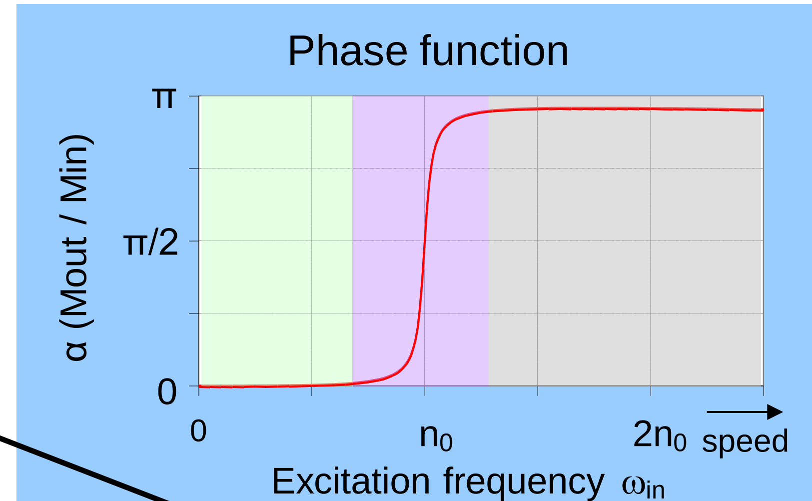
per addition:

➔ **the biggest mass is crucial**

$$J_{total} = J_1 + J_2 + \dots$$

Forced vibrations and resonance





Subcritical

$n_{in} < n_0$

- **Response amplitude ≅ excitation amplitude**
- **Limit case: like rigid connection**

Resonance range

$n_{in} \cong n_0$

- **Response amplitude much larger than excitation amplitude**

Supercritical

$n_{in} > n_0$

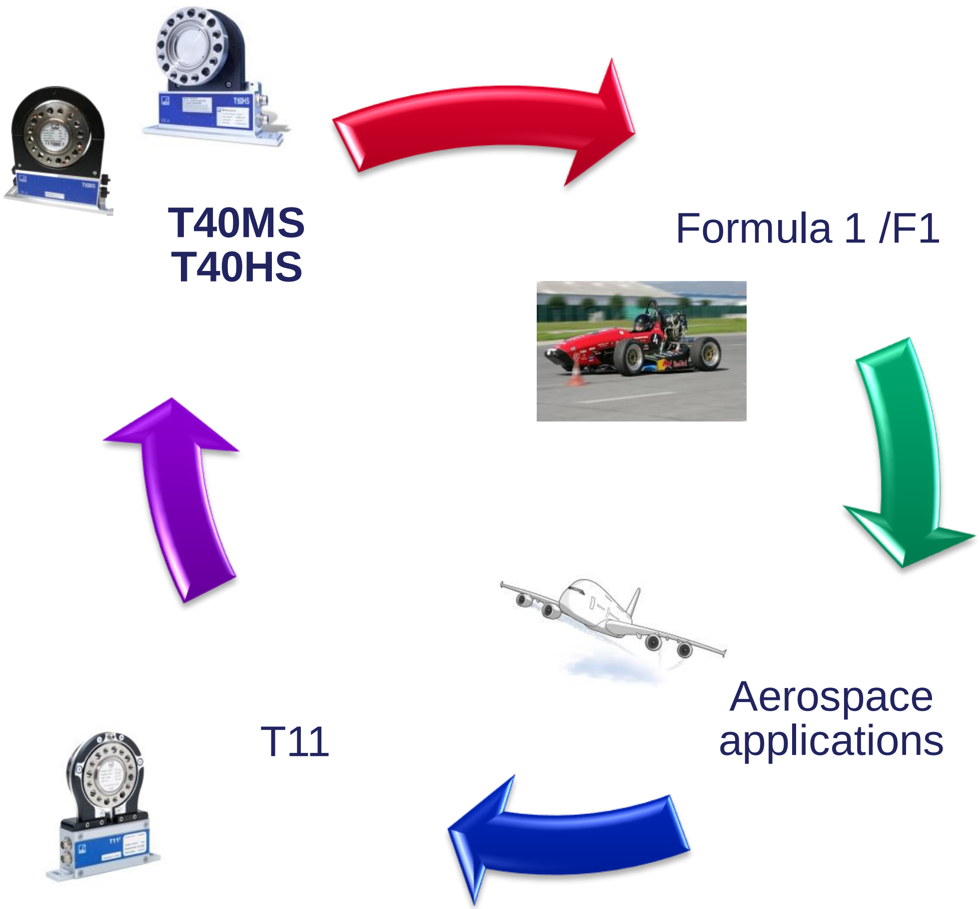
- **Response amplitude < excitation ampli-tude**
- **"Mechanical low-pass"**
- **Phase shifted by π**

Summary dynamic torque measurement

- For dynamic measurement the torque transducer should have a sufficient mechanical stiffness and a small mass
- Highest possible natural frequency of a sensor is the so called “ringing frequency”
- In a test bench application the natural frequency drop while adding components into the drive shaft with additional masses and inertia thus, the natural frequency of the system can be vary but will always less than the natural frequency “ringing frequency” of the sensor
- In the subcritical range response amplitude is closely matches the excitation amplitude.

Experience

More than 30 years experience in high speed applications



Torque flange solutions by HBM

T12HP

- Best in class transducer
- Up to 22.000 rpm
- Ultimate accuracy

T40B

- Standard transducer
- Up to 24.000 rpm
- High accuracy

T40MS

- Up to 30.000rpm
- High accuracy
- Extremly short
- Low mass - titanium

T40HS

- Very high speed up to 45.000rpm (55.000 rpm)
- High accuracy
- Low mass - titanium

Summary

- Power density in e-Drive systems constantly increasing
- Speed increasing to keep size small
- For major applications in the e-Drive business future max. speed is expected not likely bigger than 24.000rpm – 30.000rpm
- Torque transducer must have a sufficient high torsional stiffness and a low inertia => Natural frequency!
- For most challenging applications the sensor material is titanium to reduce the mass / weight to a minimum while keeping measurement performance high
- Take all important aspects of a “good” transducer into a account like accuracy, resolution, stability etc. not only maximized natural frequency!

Any questions?

- If you have any questions, please do not hesitate to contact us: webinar@hbm.com
- Or email the presenter directly: markus.haller@hbm.com

www.hbm.com

Markus Haller
Product Manager Torque Transdcuer
markus.haller@hbm.com