DOI 10.5162/SMSI2023/D4.2

Zero Signal Determination for Torque Measurement Under Rotation in Test Benches

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Summary:
This paper discusses the problem of determining the zero point when measuring torque under rotation. Two approaches are presented and analysed: static zero signal determination, which should be used for efficiency calculation, and rotational zero signal determination, which should be used for test bench torque calibration under rotation.

Keywords: zero signal determination, offset determination, torque measurement, torque under rotation, torque in test benches

Introduction

Torque transducers that use strain gauges to sense the applied torque characteristically feature an offset signal. This offset signal, called the zero signal, is caused by pre-loads that arise when strain gauges are applied. For correct torque measurement, the zero signal must be determined prior to measurement and used to tare the measurement signal. For static measurements and calibrations, the zero signal is determined as a single value at the beginning of a load sequence. By contrast, a single value for determining the zero signal is not sufficient for measurements under rotation. When measuring under rotation and in a horizontal position, misalignment errors (such as eccentricity, non-parallelism, and tilting in the drive train) and the dead weight of the transducer affect the torque output signal. Under rotation, such dead weight and misalignments can lead to periodic effects. In the following, different approaches are presented for taking these problems into account when determining the zero signal in test benches.

Established approaches

In static torque calibration, the signal in the unloaded condition at the beginning of each load cycle is tared to zero, or it is treated mathematically as zero in the evaluation of the subsequent measurements. [1]

In most test benches, the zero signal is usually defined as just a single value after the torque transducer is installed in the drive train, but in some cases as the mean value of two measurements at different positions. This value is saved and remains valid until the next calibration or until a significant variance in the zero signal is observed.

Zero signal determination in test benches

For zero signal determination in test benches, two options are available: i) static zero signal determination and ii) rotational zero signal determination. [2]

i) Static zero signal determination
The zero signal is measured in equally spaced steps over one full revolution of the drive train. In this work, 30° steps were used for a total of 12 measurement positions. Per position, the signal is averaged over 20 s after a dwell time of 30 s to let the system settle. The static zero signal is then the mean of these averaged signals for all positions over one full revolution.

ii) Rotational zero signal determination
The rotational zero signal is determined at the beginning of each torque load cycle either at minimum or at prevailing rotational speed. Because this approach can be easily integrated into the load cycle, temperature influences are automatically taken into account. The zero signal is averaged over an integer number of full drive train revolutions.

Results

When not installed, the transducer showed a zero signal of 67.76 kN m prior to the measurements in a 10 MW nacelle test bench (NTB).

After these and before the measurements in a 4 MW NTB, the unmounted zero signal of the same transducer was 69.85 kN m.

In Fig. 1, the static zero signal of the torque transducer installed in the 10 MW NTB is plotted over one full revolution. A periodicity of the signal can be seen. This is caused by the dead weight, which was compensated to the greatest possible extent, of the heavy adapters required to install the transducer, the test bench's hexapod, and the drive train itself. In addition, misalignments can have a periodic impact.

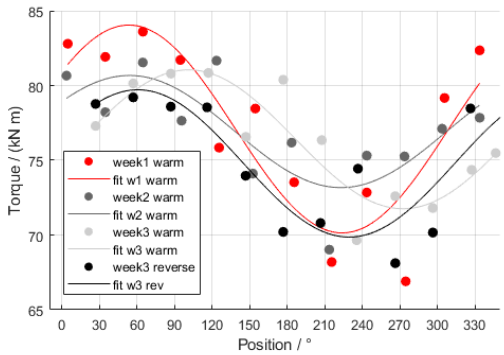

Fig. 1. Static zero signal in 10 MW NTB.

At 75.36 kN m, the average static zero signal on the test bench deviates by 7.60 kN m from the unmounted zero signal.

In the 4 MW NTB, the dead weight of the drive train is actively compensated by the non-torque load system. The averaged zero signals per angle position on different measurement days are randomly distributed; there is no recognisable position-dependent connection (Fig. 2). With an averaged zero signal of 75.31 kN m, the static zero signal in the 4 MW NTB deviates by 5.46 kN m from the non-installed signal.

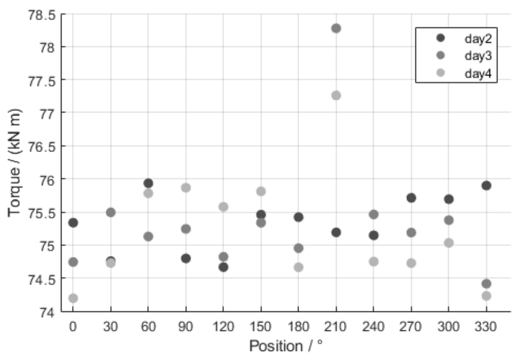

Fig. 2. Static zero signal in 4 MW NTB.

Because of the need to factor in frictional torque as a form of drive train power loss, the static zero signal should be used when determining the efficiency of drive trains on test benches.

The rotational zero signal determined under rotation at different rotational speeds in the 4 MW NTB is depicted in Fig. 3. Here again, the dead weight is actively compensated.

When the converter is switched off, the coherence between torque and rotational speed increases linearly. The increase in torque is caused by the rotational speed dependent friction in the bearings and the cogging torque of the generator. This influence is compensated by the test bench control, as can be seen by the light grey measurement points in Fig. 3. The unloaded signal at the beginning of a load cycle should, as with static torque calibration, also be used for torque calibration under rotation in a test bench. The calibration should be carried out at different rotational speeds, meaning that the zero signal must likewise be determined at different rotational speeds under the same conditions as the subsequent load cycle with control. Here, the quality of the "controlled zero" is not critical for the calibration as the signals for both transducers are tared under the same conditions.

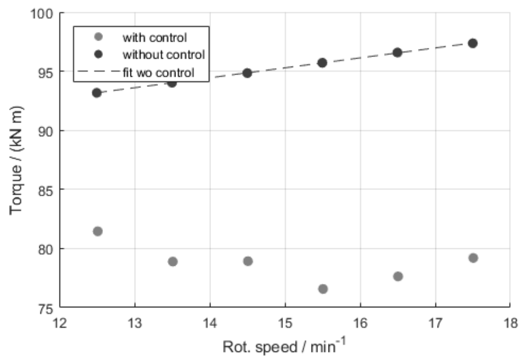

Fig. 3 Rotational zero signal with and without converter and, therefore, DUT control (4 MW NTB).

Conclusion and outlook

When torque measurement under rotation in test benches is done to determine the drive train efficiency, the zero signal should be determined statically over one full revolution. For the calibration of test bench torque under rotation, however, rotational zero point determination at different rotational speeds is the preferred method.

Acknowledgements

Project 19ENG08 has received funding from the EMPIR programme co-financed by the Participating States from the European Union's Horizon 2020 research and innovation programme.

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