

Title: Dynamic and rotating torque measurement in test benches for a net zero future

Abstract

Test benches play an important role in the development of drivetrains and optimisation of their efficiency for a net zero future. An important quantity in test benches is torque used in conjunction with rotational speed measurements to derive mechanical power/efficiency. It is measured dynamically and under rotation with only statically calibrated torque transducers. Research in the field of dynamic torque calibration has gained momentum lately but is still only carried out in the low newton-metre range; however, torques in the high newton-metre range prevail both in the field of e-mobility and in wind turbines. The proposed research aims to develop different methods for validating dynamic and rotating torque measurement in the high newton-metre range ensuring the EU can support the transition towards e-mobility and renewable energy systems.

Keywords

Dynamic and rotating torque measurement, wind turbine drivetrain, e-mobility powertrain, electrical machine test bench, transient torque event, torsional angle measurement, motor dynamics optimisation, lifetime prediction, efficiency savings, CO₂-emission-free passenger vehicles, renewable energy systems, energy production transformation

Background to the Metrological Challenges

The European automotive industry is currently undergoing a transition towards e-mobility and from 2035, only CO₂-emission-free passenger vehicles may be registered in the EU. Furthermore, the European Commission works together with the European countries to accelerate the transformation of energy production with a shift towards renewable energy systems such as wind energy. Functional and performance tests of powertrains, wind turbines as well as their individual components, in test benches are essential to meet e-mobility demands and accelerate the transformation to renewable energies. Test benches simulate boundary conditions and can provide manufacturers with the ability to reduce costs and time, however their requirements, are becoming increasingly important and a thorough review of the state of the art is needed.

One requirement that is known to present a significant challenge is increasing mechanical power, in the form of increasing torque and increasing rotational speed. Currently, the wind turbine industry is requiring test benches for entire wind turbine drivetrains with torque amplitudes of 32 MN m, as well as special test benches for high-speed generators and converter systems, with torque amplitudes of up to 125 kN m under a rotational speed of up to 1 600 min⁻¹. In addition, the automotive industry is requiring rotational speeds up to at least 10 000 min⁻¹ while higher speed is under development, challenging the performance of rotating torque sensors.

The effect on sensor performance (zero drift and sensitivity change) due to rotational speed is not yet known in the range of interest, neither is the bandwidth of the measuring system used. Dynamic oscillations cause vibrations, which further the risk of dynamic driven damage, and structure borne noise, which is converted into air borne noise. Tests for determining the efficiency of rotating electrical machines for rail and road vehicles, and for electrically propelled road vehicles are standardised. In these tests, torque is measured using statically calibrated torque transducers with an accuracy class of 0.2. Further information on how to handle the dynamic components of the torque are not given in the standards; nor is information on zero-point determination, bandwidth, or sampling and filter frequency. Dynamic torque is a growing industrial challenge. So far, only a few standard machines in the very low newton-metre range exist, which does not cover the industrial need. Also, the increased speed of motors used in electric propulsion leads to the need of a higher bandwidth in the torque measurement. The upward trend in wind turbine power and rotor diameters continues, leading to increasing torque and its dynamic components to be measured in wind turbine drivetrain test benches. In the

last years, research in the field of dynamic torque calibration has gained momentum but is still only carried out in the low newton-metre range.

Objectives

Proposers should address the objectives stated below, which are based on the PRT submissions. Proposers may identify amendments to the objectives or choose to address a subset of them in order to maximise the overall impact, or address budgetary or scientific / technical constraints, but the reasons for this should be clearly stated in the protocol.

The JRP shall focus on the traceable measurement and characterisation of dynamic and rotating torque in test benches.

1. To review and evaluate i) test benches used currently in diverse applications (such as motors, generators, and drivetrain / powertrain components) and under large torques, speed, and torsional vibrations and ii) static calibration results of torque transducers and their usage under rotation (such as zero-point determination, the different measuring chains, and the loading conditions). In addition, to determine future requirements for rotational speed and dynamic torque based on the needs of stakeholders.
2. To develop measurement methods and analysis capabilities for dynamic torques above 10 kN m under a rotational speed of around 1 500 min⁻¹. To develop and validate a digital twin by modelling the mechanical behaviour of wind turbine drivetrains using multi-body simulations. In addition, to experimentally determine the mass moments of inertia, torsional stiffness and torsional angle of the torque transducer and the drivetrain components using different approaches (such as physical or torsion pendula and laser vibrometers).
3. To develop measurement methods for dynamic torques below 1 kN m under a rotational speed up to 20 000 min⁻¹. To examine the influence of rotational speed and cross-talk on the torque measurement and the effect of different zero-point determination methods. To develop and validate a digital twin by modelling the dynamic behaviour of electric vehicle powertrains using multi-body simulations. In addition, to identify the system parameters of the electric vehicle powertrain under test.
4. To develop calibration methods for measuring dynamic rotating torque and dynamic rotational speed. To analysis, characterise and validate wireless data transmission systems (such as telemetry systems) in transient measurement events and to determine the required bandwidth to record these events.
5. To facilitate the take up of the technology and measurement infrastructure developed in the project by the measurement supply chain (e.g. calibration laboratories, NMIs, DIs), standards developing organisations (e.g. CIPM-CCM, IMEKO TC3, IEC TC 2 and TC9, ISO TC 22/SC 37), and end users (e.g. automotive and wind turbine industry). To publish, and disseminate to European and International stakeholders, an open access good practice guide on dynamic rotating torque measurement.

These objectives will require large-scale approaches that are beyond the capabilities of single National Metrology Institutes and Designated Institutes. Proposers shall give priority to work that meets documented industrial needs and include measures to support transfer into industry by cooperation and by standardisation. An active involvement of industrial stakeholders is expected in order to align the project with their needs – both through project steering boards and participation in the research activities.

Proposers should establish the current state of the art and explain how their proposed project goes beyond this. In particular, proposers should outline the achievements of the EMRP project IND09 Dynamic and how their proposal will build on this.

EURAMET expects the average EU Contribution for the selected JRPs in this TP to be 1.9 M€ and has defined an upper limit of 2.3 M€ for this project.

EURAMET also expects the EU Contribution to the external funded beneficiaries to not exceed 35 % of the total EU Contribution across all selected projects in this TP.

Any industrial beneficiaries that will receive significant benefit from the results of the proposed project are expected to be beneficiaries without receiving funding or associated partners.

Potential Impact

Proposals must demonstrate adequate and appropriate participation/links to the 'end user' community, describing how the project partners will engage with relevant communities during the project to facilitate knowledge transfer and accelerate the uptake of project outputs. Evidence of support from the "end user" community (e.g. letters of support) is also encouraged.

You should detail how your JRP results are going to:

- Address the SRT objectives and deliver solutions to the documented needs,
- Feed into the development of urgent documentary standards through appropriate standards bodies,
- Facilitate improved industrial capability or improved quality of life for European citizens in terms of personal health, protection of the environment and the climate, or energy security,
- Transfer knowledge to the automotive and wind turbine sector.

You should detail other impacts of your proposed JRP as specified in the document "Guide 4: Writing Joint Research Projects (JRPs)"

You should also detail how your approach to realising the objectives will further the aim of the Partnership to develop a coherent approach at the European level in the field of metrology and include the best available contributions from across the metrology community. Specifically, the opportunities for:

- improvement of the efficiency of use of available resources to better meet metrological needs and to assure the traceability of national standards
- the metrology capacity of EURAMET Member States whose metrology programmes are at an early stage of development to be increased
- organisations other than NMIs and DIs to be involved in the work.

Time-scale

The project should be of up to 3 years duration.