European Partnership on Metrology
Call 2025 – Health, Integrated European Metrology, Regulation and Research Potential

Selected Research Topic number: **SRT-s11**
Version: 1.0

Title: Traceability of dimensional and torque metrology for high-speed EV powertrain components

Abstract

Reliable methods, including uncertainty statements, are needed to enable trustworthy performance analysis and efficiency statements for electric vehicle (EV) powertrains that are developing quickly. Proposals addressing this topic should aim to investigate future needs of EVs, develop measurement standards and calibration methods, establish traceability for test benches, generate digital test certificates and reports as well as prepare user manuals and good practice guidelines.

Keywords

bearings, digital calibration certificates, digital test reports, dynamic torque, efficiency, EV powertrain, shafts

Background to the Metrological Challenges

Transportation causes one quarter of all greenhouse gas emissions in the EU, of which 70 % is due to land-based transportation. Automotive is currently undergoing a transition towards e-mobility, consequently from 2035 onwards only CO_2-emission-free passenger vehicles may be registered in the EU. Decarbonisation through e-mobility has become a global matter of interest. Functional requirements of EVs are rapidly changing based of government policy and customer demands. Foresight is required to understand the demands on metrology as each generation of powertrain advances. Motor speeds are currently at 10 000 min^{-1}, speeds at 20 000 min^{-1} are under test and designs beyond 30 000 min^{-1} are in discussion, for instance.

Additionally, quality requirements are becoming increasingly critical, because of the growing demand of customers on the driving performance. Noise emission by the gearboxes is no longer masked by the combustion engine. To reduce perceived noise, manufacturing tolerances of gears need to be improved by 50 %. To meet these requirements, advanced methods are needed to characterise the mechanical parts of powertrains. This includes full gear and bearing surface micro and macro geometry, as well as improved dynamic torque measurement. A significant challenge is the increased rotational speed combined with high precision torque measurement between 0.005 N m and 1.5 kN m. Functional and performance tests are essential to meet e-mobility demands and accelerate the transformation towards emission free transportation. Test benches simulate boundary conditions and can provide manufacturers with the ability to reduce costs and time. Results from test benches also inform function models of components which are used during concept and design stages to optimise configurations, but the traceability for these are missing and measurement uncertainty cannot be quantified. Traceable metrology is required to make informed decisions when efficiency is a key design consideration. Improvements in EV powertrain efficiency directly relates to reduction in battery weight or increased range. Furthermore, the EMN for Advanced Manufacturing identified the need for “use cases for the integration and development of Digital Calibration Certificate(s)” [1, 2]. Those certificates, as well as digital test reports are not available yet, neither in the field of dimensional gear metrology, nor in torque metrology, though they are needed as a building block for an enhanced digital process cycle.

Gear and coordinate measuring machines enable inspections of the functional gear geometry by determining the macro shape, which comprises the involute profile, helix and pitch according to ISO 1328-1, as well as the surface texture described by waviness and roughness parameters following the ISO 21920 series. However, combining these measurements is still challenging. For the qualification and traceability of corresponding measuring machines, calibrated workpiece-like standards are missing. Those standards should embody both, the curved involute shape of the gear flanks and deterministic surface texture parameters to close the gap

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between the macro and micro geometry in gear measurement. Based on the current state of knowledge, the surface texture has an impact on the load-bearing capacity, on lubrication conditions and noise emission. Today, no established methods exist for torque calibration under rotation, neither for dynamic torque, that is torque ripple superimposed over the rotational constant torque. Also, to enable torque ripple measurements, it is necessary to measure the momentary rotational speed or angular velocity with sufficient resolution corresponding to the frequency of the ripple. This makes it impossible to establish any evidence of the quality of the efficiency measurements. Differences in torque estimations between test benches can reach several percent. Measurements of torque ripple and other dynamic effects are not possible to estimate with any accuracy due to effects of vibration, installation and signal transmission effects among others.

Crosstalk between the electric power lines and magnetic fields and the measurement signals is also a significant problem not always considered. Particularly in e-mobility, transmission acoustics is analysed with tangential and radial composite inspection on single and double flank test rigs, respectively, by meshing a gear pair consisting of a gear under test and a gauge gear according to the mounting position in gearboxes, aiming to quickly capture the entire functional gear geometry. Traceability for these test benches is missing. Gear efficiency is measured on test benches with a complex interaction of torque, speed, load, temperature, and lubrication delivery and viscosity. These can be component level testing which are measuring very small losses in torque (< 0.1 N m) or system level testing which may be characterising changes of efficiency of 0.1 % at higher torques (1.5 kN m). Gear mesh frictional torque losses are a significant proportion of overall efficiency losses, and the effect of combined gear pair surface geometries requires traceable gear surface measurement and traceable dynamic torque calibration. Traceable surface measurement of drivetrain components (gears, shafts, bearings) for renewable energy systems has been developed by EMRP project ENG56 DriveTrain. EMPIR project 19ENG07 Met4Wind developed a range of new measurement capabilities including uncertainty evaluations for shopfloor applications. Methods for traceability for constant rotating torque at low-speed and periodic oscillating dynamic torque measurements were developed and established by EMRP project IND09 Dynamic and EMPIR projects 14SIP08 Dynamic and 19ENG08 WindEFCY. The efficiency of drivetrains used in wind energy systems has been analysed and improved by EMPIR project 19ENG08 WindEFCY.

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 proposal shall focus on the development of new measurement standards, calibration services and measuring systems at NMIs/DIs for torque and dimensional metrology.

The specific objectives are

1. To validate drivetrain performance analysis models by e.g. Tooth Contact Analysis (TCA) and CAD based models in order to evaluate current and future EV requirements. The evaluation also includes i) dimensional traceability requirements for specialised production measurement methods used by component manufacturers, ii) requirements of high-speed test benches for mechanical power transmission systems focussing on torque and rotational speed requirements.
2. To develop primary standards and calibration methods relating to complex mechanical properties of powertrains and to extend traceability for gear surface form, waviness, and roughness parameters for EV gear needs. This includes development of primary workpiece-like artefacts for involute gear waviness and roughness with content of (0.1-2) µm with appropriate uncertainties and traceable measurement chains for dynamic torque ripple in the envelope of 1.5 kN m and 20 000 min^{-1} with uncertainties of 0.2 % for the constant rotational torque. In addition, to investigate the influence of rotational speed and crosstalk, bandwidth, frequency response, and wireless transmission of data.
3. To develop primary standards and calibration methods for establishing test bench traceability for the component and system testing of mechanical components of powertrains used in industry. This includes developing a strategy for establishing traceability for single flank and double flank measurements required for EV gear manufacturers to test the resolution, frequency response and magnification of the testing system. Additionally, to provide traceable dynamic torque measurements and mathematical models for the additional inertia loads in test bench applications.
4. To develop specific digital calibration certificates (DCC) and test reports for dimensional calibrations including surface texture according to ISO 1328-1 and ISO 21920-2 as well as for torque calibrations and measurements according to ISO 21782. and gear efficiency measurements. This includes developing specific robust method for each standard to transfer measured data to analysis models

to enable a seamless dataflow through the entire manufacturing cycle, e.g., gear surface deviations to Tooth Contact Analysis (TCA) models and rotational effects for torque transducers including signal transmission links. Specific DCC and test report for gear efficiency measurements according needs of end users will be developed too.

5. To demonstrate the establishment of an integrated European metrology infrastructure and to facilitate the take up of the technology and measurement infrastructure developed in the project by the measurement supply chain (calibration laboratories, NMIs/DIs, accreditation authorities), standards developing organisations (CIPM CCM/CCL, IMEKO TC3, IEC TC2 and TC9, ISO TC 22/SC37, ISO TC 60/SC2) and end users (test bench manufacturers, automotive).

These objectives will require large-scale approaches that are beyond the capabilities of single National Metrology Institutes and Designated Institutes. To enhance the impact of the research work, the involvement of the larger community of metrology R&D resources both within and outside Europe, plus engagement with existing European research infrastructures and European Partnerships is recommended. A strong industry involvement is expected in order to align the project with their needs and guarantee an efficient knowledge transfer into industry and end users. Where relevant, proposals are encouraged to build on, or seek collaboration with, existing projects and develop synergies with other relevant European, national or regional initiatives and funding programmes. In particular, links are encouraged with (i) the projects funded under earlier relevant topics of the Horizon Europe programme; or (ii) other relevant European Partnerships.

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 projects ENG56 DriveTrain and IND09 Dynamic, and EMPIR projects 14SIP08 Dynamic, 19ENG07 Met4Wind and 19ENG08 WindEFCY, and how their proposal will build on those.

Proposers should note that the programme funds the activity of researchers to develop the capability, not the required infrastructure and capital equipment, which must be provided from other sources.

EURAMET expects the average EU Contribution for the selected JRPs in this TP to be 2.1 M€ and has defined an upper limit of 2.6 M€ for this proposal.

EURAMET also expects the EU Contribution to the external funded beneficiaries to not exceed 25 % 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 proposal's 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 transportation 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 Metrology 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.

Timescale

The project should be of up to 3 years duration.

Additional information

The links provided in this section are only correct at the time of publication up until the end of the Call year.

The references below were provided by PRT submitters; proposers should therefore establish the relevance of any references.

[1] EMN for Advanced Manufacturing Orientation Paper on the Call 2025
https://www.metpart.eu/applicants-2025/integrated-metrology-call-2025-s1.html

[2] EMN for Advanced Manufacturing Strategic Research Agenda
https://www.euramet.org/european-metrology-networks/advanced-manufacturing/strategy/strategic-research-agenda