

Title: Standards for high accuracy dimensional references

Abstract

Gauge blocks and spheres are high-accuracy references at the top of the dimensional traceability chain. They can be calibrated to a very small uncertainty but the measurands in the calibration are typically not the same down the traceability chain and in industry. Therefore, this proposal aims to standardise and resolve the measurand mismatch, along with the needed research to make the calibration of the new measurands viable with no loss in accuracy. Furthermore, standardisation action will also define digital twins to interact with those of more complex instruments, so that the digital representation of complex measuring systems including these standards is possible, as well as the prediction of the fine effects of the form error in specific measurements.

Keywords

Gauge block, spherical standard, measurand mismatch, traceability chain, EN ISO 3650, digital twin

Background to the Metrological Challenges

Currently, gauge blocks and spherical standards are among the most accurate dimensional references available on the market. Their elementary shapes parallelepiped and sphere, respectively and optical-grade finish of their measuring surfaces enable high accuracy interferometric calibration. The typical measurands for these standards are the central length l_c (gauge blocks, EN ISO 3650), and the diameter and form error (spherical standards). EN ISO 3650 defines the central length l_c as the distance of the central point of a measuring face to the plane of the other face as materialised by an auxiliary plate of the same material and surface finish on which the gauge block is wrung. This definition has the advantage of including the wringing width, which is clear when piling gauge blocks to meet a predefined length. It is also advantageous in calibration by interferometry, which is typically done by wringing a gauge block to a platen so that both faces of the gauge block can be probed interferometrically from the same side. However, spheres are very difficult to calibrate thus the need for a new spherical standard.

Furthermore, these measurands do not capture the present use and currently there is measurand mismatch between calibration and actual use of gauge blocks and spherical standards raises additional uncertainty. The calibration measurand of gauge blocks is defined in EN ISO 3650 and adapting it to the actual use is not allowed for most calibration laboratories. There is no official guidance on how to bridge these measurand mismatches or how to quantify the additional uncertainty, nor terms and symbology to distinguish between them thus the need for a new ISO standard on spherical standards.

The widespread use of measurands in industry requires a significant improvement of the calibration capabilities. For gauge blocks, conventional unilateral interferometry relying on wrung platens to bilateral interferometry using the opposite measuring faces as mirrors of the two arms. A specific problem is the correction of the significant phase shifts at the reflecting faces, which sum up instead of subtracting to each other as in monodirectional interferometry and therefore, for spherical standards, new interferometric set ups are needed to probe the sphere as a whole. In addition, the traceability in dimensional metrology is but obvious to establish. Standards' and workpieces' shapes and dimensions are virtually infinite and in principle dedicated dimensional instruments are needed for each shape and range. The more versatile and reconfigurable the instrument, the broader the set of measurable standards and workpieces but the more difficult to ensure traceability. CMSs (Coordinated Measuring Systems) are a clear example: they can measure any geometry (in principle) within a range, but the traceability of the measurements they yield is very difficult or impossible to document on a general base. On the other hand, the stricter and more constrained the measurands measurable with an instrument the easier documenting its traceability, ideally with a single calibration. Material

measures are the least flexible measuring instruments as they yield always the same indications or discrete sets of indications hence the need for novel calibration methods.

Moreover, the trend toward digital twins to monitor, simulate and predict the behaviour of the real entities they represent requires them to interact to each other. In the digital representation of a complex measurement, the digital twins of gauge blocks and spherical standards cannot be missing because these standards participate in many dimensional measurements in support to sophisticated instruments such as CMSs and therefore, the need for developing novel calibration methods. To conclude, consultative committee for length – discussion group 1 on gauge blocks has been keeping record over the years of the problems encountered in calibrating gauge blocks and thus the need for a future revision of the ISO 3650.

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 metrology research necessary to support revision and development of written standards by ISO/TC 213, in particular EN ISO 3650:1998 on gauge blocks and a new ISO standard on spherical standards, to improve accuracy of industrial calibrations.

The specific objectives are

1. To investigate and analyse the magnitude of the measurand gap currently in place for gauge blocks and spherical standards between high-end calibration (point-to-plane distance of gauge blocks, derived from few great circles of spherical standards) and widespread use in industry (point-to-point distance and integral sphericity). This includes provision of guidance to industrial users on bridging the measurand gap and evaluating the additional uncertainty incurred in such gap.
2. To develop novel calibration methods and high-end equipment for gauge blocks and spherical standards pursuing measurands matching their widespread use in industry and resulting in reducing or eliminating the existing measurand gap. Target uncertainties should be, at least, similar than the current CMCs (Calibration and Measurement Capabilities) for similar measurands.
3. To develop methods for improved characterisation of the measuring surfaces of gauge blocks and spherical standards to implement traceable 3D digital twins of these standards. This includes, defining a standardisable digital format for representing the form errors of the measuring surfaces in 3D.
4. To contribute to a revision of EN ISO3650:1998 on gauge blocks, and to contribute to the development of a new ISO standard on spherical standards, eliminating the measurand gap by revision of the formal definition of measurands. Outputs should be in a form that can be incorporated into the standards at the earliest opportunity and communicated through variety of media to the standards community and to end users.

The proposed research shall be justified by clear reference to the measurement needs within strategic documents published by the relevant Regulatory body or Standards Developing Organisation or by a letter signed by the convenor of the respective TC/WG. EURAMET encourages proposals that include representatives from industry, regulators and standardisation bodies actively participating in the projects. The proposal must name a “Chief Stakeholder”, not a member of the consortium, but a representative of the user community that will benefit from the proposed work. The “Chief Stakeholder” should write a letter of support explaining how their organisation will make use of the outcomes from the research, be consulted regularly by the consortium during the project to ensure that the planned outcomes are still relevant, and be prepared to report to EURAMET on the benefits they have gained from the project.

Proposers should establish the current state of the art and explain how their proposed research goes beyond this.

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 1.0 M€ and has defined an upper limit of 1.3 M€ for this proposal.

EURAMET also expects the EU Contribution to the external funded beneficiaries to not exceed 30 % 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 manufacturing 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.

These references have been provided by EURAMET.

- [1] *004 ISO TC213 Standardisation of high-accuracy dimensional standards.*
<https://www.metpart.eu/go/need004>