EMPIR Call 2020 – Fundamental, Industry and Normative

Selected Research Topic number: **SRT-i15**
Version: 1.0

Title: Ultra-high precision cylinder and sphere metrology for bearings and piston manometers

Abstract

In industrial manufacturing, most workpieces such as bearing elements and piston-cylinder assemblies (PCA) must be manufactured and measured with low uncertainty. Nevertheless, the existing metrological infrastructure in Europe does not support these measurements. Proposals addressing this SRT should address this by developing ultra-high precision cylinder and sphere metrology for bearings and piston manometers. This new infrastructure should enable the combined measurement of roughness, form and size with ultra-high accuracy for small parts, and high accuracy for large parts. Additionally, datasets generators should be developed, and the acquisition and processing of data should be improved.

Keywords

Dimensional metrology, ultra-high precision cylinder metrology, ultra-high precision sphere metrology, bearing elements, piston manometers, ultra-low uncertainty, ISO 16610 series, datasets generators, transformations algorithms, filtration algorithms

Background to the Metrological Challenges

Bearing elements, PCA and similar simple geometrically shaped workpieces must be manufactured with high precision, but the available measurement infrastructure is not fit for purpose. A significant reduction of uncertainties arising from measurement procedures and evaluation strategies is required. The engineering sector needs new measurement procedures and equipment able to combine surface texture (e.g. roughness), form (e.g. roundness) and size measurements. These requirements were confirmed as ISO/TC 4 (Rolling bearings) and ISO/TC 213 (Dimensional and geometrical product specifications and verification) have expressed the need for further work on pre-processing of roundness testing (influence of probing ball size and eccentricity of turning table axis). ISO/TC 213/WG 15 (GPS extraction and filtration techniques) has provided specifications for a variety of filter algorithms included in the ISO 16610 series (developed by ISO/TC 213), but the algorithms are not specific for form and coordinate metrology.

The state of the art in this field includes form measuring devices and scanning coordinate measuring machines (CMMs) most often collecting data as profiles, which can be averaged and de-noised (e.g. data filtering or average measurements). The achievable measurement uncertainty spans from approximately 10 nm (for roundness measurements) to 100 nm (for parallelism or cylindricity measurements). Nevertheless, these uncertainties should improve so workpieces (e.g. sphere and cylinder) can provide ultra-high precision.

Diameter measuring machines have similar limitations. There are few measuring systems available at NMIs that combine form and diameter measurement and use interferometers as a length scale, which enables direct traceability to the SI metre definition. Additionally, only few systems can achieve uncertainties lower than 50 nm for outer diameters and no system can achieve a similar uncertainty for inner diameters with the present infrastructure.

For the characterisation of the form deviation of cylindrical parts, the decomposition of the waviness into harmonics can be carried out using a digital filter, which requires uniformly sampled data points. However, most modern measurement instruments sample time synchronised and not space synchronised. Therefore, filtration and transformation algorithms are needed that deal with non-uniformly sampled data.

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

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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 ultra-high precision cylinder and sphere metrology for bearings and piston manometers to provide good practice guides on the application of advanced data processing procedures.

The specific objectives are

1. To develop a novel metrological infrastructure to achieve ultra-low uncertainty (U << 50 nm) in combined traceable measurements of (i) roughness, (ii) roundness, (iii) straightness, (iv) cylindricity, (v) parallelism and (vi) diameter of inner and outer cylindrical and (hemi-) spherical objects such as bearing elements and piston-cylinder units with dimensions < 100 mm. This should include the development and validation of measurement models according to the GUM and the evaluation of the measurement.
2. To develop a novel metrological infrastructure to achieve low uncertainty in the traceable measurements of (i) roughness, (ii) roundness (< 10 nm for high precision roundness measurements), (iii) straightness, (iv) cylindricity (< 100 nm), (v) parallelism (< 100 nm) and (vi) diameter of larger scale parts of bearings and similar workpieces (e.g. based on high accuracy CMMs).
3. To improve the acquisition and processing of data obtained in the combined measurements of texture, form and size by generalising the standardised pre-processing methods defined in international standards e.g. ISO 16610 series. This should include the generalisation of filters and recommendations for their tailored use. Easy to read scripts should be developed and made available open access.
4. To develop datasets generators and use these for the validation of procedures used for processing combined roughness and form data, including coordinate transformations and filtration algorithms. Additionally, to assess and validate datasets to be distributed and disseminated as software measurement standards on online platforms.
5. To facilitate the take up of the technology, measurement infrastructure and good practice guides developed in the project by the measurement supply chain (NMIs, accredited laboratories), standards developing organisations (e.g. ISO/TC 213 and ISO/TC 4) and end users (industrial manufacturers).

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.

EURAMET expects the average EU Contribution for the selected JRPs in this TP to be 1.5 M€, and has defined an upper limit of 1.8 M€ for this project.

EURAMET also expects the EU Contribution to the external funded partners to not exceed 30 % of the total EU Contribution across all selected projects in this TP.

Any industrial partners that will receive significant benefit from the results of the proposed project are expected to be unfunded 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,
- Transfer knowledge to the engineering 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 EMPIR 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.