EMPIR Call 2018 – Health, SI Broader Scope, Normative and Research Potential

Selected Research Topic number: **SRT-s08**
Version: 1.0

Title: Ultra-high accuracy cylinder and sphere metrology

Abstract

Cylindrical shaped objects are increasingly common in current industrial manufacturing, but although some high precision instruments exist for their measurement and characterisation, the accuracy and speed of these instruments must be further improved. Proposals addressing this SRT should address this by establishing advanced metrology approaches for the dimensional measurement of cylindrical and (hemi-) spherical objects with worldwide leading measurement uncertainties.

Keywords

Form measurement, size and diameter measurements, ultra-high precision instruments, coordinate measuring machines (CMM), data fusion, Atomic Force Microscopy (AFM), data analysis

Background to the Metrological Challenges

Form measuring devices and 3D instruments such as coordinate measuring machines (CMMs) most often collect data in the form of profiles. These can be averaged and de-noised using different methods, either using filtering during the data acquisition of a single profile, or by measuring the profiles many times to get an average. The achievable measurement uncertainty spans from approximately 10 nm or even less for high precision roundness measurements to some 100 nm and worse for parallelism or cylindricity measurements. Similar limitations are valid for diameter measuring machines. There are no commercially available measuring machines that combine form and diameter measurement and use interferometers as a length scale, which would enable direct traceability to the SI metre definition. Additionally, only a few systems can achieve diameter uncertainties better than approximately 40 nm for outer diameters, and no system exists which has achieved such an uncertainty for inner diameters.

In recent years there was significant progress in high-resolution measurements using tactile probes that are much sharper than tactile form instruments and CMM. The measurement capabilities of Scanning Probe Microscopy (SPM) devices have been extended to the millimetre and centimetre range and there are various approaches for constructing high-speed large area SPMs. The adoption of rotary scanning based methods has the potential to increase the scanning speed of AFMs by a factor of 10, opening up the potential for large area scanning. This technology has not been applied so far for form measurements but would open a new era of high resolution probing based on AFM sensors. The adoption of high speed metrological AFM sensing heads and scanning methods would both extend the technique to higher rotation rates and facilitate traceable metrology of spindle error in stages and bearings.

Existing standards on form metrology (e.g. ISO 12181) determine filter algorithms to separate form from roughness profile components and to improve the achievable uncertainty. Existing filtering algorithms mostly lead to information and high spatial frequency loss, and therefore the profile fine structure is lost. There are many instruments on the market which do not store the raw profile, and which hide the profile treatment process from the user. Many specialised instruments can only acquire form, size or position data and cannot fuse them to a 3D object point cloud without loss of uncertainty. This is especially true when the data stems from different measurement machines or even probing principles – such as form instruments vs. CMM, and tactile vs. non-tactile data. Some high precision applications need data fusion steps after the individual measurements, and this data treatment step is not supported by typical commercial acquisition software. Therefore, suitable software tools are needed to overcome these limitations.

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 cylindrical and (hemi-) spherical objects.

The specific objectives are

1. To develop and validate ultra-low (U = 10 … 50 nm) uncertainty metrology approaches for diameter, roundness, straightness, cylindricity, and parallelism on inner and outer cylindrical and (hemi-) spherical objects with dimensions < 100 mm.
2. To develop form measurement probes based on fast (order of cm/s for Atomic Force Microscopy (AFM) scanning) and/or very high-resolution probing (lateral resolution < 0.1 µm, vertical resolution < 1 nm) systems, such as high-speed Scanning Probe Microscopy systems and fibre interferometry-based probes.
3. To implement software algorithms and tools for analysing and fusing 1D (profiles), 2D (sets of profiles) and general 3D (form and size) data that has been acquired by various probing techniques while using hybrid metrology approaches including uncertainty propagation handling during these data operations. The target uncertainty for the fused data shall be in the range of U < 50 nm.
4. To facilitate the take up of the technology and measurement infrastructure developed in the project by engaging stakeholders (interested in joining comparison measurements), standardisation bodies (CEN/ISO), the measurement supply chain (accredited laboratories, instrument manufacturers) and end users (machine industry).

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 outside Europe 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.

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 IND10 and EMPIR project 15SIB01 and how their proposal will build on those.

EURAMET expects the average EU Contribution for the selected JRPs in this TP to be 1.8 M€, and has defined an upper limit of 2.1 M€ for this project.

EURAMET also expects the EU Contribution to the external funded partners to not exceed 20 % of the total EU Contribution across all selected projects in this TP.

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 different industry manufacturing sectors e.g. automotive, aerospace and energy.

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.