EMPIR Call 2017 – Industry, Fundamental, Normative and Research Potential

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

Title: Multifunctional ultrafast microprobes for on-the-machine measurements

Abstract

Traceable measurements are essential for controlling the use of machined parts in high precision mechanical manufacturing machines due to tool wear. However, this metrology is currently done off-line, which increases the total manufacturing time and existing optical measurement systems are not suitable for in-line measurement of contaminated workpieces. Therefore, a new generation of tactile microprobes is needed for reliable and ultrafast topographical micro-form and roughness measurements, as well as, the potential for measuring mechanical surface properties using force-distance curves.

Keywords

Tactile microprobes, ultrafast microprobes, on-the-machine measurements, force-distance curves, roughness measurement, micro-form measurements

Background to the Metrological Challenges

The use of dimensional metrology on manufacturing machines is necessary for quality control, however most measurements are carried out off-line, and thus require the workpiece to be dismounted and then re-mounted after measurement for further processing. This off-line measurement is time consuming because the workpiece must be positioned in exactly the same place and orientation, therefore in- situ characterisation is urgently needed for high precision mechanical engineering.

Fast optical sensors can be integrated (in situ) into manufacturing lines, but these are not adequate for measuring contaminated surfaces. Contamination of workpieces by oil or lubricants is an issue if the parts to be measured have to be coated, and probes must be able to measure force-distance curves to detect such layers.

Another option is to use, tactile small coordinate measuring sensors, however these are currently not small enough, fast enough or mechanically robust enough to serve as a multifunctional probes on high precision manufacturing machines. Tactile form and roughness measurements are very reliable and are used for in-line quality assurance in precision engineering but the measurement times are usually much higher for tactile probes than for optical areal measurement systems. Conventional tactile probes can also scratch parts which are easily deformed, and therefore tactile microprobes with small probing forces are needed.

Currently, parts manufactured in industry are becoming smaller and thus the accuracy of surface roughness and micro-form measurements is gaining in importance. For precise measurements of the topography and form of micro structures, the influence of the probing tip shape on the measured profile must be corrected according to ISO 17450-1 in order to determine the mechanical surface. In recent years, morphological filter methods have been developed and described for spherical probe tips in ISO 16610-40 and ISO 16610-41, but for non-spherical probe tips, such as pyramid-shaped silicon tips in piezo-resistive microprobes, no morphological filter process currently exists and the standard only defines the circular disk as a structuring element and a horizontal element. Therefore, high speed low tip wear microprobes for simultaneous measurement of micro-form and roughness in industrial conditions are needed. Furthermore, because measuring objects are usually not well aligned on the machine, a large deflection, higher than 200 µm, is needed for the microprobe.

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 multifunctional ultrafast microprobes for integration into manufacturing machines.

The specific objectives are

1. To develop validated methods for the integration of multifunctional ultrafast tactile microprobes into manufacturing machines. This should include the probe-machine interface, compact video microscopes with 5 µm lateral resolution and an interface for guiding the microprobe, and sequence wireless operation.
2. To develop methods for the fast measurement of topographic micro-form, structure and roughness. This should include the i) tip characterisation with a target uncertainty better than 0.05 µm, ii) development of the morphological filtering of the tip influence on measurements and, iii) validation of the measurement methods on-the-machine.
3. To develop new large deflection (> 200 µm), high speed (> 10 mm/s), low tip wear microprobes for simultaneous measurement of micro-form and roughness in industrial conditions. This should include the development of i) pre-deflected cantilevers, actively damped or material-damped cantilevers with thin-film piezoelectric or electro-thermal actuators and single crystal diamond tips with controlled radii of 2 µm and, iii) thin-film strain gauge with on-chip instrumentation amplification.
4. To develop validated methods for the measurement of enhanced surface properties on-the-machine, including methods to measure the adhesion between probe and sample, thickness of liquid films on the sample surface and dynamic methods, in particular contact resonance, for the detection of property changes on the surface of machined parts on-the-machine. These methods should include the acquisition of force-distance curves, which should be used to measure the adhesion between sample and probe with a target resolution of 10 pN, and to detect contaminants through adhesion contrast. In addition, the force-distance curves should be used to measure the elastic modulus of samples in the range 100 MPa – 3 GPa and to characterise the thickness of soft coatings on hard substrates in the range 1 - 200 nm.
5. To facilitate the take up of the technology and measurement infrastructure developed in the project, in particular calibration standards, methods for traceable microprobe measurements on-the-machine by the measurement supply chain e.g. manufacturers of machines, standards developing organisations e.g. ISO/TC 229 and VDI/VDE-GMA Technical Committee 3.41 Surface Measurement Technology in Micro- and Nanometer range, and end users e.g. high precision mechanical engineering, printing and surface foil industries.

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 to the project.

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 precision mechanical 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.