Title: Advanced Computed Tomography for dimensional and surface measurements in industry

Abstract

Computed tomography (CT) has become a powerful tool for the dimensional characterisation of workpieces and their surface texture including inner features. However, metrological aspects, such as traceability, the determination of measurement uncertainty and measurement speed are still insufficient, and this impedes the broad use of industrial CT. Therefore, the development of traceable CT measurement techniques for dimensions and surface textures are required in order to support dimensional metrology in industry.

Keywords

Computed tomography, dimensional measurements, surface texture measurement, traceability, measurement uncertainty, geometry correction, simulations.

Background to the Metrological Challenges

Over the past few years, industrial computed tomography (CT) has been increasingly used for dimensional measurement of both the inner and outer geometry of workpieces, such as cavities and parts in mounted assemblies. CT offers unique advantages for the characterisation of surface properties as it allows non-destructive measurements and it is faster than tactile and more versatile than optical measurements. However, there is a lack of traceability with CT in terms of surface measurements due to unknown geometry errors in the systems, the complex interactions between X-rays and the workpiece and the complex nonlinear data evaluation process.

Currently, most existing CT systems suffer from stage errors and there is a need to improve the corrections of geometry errors by 9 degrees of freedom (DOF). The long scanning time of CT is also an obstacle which prevents the integration of tomography into production lines. There have been several attempts to realise inline CT systems, reducing the measurement time and enabling automated handling of the measured parts. Although advanced data processing algorithms can deliver low-noise images from a small number of projections, the impact of the reduced data on uncertainty of dimensional measurements is unknown. Therefore there are currently only few industrial applications of such CT systems, because the measurement deviations are in the order of tenths of millimetres which are only sufficient for the measurement of unprocessed cast parts.

Attempts to estimate the uncertainty of CT measurements via simulation (virtual CT) were carried out in the EMRP JRP IND59 (Microparts) but the estimation was not precise enough due to the complex determination of the model parameters. Quality parameters based on 2D-data (X-ray projections) and 3D-data (volume data) were also developed to evaluate the quality of CT data. Specific assemblies, such as multi-material, forming artefacts are well-known. However, in order to characterise freeform and sculptured surfaces, simulations and correction methods need to be further developed and improvements regarding robustness, efficient workflow and standardisation are required.

Although many of these issues are being addressed by instrument manufacturers, there is a need to speed up the improvement of traceability and hence to produce more reliable CT measurement results for dimensions and surfaces. In support of this, the German standardisation committee VDI/GMA 3.33 has developed guidelines (VDI/VDE 2630-series) regarding dimensional measurements using industrial CT. An international standard defining acceptance and reverification tests using the CT principle is currently under development by ISO TC213 WG10.

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 development of metrological capacity in Advanced Computed Tomography (CT) for dimensional and surface measurements in industry.

The specific objectives are

1. To develop traceable and validated methods for absolute CT characterisation including the correction of geometry errors by 9 degrees of freedom (DOF). This should include the development of reference standards, traceable calibrations methods and thermal models for instrument geometry correction, as well as the correction of errors originating in the X-ray tube and the detector in order to improve CT accuracy.
2. To develop improved and traceable CT methods for supplementary material characterisation including multi-material effects and measurements of sculptured surfaces, freeform surfaces and roughness.
3. To develop fast CT methods for inline applications based on improved evaluation of noisy, sparse, few, or limited angle X-ray projections, reconstruction methods. This should be done using projections from arbitrary but well known directions and include enhanced post-processing.
4. To develop traceable methods for uncertainty estimation using virtual CT models and Monte-Carlo simulations. This should include calibrated reference standards, the determination of accurate model parameters and the development of correction methods for specific CT image forming artefacts.
5. To facilitate the take up of the technology and measurement infrastructure developed in the project by the measurement supply chain (accredited laboratories, instrumentation manufacturers), standards developing organisations (ISO TC213, VDI-GMA 3.33 Technical Committee Computed Tomography in Dimensional Measurements) and end users (e.g. plastic manufacturers, automotive, telecommunication, medical and pharmaceutical industries and metrology service providers).

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. In particular, proposers should outline the achievements of the EMRP JRP IND59 'Multi-sensor metrology for microparts in innovative industrial products' (Microparts) and the EMPIR JRP 15HLT09 'Metrology for additively manufactured medical implants' (MetAMMI) and how their proposal will build on those.

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 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 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.