European Partnership on Metrology
Call 2023 –Fundamental Metrology, Industry, Normative and Research Potential

Selected Research Topic number: **SRT-n05**
Version: 1.0

Title: Advanced detail sensitivity monitoring by new concepts to improve the reliability of safety relevant products using industrial computed tomography

Abstract

Industrial Computed Tomography (iCT) has become an essential tool for quality assurance in industrial production, particularly in Industry 4.0 applications. However, the detail detection sensitivity of these iCT systems currently has to be evaluated by human operators using objects with artificial or natural flaws, which is unreliable. To increase the reliability of advanced detail sensitivity monitoring, new traceable test gauges need to be designed and manufactured. Additionally, new advanced evaluation algorithms need to be developed. New standards need to be developed with relevant standard organisations, e.g. CEN, that complement the novel technological advances. Having automated and reliable digital detail sensitivity monitoring will provide much needed metrology for the iCT industry, and developing new, dedicated standards will help to improve the safety of products.

Keywords

Computed Tomography, detail sensitivity, spatial resolution, gauges, Industry 4.0, automated digital evaluation, technical safety,

Background to the Metrological Challenges

Currently, iCT is one of the most powerful inspection technologies for quality assurance in industries, such as investment castings, engine blocks (fuels and electric), electronics, and batteries. This is due to its ability to non-destructively test objects. iCT has been developed from a scientific research technique to a quality assurance method for industrial production from the mm scale up to medium and large investment castings and complex parts, e.g. cars or engines. In additive manufacturing, iCT is also a key method for the quality assurance and evaluation of products in terms of flaw characterisation and dimension measurement.

However, iCT is also one of the most complex testing and measurement technologies and requires operators to undergo extensive training. Its ability to detect small deviations from the design (flaws, defects) depends on many factors such as the correct focal spot size, the selected tube parameters, the mechanical accuracy of the manipulators, magnification, digital detector selection, and detector parameter settings, exposure values, detector pixel corrections, and the selected reconstruction algorithm with its numerical parameters. This makes reliable characterisation of the sensitivity of such a system a challenging task, and currently no standardised, automated methods exist. Therefore, new and validated multi-scale test gauges with standardised designs, materials, and dimensions, new evaluation algorithms, and standard procedures are needed for automated detail sensitivity measurements and monitoring. These need to be accompanied by related software development, in order to adjust and verify the detail sensitivity limit of iCT devices i.e. for flaw detection depending on their size and shape (e.g. pores, shrinkage, cracks, inclusions, and others).

Currently, no standards are available that permit the automated detail sensitivity evaluation and monitoring (contrast sensitivity, spatial resolution, and noise) of iCT systems. Instead, the detail sensitivity of iCT systems is evaluated by human operators using reference quality indicators (RQI), which are users' manufactured parts with artificial or natural flaws, similar to the material and geometry to be evaluated and the flaws to be detected. Thus, the evaluation of iCT images by human operators is currently time consuming and insufficiently accurate. iCT has already been accepted by many industrials as a quality assurance tool, therefore new standards are urgently needed to evaluate the reliability of iCT and ensure the safety of products, this includes automated surveillance of iCT systems in industrial applications.

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 advanced detail sensitivity monitoring in iCT systems for safety assurance procedures.

The specific objectives are

1. To develop accurate and traceable multi-scale gauges with features from a few millimetres down to sub-micrometre size, and (i) associated measurement algorithms, (ii) automated evaluation procedures for evaluation of iCT systems, and (iii) advanced monitoring of the digital detail detection sensitivity. In addition, to develop the aforementioned gauges and algorithms using computer-based modelling (i.e. digital twins) and taking into account radiation processes and a variety of iCT reconstruction algorithms.
2. To manufacture prototypes of the multi-scale gauges from Objective 1, and then verify their use for evaluation procedures in iCT measurements. This should include the determination of detectability limits and an evaluation of the accuracy of these limits. In addition, (i) to determine the optimal manufacturing technology for each of the different feature sizes of the gauges and (ii) to develop advanced evaluation methods based on the analysis of noise and resolution performance (spatial and contrast resolution) for use with the gauges.
3. Using the developments from Objectives 1 and 2, to traceably measure the features of the multi-scale gauges from a few millimetres down to sub-micrometre size. This will include the selection and application of the most suitable metrological method for the characterisation of the multi scale gauges depending on their feature size.
4. To develop freely accessible reference software, based on the algorithms from Objective 1, for the analysis of detectability limits for detail sensitivity for medium- and small-sized defects. In addition, to develop software based on automated digital algorithms, which includes long-term detail sensitivity evaluation, for quality assurance in iCT. Then to validate the developments from Objectives 1-4 in Round Robin tests.
5. To contribute to the standards development work of the technical committees CEN/TC138/WG1 (Ionising radiation testing) and ISO/TC135/SC5 and SC7 to ensure that the outputs of the project are aligned with their needs, communicated quickly to those developing the standards and to those who will use them, and in a form that can be incorporated into the standards at the earliest opportunity.

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. In particular, proposers should outline the achievements of the EMPIR projects 17IND08 AdvanCT and 18NRM07 NanoXSpot and how their proposal will build on those.

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 project.

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 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,
- 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 industry 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 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.

Time-scale

The project should be of up to 3 years duration.

Additional information

The references were provided by PRT submitters; proposers should therefore establish the relevance of any references.

[1] 001_CEN TC138 Digital sensitivity monitoring industrial computed tomography

http://www.metpart.eu/nrm-call-2023