EMPIR Call 2020 – Fundamental, Industry and Normative

Selected Research Topic number: **SRT-i16**
Version: 1.0

Title: Probabilistic evaluation of the ability to perform dimensional measurements of buried structures in industrial additively manufactured parts

Abstract

The additive manufacturing (AM) market is predicted to grow by 23 % with a value of 23 billion euros by 2030. A growing number of industrial sectors (e.g. aerospace, automotive and medical) are considering AM to improve their production capabilities. AM enables the production of components with complex geometries, both internal and external. However, the resulting geometrical complexity poses a challenge to quality control. To inspect the parts' geometry and dimensional accuracy and check for internal flaws without damage, volumetric non-destructive evaluation (NDE) methods are required. Two promising methods are X-ray computed tomography (XCT) and resonant ultrasound spectroscopy (RUS). However, the probability of cavity detection, accurate sizing and associated uncertainties of the internal features of the parts using these methods have not been assessed. The goal of this project is to fill this knowledge gap, increasing confidence in the AM technology in industry as well as in the certified bodies.

Keywords

Additive manufacturing (AM), non-destructive testing (NDT), non-destructive evaluation (NDE), X-ray computed tomography (XCT), resonant ultrasound spectroscopy (RUS) methods, reliability of NDT or NDE, probability of sizing (PoS), measurement uncertainty.

Background to the Metrological Challenges

The additive manufacturing market is predicted to grow by 23% with a value of 23 billion euros by 2030. A growing number of industrial sectors (e.g. aerospace, automotive and medical) are considering AM to improve their production capabilities. AM enables the fabrication of very complex shapes and inner cavities that cannot be manufactured with conventional techniques. However, AM has been shown to produce specific types of defects in the 'as-built' parts. Industry needs certified procedures and accredited quality processes before their products can be used in safety-critical areas. Stringent, non-destructive, volumetric and insensitive to surface conditions methods are required, especially for internal features. The probabilistic evaluation of the testing method is essential to ensure the reliability of the components and products and hence allow AM part producer to provide evidence to the original equipment manufacturer (OEM) of their capabilities.

Currently, XCT is the most suitable method due to its high spatial resolution. However, alternative methods are required as XCT has practical limitations (size and material density of the part), is both expensive and time-consuming and the size of the XCT chamber is not suited for routine inspection. Previous investigations have demonstrated that RUS methods are the most efficient alternatives for complex shape AM parts. Furthermore, even though these are global methods, which can only detect the quantity of defects in the parts, but not locate them, they do offer several other advantages (e.g. fast, simple to use for routine inspection as well as no restrictions on size, shape and roughness of the parts).

ISO/IEC 17025, the main ISO standard used by testing and calibration laboratories, demands a new way of evaluating systems like XCT and RUS and combining the probabilistic view on the results with the probabilistic structural integrity could offer such an alternative. The probabilistic evaluation of XCT and RUS methods involves different kinds of influencing parameters. The results of the analysis are typically expressed in the probability of detection (PoD) and probability of sizing (PoS) and represent a well-established means to evaluate the capability of non-destructive testing (NDT) systems, especially in safety relevant industries in order to guarantee the reliability of AM parts for critical applications.

Two previous EMPIR projects, 15HLT09 MetAMMI and 17IND08 AdvanCT, have investigated several NDT methods (e.g. CT) for device characterisation in the AM process chain however neither of them addressed the PoD and PoS of these methods.

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 buried structures in industrial additively manufactured parts.

The specific objectives are

1. To establish the limits of the XCT and RUS methods for the detection and dimensional measurements (including associated uncertainties) of buried structures in industrial AM parts.
2. To develop an accurate reliability model to evaluate the probability of detection (PoD) of the XCT method compared to the RUS method for buried structures (e.g. flaws and internal channels) in industrial AM parts.
3. To develop a model to evaluate the probability of identification and characterisation (PoI) of flaws in industrial AM parts. In addition, a procedure for differentiating planned structures like cooling channels and fixtures from undesired structures (e.g. cavities) will be developed.
4. To develop models for traceability and uncertainty estimation of the probability of sizing (PoS) of buried structures (e.g. such as flaws and internal channels) in industrial AM parts. In addition, a procedure to obtain traceable and valid results in the metrological application of XCT and RUS systems will be developed.
5. To facilitate the take up of the technology and measurement infrastructure developed in the project by the measurement supply chain (NMIs, DIs, accredited laboratories), standards developing organisations (ISO TC 261) and end users (aerospace, medical and automotive industry).

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 EMPIR projects 15HLT09 MetAMMI and 17IND08 AdvanCT and how their proposal will build on those.

In addition, proposers should interact with EMPIR project 19NET01 AdvManuNet during the development of their proposal and this should be reflected in the proposal.

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 aerospace, automotive and medical sectors.

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.