Uncertainty in dimensional X-ray computed tomography

Chair: Richard Leach, University of Nottingham

X-ray computed tomography (XCT) has a number of benefits over traditional contact and optical techniques for coordinate metrology; not least because it allows one to peer inside the object being measured. But how do we know we are getting the right answers? As yet, there is no commonly adopted performance verification or calibration infrastructure in place for XCT, so the sceptic's to the question is: we don't. Specification standards for performance verification are being drafted in ISO 213, which make an attempt to map onto the standards developed for contact and optical methods, but is this really the most effective way to go? To achieve traceable measurements with contact coordinate measuring systems, complex kinematic models of the system are combined with Monte-Carlo simulations to estimate measurement uncertainties for a given object. There is as yet no equivalent for optical instruments, and XCT instruments are even further behind. Whilst there have been valiant attempts to produce such so-called "virtual instruments" for XCT, the complex physics of X-ray-matter interactions means that there is still a long way to go. At this workshop, experts in the field will review the many aspects and approaches to uncertainty estimation for XCT.

0900 – 0910 Chairman's introduction

0910 – 0930 CT Metrology verification: The drive to ISO 10360-11

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With the growth of additive manufacturing, there is a major need for CT metrology for structures not accessible by traditional methods. At present, there are no international standards for this. A first step is a verification standard as part of the ISO 10360 series. In this talk, the nature of verification will be discussed. After that, the talk will delve into some of the major technical challenges that have been addressed such as material influence, reference standard design and measurands to test. Finally, the latest status of the ISO 10360 part 11 draft and the timeline for issuing the verification standard will be discussed

0930 – 0950 Determination of measurement uncertainty in the EMPIR Project "AdvanCT"

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Important topics of the current EMPIR project "Advanced Computed Tomography for dimensional and surface measurements in industry (AdvanCT)" are increased accuracy, advanced CT methods, fast CT and traceability. To achieve traceable CT measurement results, the determination of the measurement uncertainty is investigated. The procedure to determine the measurement uncertainty is based on simulations combined with Monte Carlo methods supported by CT scans of reference standards. For the simulations, accurate model parameters of CT systems are being determined. Software tools to automate the Monte-Carlo calculations will be developed.

0950 – 1010 Uncertainty for XCT dimensional measurements using GUM approach

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There are several methods for determining the measurement uncertainty of XCT-measurements. One of the methods is determining the uncertainty contributions of the measurement geometry, imaging and data analysis to the measurement results. This requires traceable measurements of the detector geometry, sample positioning and the focal spot position and shape. The sample positioning can be directly measured whereas indirect characterisation using artefacts is needed for detector, focal spot and data analysis. The estimated uncertainty budget allows XCT measurements with a geometry that minimises measurement uncertainty. The GUM uncertainty approach also includes experimentally acquired estimates for input parameters.

1010 – 1030 Uncertainty in dimensional X-ray computed tomography using the substitution method

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The substitution method, known also as the comparator method, is so far the only confident method for uncertainty calculation in dimensional X-ray computed tomography (CT) measurements. ISO 15530 part 3 describes the substitution approach for uncertainty evaluation of tactile coordinate measuring machines, however, it has been adapted for calculation of CT measurements uncertainty. This talk will review the state of the art of the evolving scene discussing advantages and disadvantages of the method also considering the challenges that arise when applying it in industry. In fact, the modelling of CT measurements is still incomplete due to several unknown factors, such as geometry errors in the system and complex data evaluation and image artefacts created by the interaction X-rays and workpiece.

1030 – 1050 Coffee break

1050 – 1110 Road to uncertainty – how virtual CT models could evaluate task specific measurement uncertainties

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Computed tomography (CT) is regularly used in industrial applications for non-destructive testing. Due to the complexity of the measurement process, analytical approaches to evaluate task specific uncertainties are currently infeasible. Available methods as described in the VDI/VDE standard 2630 Part 2.1 do not meet the criteria of scalability and cost efficiency. Therefore alternatives, such as the Monte Carlo based approach described in the GUM Supplement 1, are promising to evaluate task specific uncertainties even on an industrial scale. The talk will present a basic framework for this approach and provide an inside view of the current research in this field.

1110 – 1130 Uncertainty in X-ray computed tomography using metrological characteristics

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In the surface topography measuring world, there is a calibration framework being standardised that relies on so-called “metrological characteristics” that are designed to quantify the various influence factors that affect the uncertainty in a measurement carried out with a surface topography instrument. These characteristics include familiar concepts such as scale linearity and amplification coefficient for the height response of an instrument. Once in place, users determine the various metrological characteristics with a set of calibration artefacts, then use the resulting values along with an appropriate measurement model to estimate measurement uncertainty. This framework is not perfect – there are some technical issues that mean it only applies with a limited range of surface types, although there is on-going research to address the remaining issues. In this talk, we will discuss the background to calibration in coordinate metrology and ask the question: can we define a calibration framework for XCT based on a defined set of metrological characteristics?

1130 – 1150 Towards primary dimensional X-ray computed tomography

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To establish traceability in dimensional computed tomography (CT), an unbroken chain to the metre definition is required. Such traceability can be achieved with or without intermediate reference objects. If a CT measurement procedure does not rely on a length measurement standard, it would be considered primary. METAS-CT with its interferometric geometry measurement system is an attempt in this direction. We will discuss the influence of intrinsic error sources, i.e. workpiece independent contributions including CT geometry, X-ray focal spot drift, flat-panel detector distortions and temperature stabilisation, on dimensional measurements.

1150 – 1210 Review of reference samples for tomographic measurements

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Dimensional measurements using X-ray computed tomography (XCT) have become an important research field due to advantages of XCT in measuring non-line-of-sight surfaces and features. To establish confidence in the measurements of complex parts using XCT, reference samples for calibration and verification purposes have been developed in the last decade. This talk is an overview of the existing reference samples and the latest development in the EMPIR AdvanCT project. Philosophy behind the design will be elaborated and test results will be discussed.