Multiple measurements approach for the uncertainty determination of X-ray computed tomography dimensional measurements

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CIRP WINTER MEETINGS in PARIS

19-21 February 2020

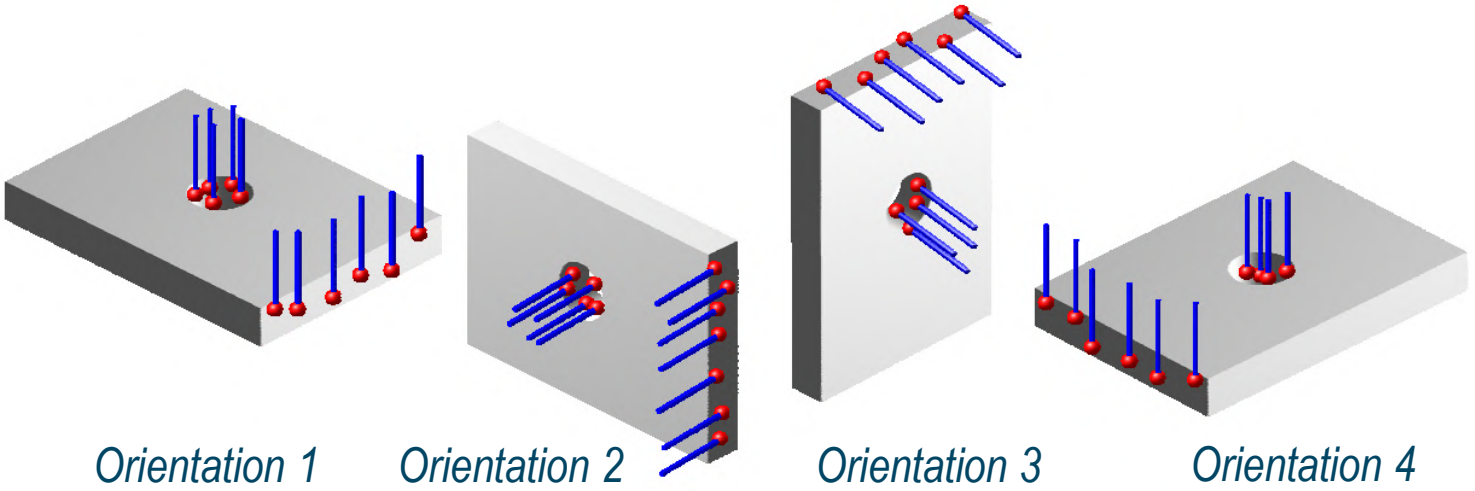
Multiple measurements strategies

- The approach was previously proposed for tactile coordinate measuring machines (CMMs) *(Trapet E, Savio E, De Chiffre L; **CIRP Annals** 2004)*
- Currently under refinement within the European project **EUCoM** (*Evaluating Uncertainty in Coordinate Measurement*)

http://eucom-empir.eu/

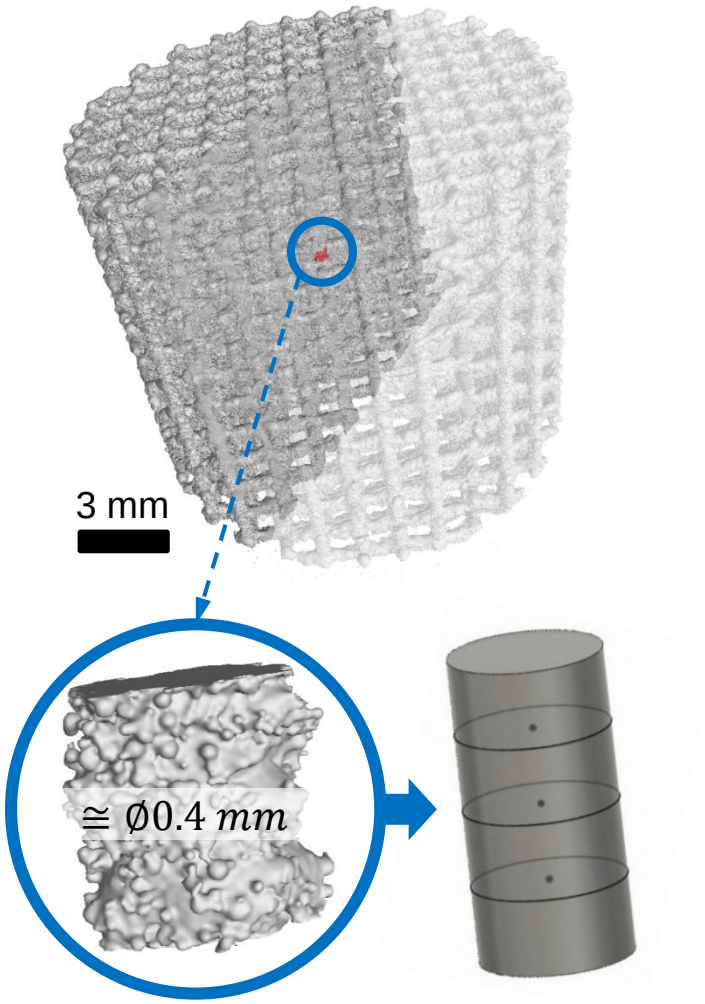
EUCoM
Evaluating Uncertainty in Coordinate Measurement

- **Principle**: repeated measurements varying the sample orientation to randomize the systematic errors so that an averaging and an evaluation of uncertainty based on the variance of results can be applied.
- **Main advantage**: calibrated samples (that can be difficult and/or expensive to manufacture and/or calibrate) similar to the objects to be measured are not needed



Multiple measurements approach: case study

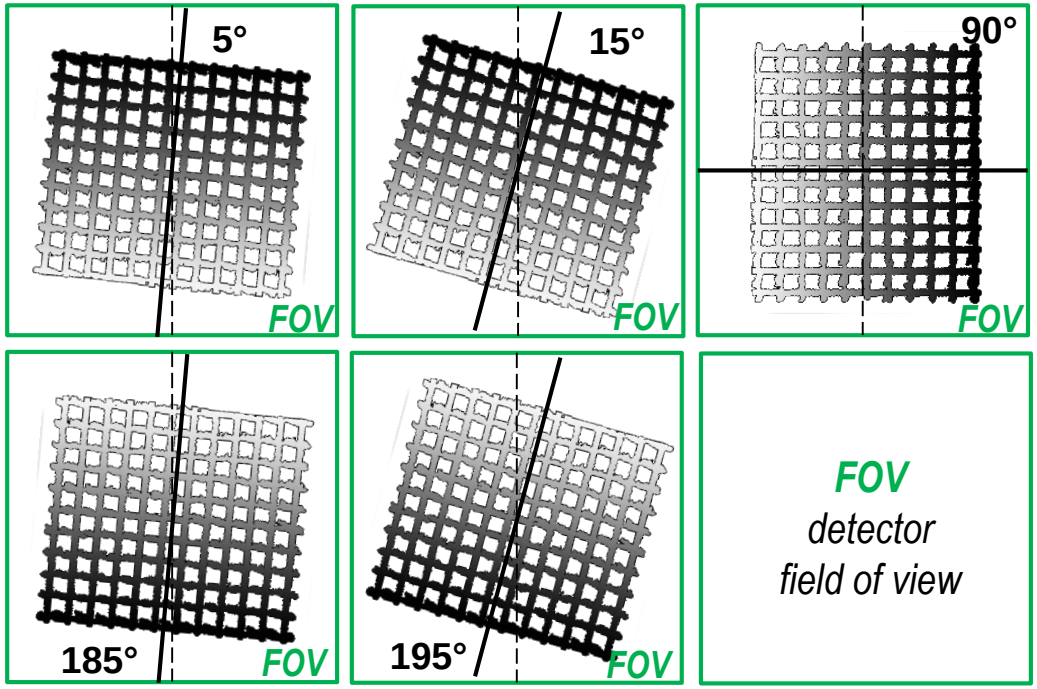
CT reconstruction of AM lattice structure



Example of non-accessible feature

Measurands (circles, cylinders)

❑ *Repeated measurements at 5 orientations*

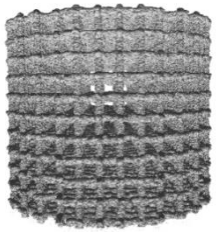


❑ *Additional tests*

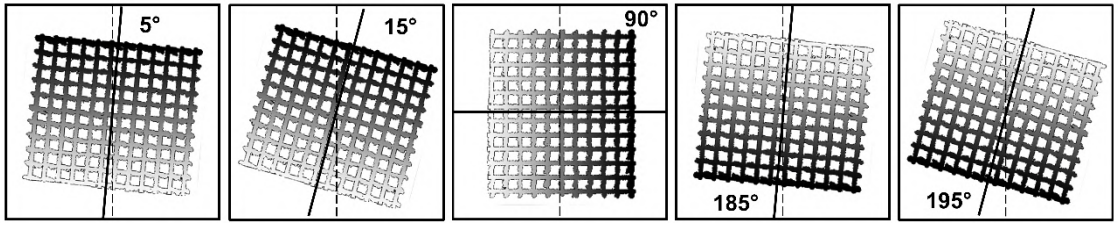
- Form & length standards (not required to be similar to lattice structure)
- Evaluation/correction of *scale error* and *probing error of size*

Multiple measurements approach: case study

1. Multiple measurement approach *(measurement uncertainty of lattice structure)*

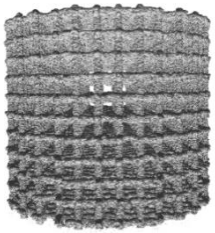


Lattice structure

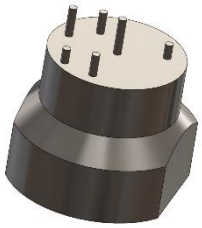


+ scan of form & length standards

2. Substitution approach *VDI/VDE 2630-2.1 (measurement uncertainty of lattice structure)*



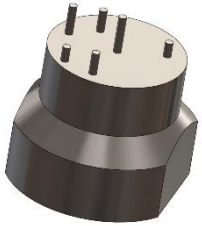
Lattice structure



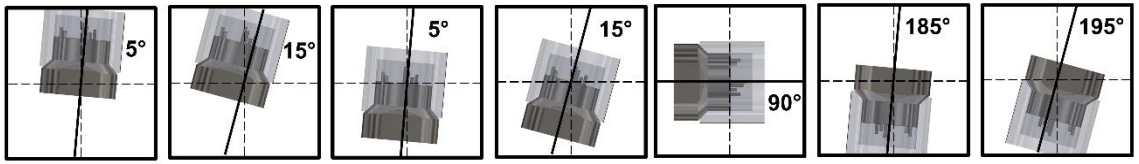
Calibrated object

Repeated measurements
Single position/orientation

3. Multiple measurement approach *(validation using the calibrated object)*



Calibrated object



+ scan of form & length standards

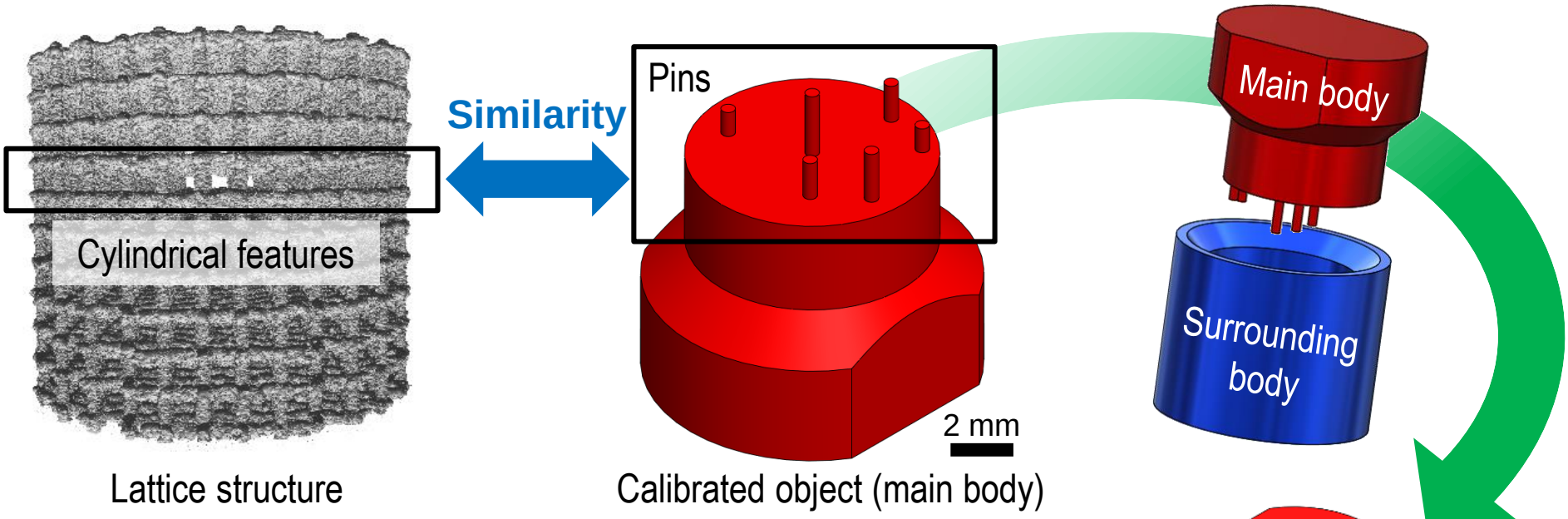
Comparison

Validation

Multiple measurements approach: case study

Substitution approach

(VDI/VDE 2630-2.1:2015)



Similarity between ref. object and lattice structures

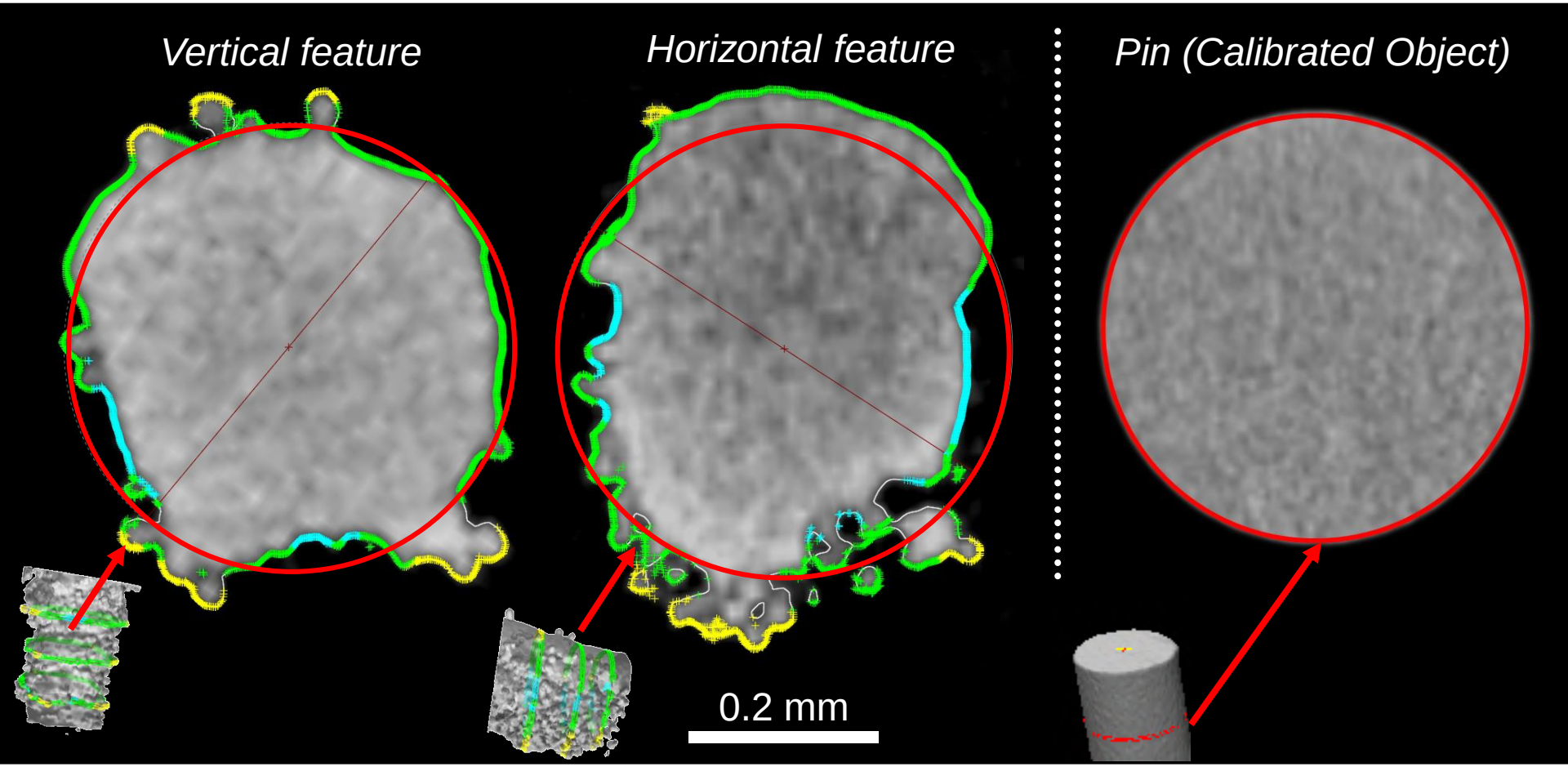
- Material (Ti6Al4V)
- Geometry (pins – cylindrical features)
- Dimensions (ø0.4 mm; h = [0.8, 2.0] mm)
- Non-accessible features (in assembly state)

Multiple measurements approach: case study

Substitution approach

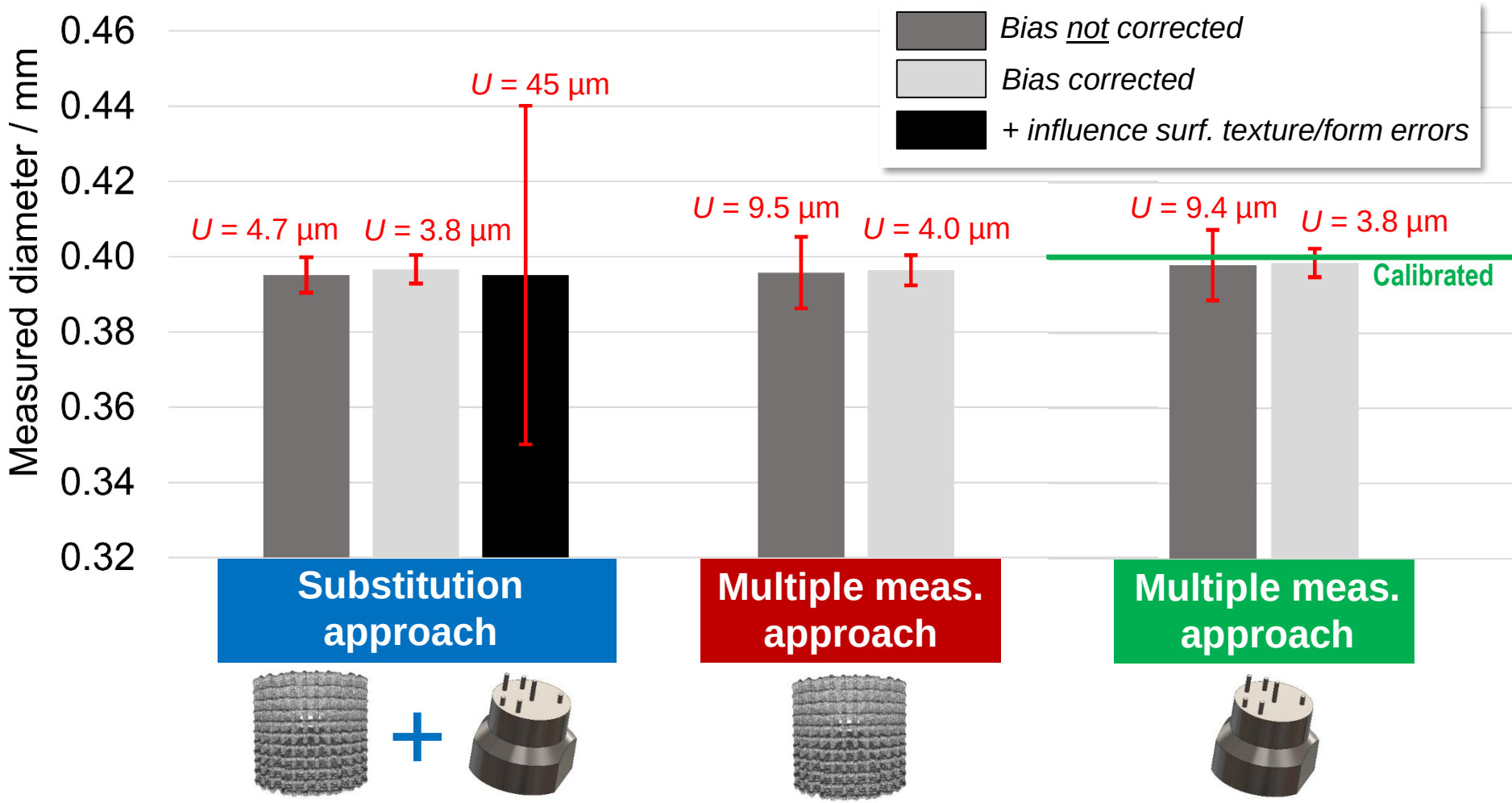
Influence of form errors and surface texture

→ *to be taken into account in the uncertainty*



Comparison of approaches

CT measurement of lattice structure: diameters (nominal 0.4 mm) of horizontal features

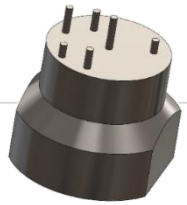


U = expanded uncertainty (95 % confidence interval)

Multiple measurement approach
applied to the calibrated object

$$E_N = \frac{|X_{CT} - X_{cal}|}{\sqrt{U_{CT}{}^2 + U_{cal}{}^2}} *$$

Bias not corrected
Bias corrected



*ISO/IEC 17043:2010, Conformity assessment — general requirements for proficiency testing, ISO, Geneva.

Open issues and future works

❑ Comparison of approaches

Bias not corrected	Bias corrected
$U_{multiple\ meas} > U_{substitution}$	$U_{substitution} \cong U_{multiple\ meas}$
+ contribution of surface texture and form errors (only substitution app.)	
$U_{substitution} \gg U_{multiple\ meas}$	

- ✓ **Main advantage of multiple measurement approach**: it does not require the use of calibrated samples similar to the measured objects
- ✓ **Further investigations are needed** to better understand if the multiple measurement approach gives sufficient weight to the effect of form errors and surface texture.

❑ Multiple measurements approach applied on the reference object

- ✓ E_N < 1 for all the investigated measurands
- ✓ Increase of E_N when the bias is corrected → **further investigations are needed**

❑ Choice of multiple orientations might be difficult

- ✓ It depends on the specific sample geometry and dimensions

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Thank you for your attention

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