ACADEMIA NDT INTERNATIONAL

Science, Technology and Diagnostics in Non-Destructive Testing

LNE activities on additive manufacturing (AM) and NDT methods

Dr/Habil. Anne-Françoise Obaton
Researcher in metrology for Additive Manufacturing (AM)
National Metrology Institute (NMI) in France
Laboratoire national de métrologie et d’essais (LNE)
anne-francoise.obaton@lne.fr

LABORATOIRE NATIONAL DE MÉTROLOGIE ET D’ESSAIS LNE

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Science, Technology and Diagnostics in Non-Destructive Testing

1. Joint group JG59 “NDT for AM parts” of the ISO-TC261/ASTMF42 standardization group on AM
2. Part designed and additively manufactured to investigate NDT methods especially for AM
3. Investigated NDT methods for AM
4. Focus on studies performed with XCT methods
5. Focus on studies performed with resonant ultrasound spectroscopy (RUS) methods
6. LNE projects

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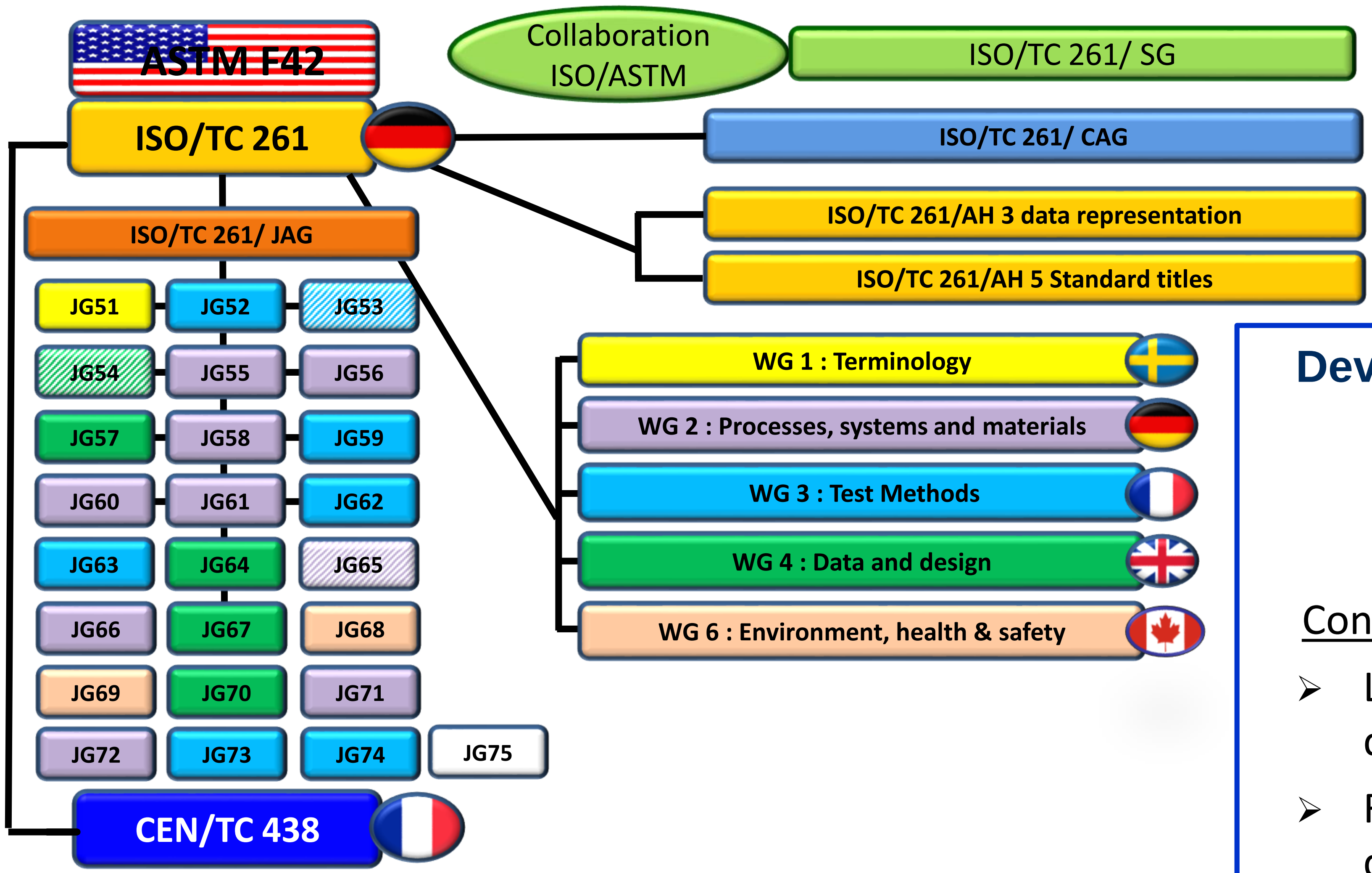
ISO-TC261/ASTM-F42 standardization group on AM



JG59 NDT for additively manufactured parts

Convenor:
Ben Dutton-MTC, UK

Developing a guide which provide advices to users to inspect their AM metallic parts with post-process NDT methods.

<u>Content of the guide:</u>

- List of typical AM defects in power bed fusion (PBF) and direct energy deposition (DED) process categories
- Recommendations of post-process NDT methods dedicated to AM parts

<u>Means to reach the goal</u>:

- Design and fabrication of test artefacts with typical AM defects
- Evaluation of NDT methods with these artefacts

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JG59 star artefacts with typical AM defects

AM only type of defects ranging from 100 µm to 800 µm:

1. Cross layer defects (vertical cylinders of different diameters but same length. Connected by small link for releasing powder at the largest diameter cylinder);
2. Layer defects (horizontal cylinders of different diameters but same length. Open end to release powder);
3. Unconsolidated/trapped powder (spheres of different diameters, cylinders in various orientation);

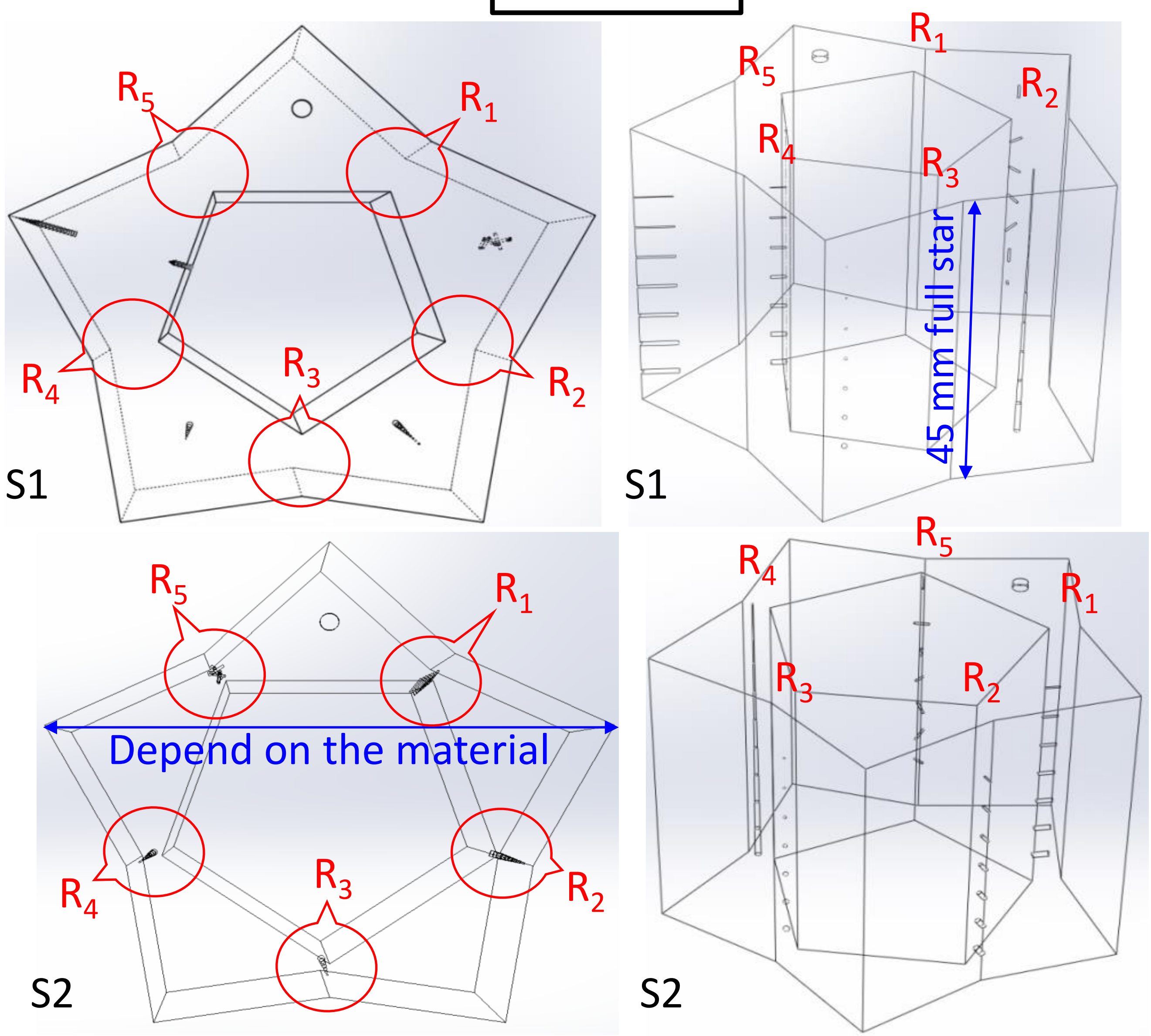
(voids and porosities have shown relative coverage by current NDT standards)

Defect location into critical areas:

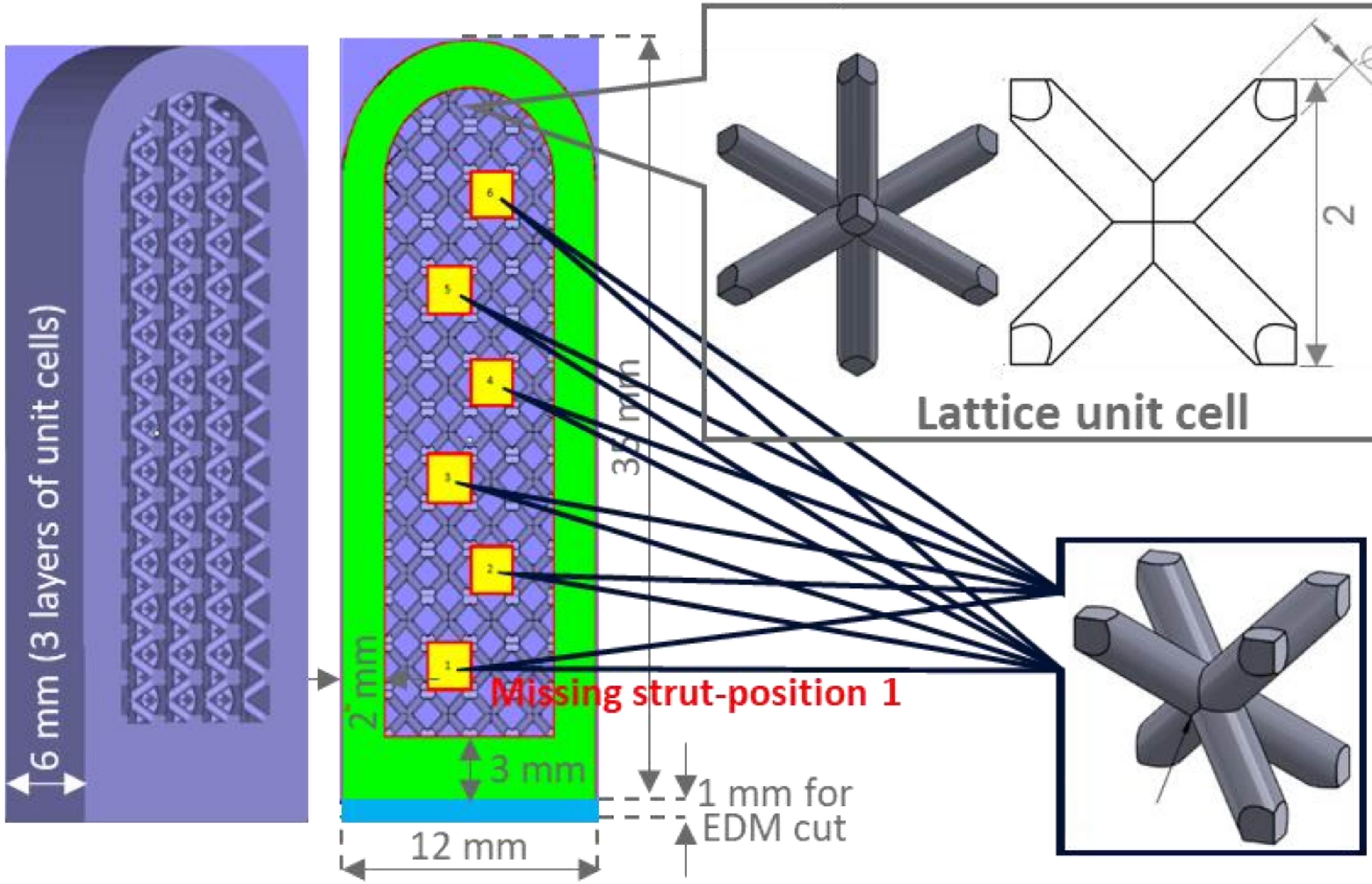
1. Critical locations;
2. Deep sections;
3. Hard to reach areas;
4. Close to surface.

ISO/TC261-ASTM/F42

2 designs



Lattices with different number of missing struts

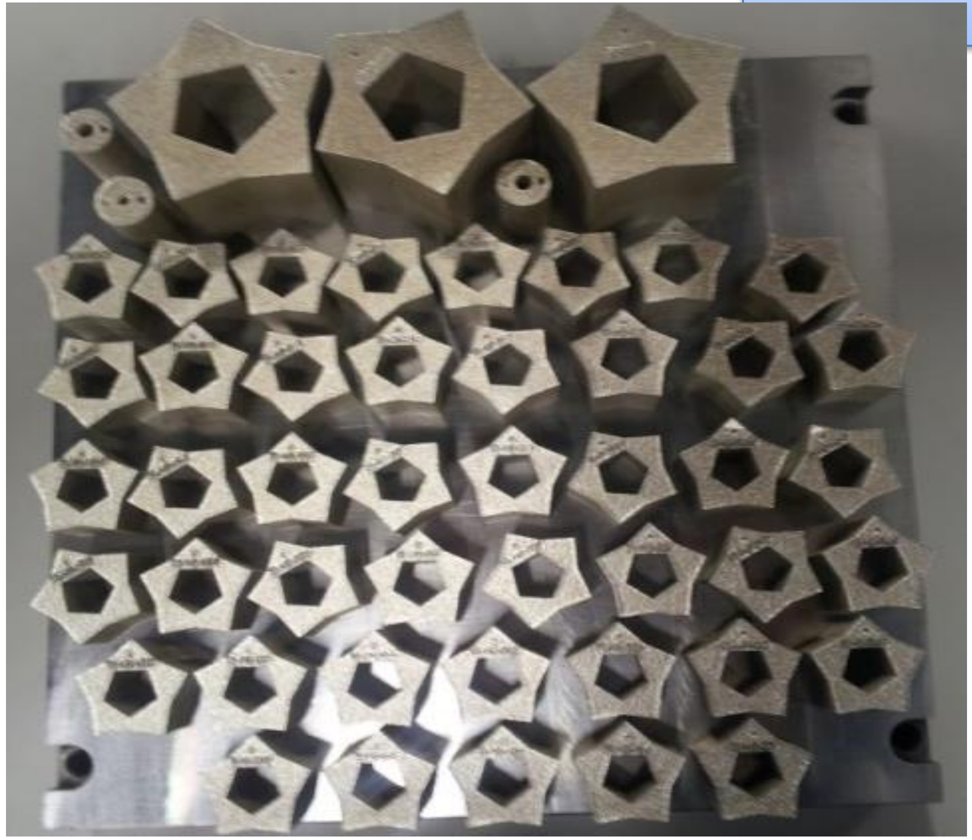


1 out defect	2 out defect	4 out defect	6 out defect	8 out defect	10 out defect	12 out defect	1 inner defect	2 inner defect	4 inner defect	6 inner defect
101	106	111	116	120	130	140	150	160	170	180
102	107	112	117	121	131	141	151	161	171	181
103	108	113	118	122	132	142	152	162	172	182
104	109	114	119	123	133	143	153	163	173	183
105	110	115	210	124	134	144	154	164	174	184
205	195	190	200	185	175	165	125	135	145	155
206	196	191	201	186	176	166	126	136	146	156
207	197	192	202	187	177	167	127	137	147	157
208	198	193	203	188	178	168	128	138	148	158
209	199	194	204	189	179	169	129	139	149	159

A-F Obaton was a guest researcher at NIST (Gaithersburg) from Nov. 2017 until Nov. 2018 and in August 2019.

A-F. Obaton, Y. Wang, B. Butsch, Q. A Huang, "Non-Destructive Resonant Acoustic Testing and Defect Classification of Additively Manufactured Lattice Structures", Weld World, **65**, 361–371, 2021, https://doi.org/10.1007/s40194-020-01034-7.

Fabrication of AM parts with simulated defects to investigate NDT methods



94 star artefacts in stainless steel from 2 different builds:

<u>88 half sizes</u> (h=22.5 mm, a=30 mm):

- 20+20 without defect
- 20+20 S2 design with different numbers of defects
- 4+4 S1 design with different numbers of defects

<u>6 full sizes</u> (h=45 mm, a=60 mm):

- 2+2 S2 design
- 1+1 S1 design

Laser powder bed fusion process

EOS default parameters used		
Parameters/material	CoCr	SS
Laser power (W)	290	220.1
Laser speed (mm/s)	950	755.5
Hatch spacing (mm)	0.11	0.11
Layer thickness (µm)	40	40

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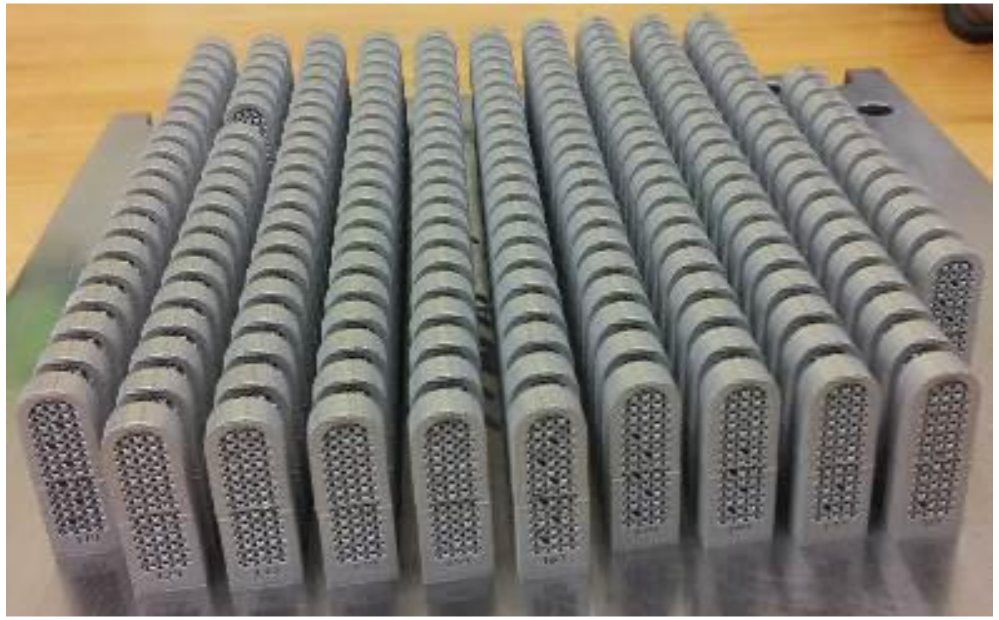

210 lattice structures in CoCr:

- 100 lattice structures without missing strut
- 110 lattice structures with different inner and outer missing struts

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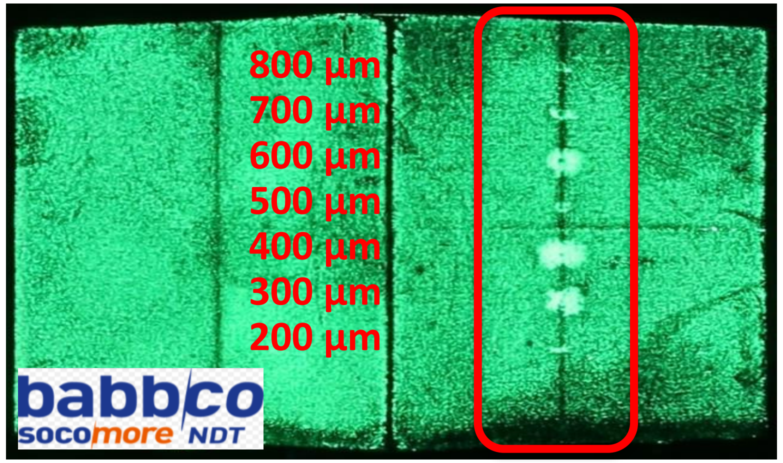
Investigated NDT methods for Additive Manufacturing (AM)

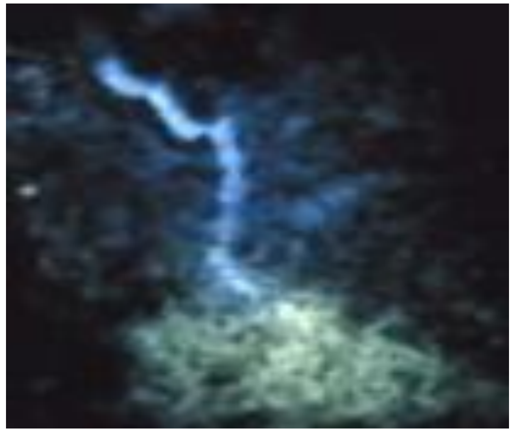
1. Penetrant testing
2. Infrared thermography
3. Eddy current
4. Conventional ultrasound testing (CUT)
5. Phased array ultrasound testing (PAUT)-Plane wave imaging (PWI)/Total focusing method (TFM)
6. Archimedes' method and gas pycnometry
7. Film (RT) and computed (CR) radiography
8. Terahertz spectrometry
9. Terahertz tomography (THz-CT)
10. Microwave tomography
11. X-ray computed tomography (XCT)
12. Resonant ultrasound spectroscopy methods (RUS)

Investigated surface NDT methods for Additive Manufacturing (AM)

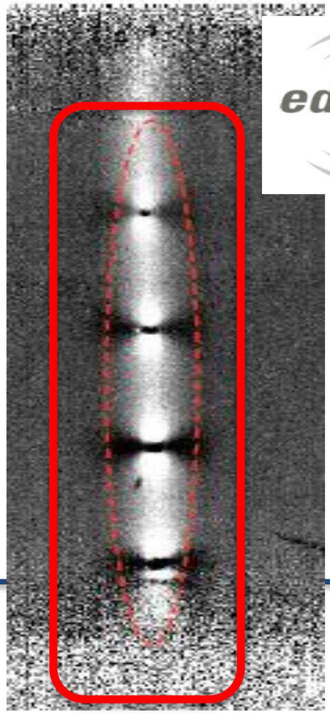
Penetrant testing



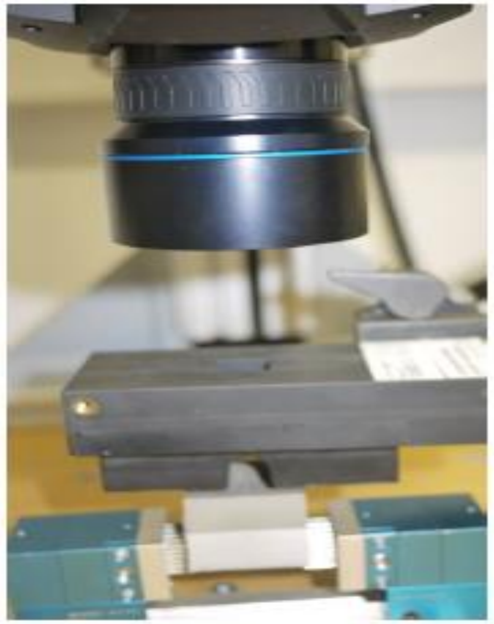
babbco socomore NDT



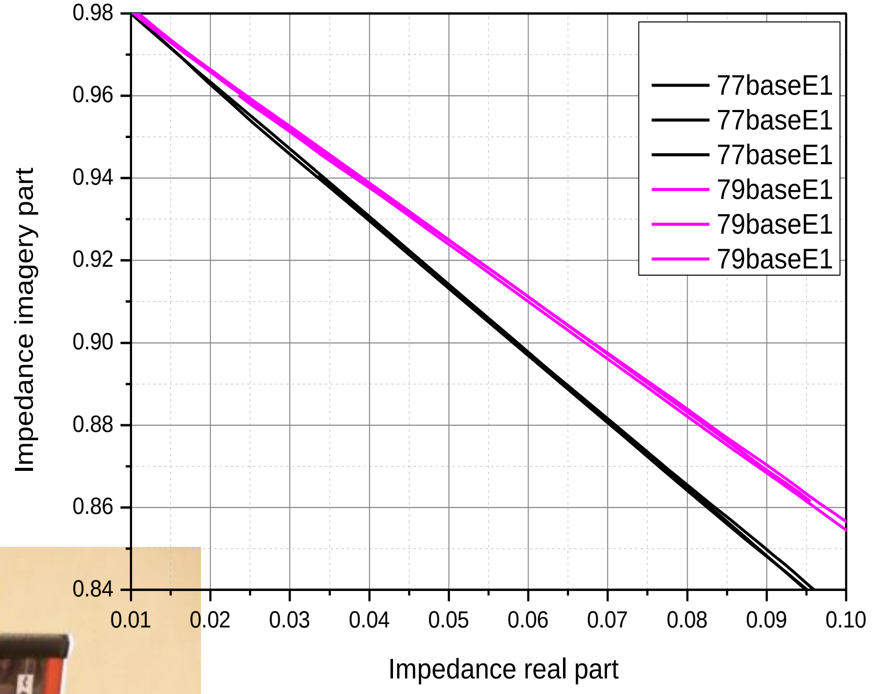
IR thermography

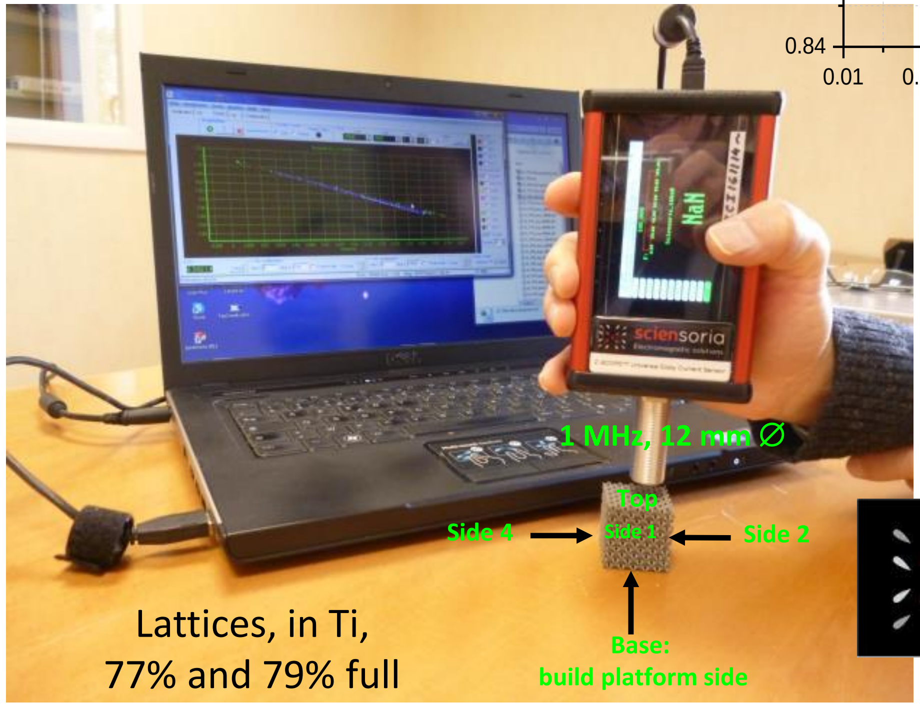


edevis active thermog



Eddy current



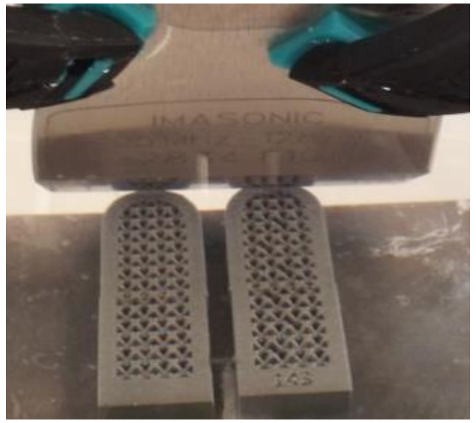


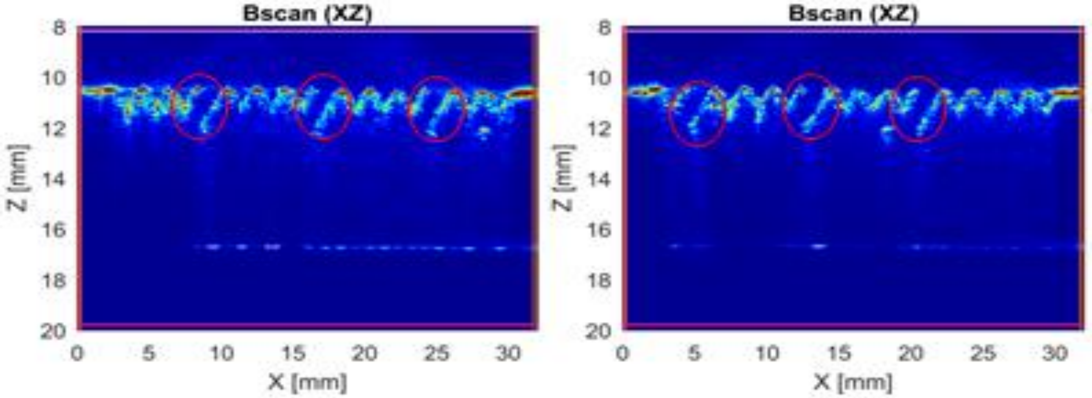
- EC enables to differentiate 2 specimens with different lattice sizes on the surface

sciensoria Electromagnetic solutions

AF. Obaton, M-Q. Lê, V. Prezza, D. Marlot, P. Delvart, A. Huskic, S. Senck, E. Mahé , C. Cayron., 'Investigation of new volumetric non-destructive techniques to characterise additive manufacturing parts', *Weld World*, vol. 62, no. 5, pp. 1049–1057, Sep. 2018, doi: 10.1007/s40194-018-0593-7.

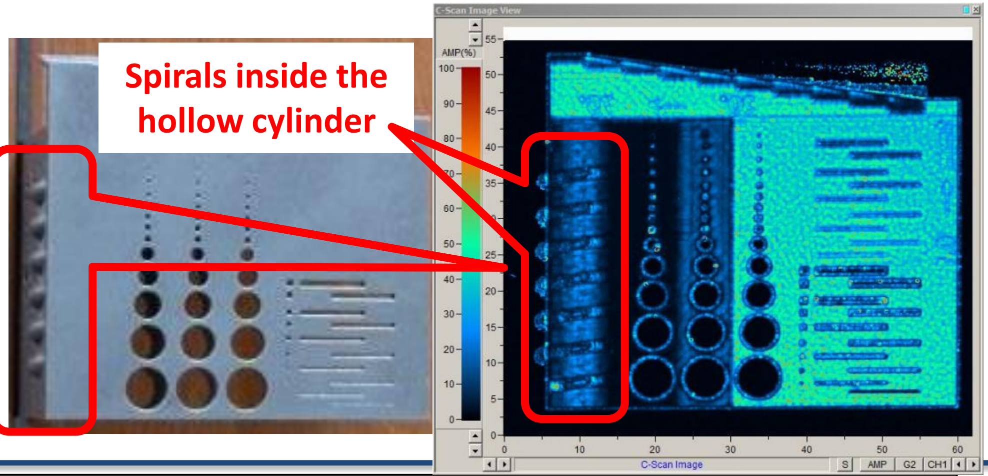
Investigated volumetric NDT methods for AM





Conventional ultrasonic testing

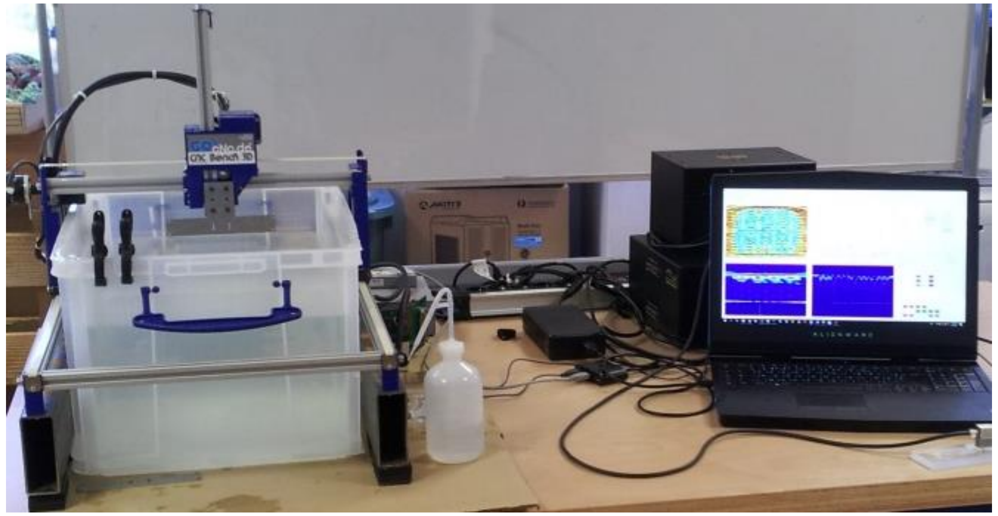
MISTRAS GROUP, S A
EUROSONIC Products & Systems UT Division

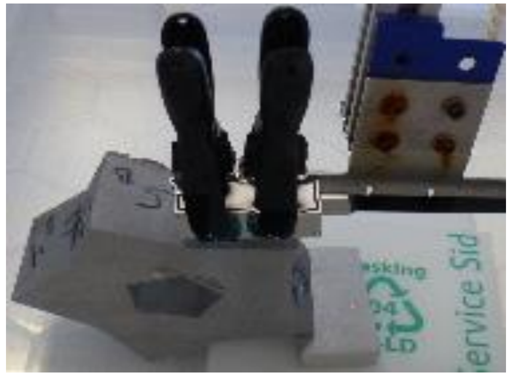


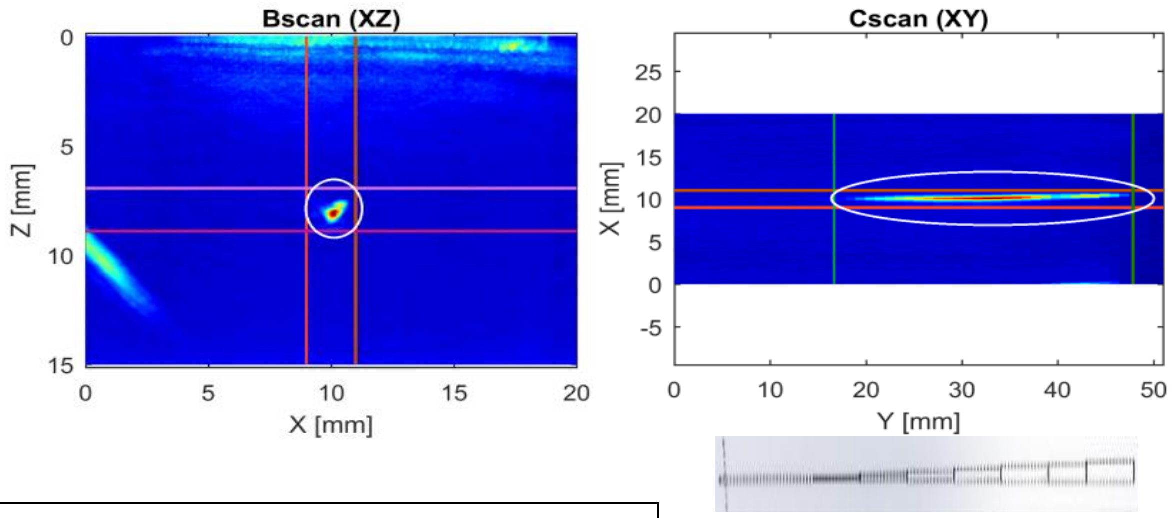
AF. Obaton, M-Q. Lê, V. Prezza, D. Marlot, P. Delvart, A. Huskic, S. Senck, E. Mahé , C. Cayron., 'Investigation of new volumetric non-destructive techniques to characterise additive manufacturing parts', *Weld World*, vol. 62, no. 5, pp. 1049–1057, Sep. 2018, doi: 10.1007/s40194-018-0593-7.

Phased array ultrasound testing (PAUT)- Plane wave imaging (PWI) Total focusing method (TFM)

TPAC The Phased Array Company







AF. Obaton, B. Butsch, S. McDonough, E. Carcreff, N. Laroche, Y. Gaillard, J. B. Tarr, P. Bouvet, R. Cruz, and A. Donmez, "Evaluation of Nondestructive Volumetric Testing Methods for Additively Manufactured Parts," in Structural Integrity of Additive Manufactured Parts, ed. N. Shamsaei, S. Daniewicz, N. Hrabe, S. Beretta, J. Waller, and M. Seifi (West Conshohocken, PA: ASTM International, 2020), 51–91. http://doi.org/10.1520/STP1620201800997, vol. 62, no. 5, pp. 1049–1057, Sep. 2018, doi: 10.1007/s40194-018-0593-7.

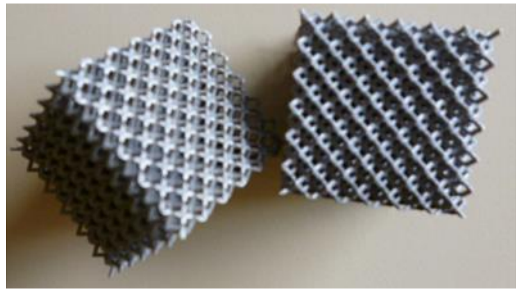
∅150, 100, 200,…700, L5 mm

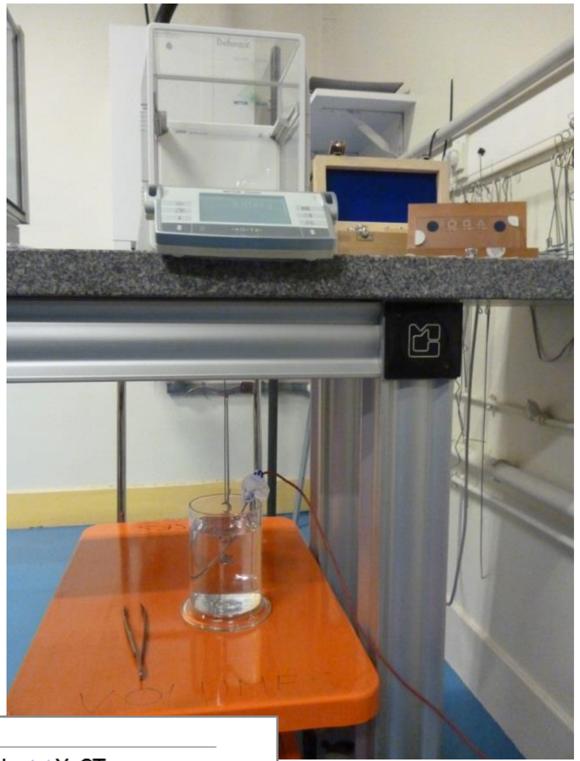
LNE

The EMPIR initiative is co-funded by the European Union's Horizon 2020 research and innovation programme and the EMPIR Participating States

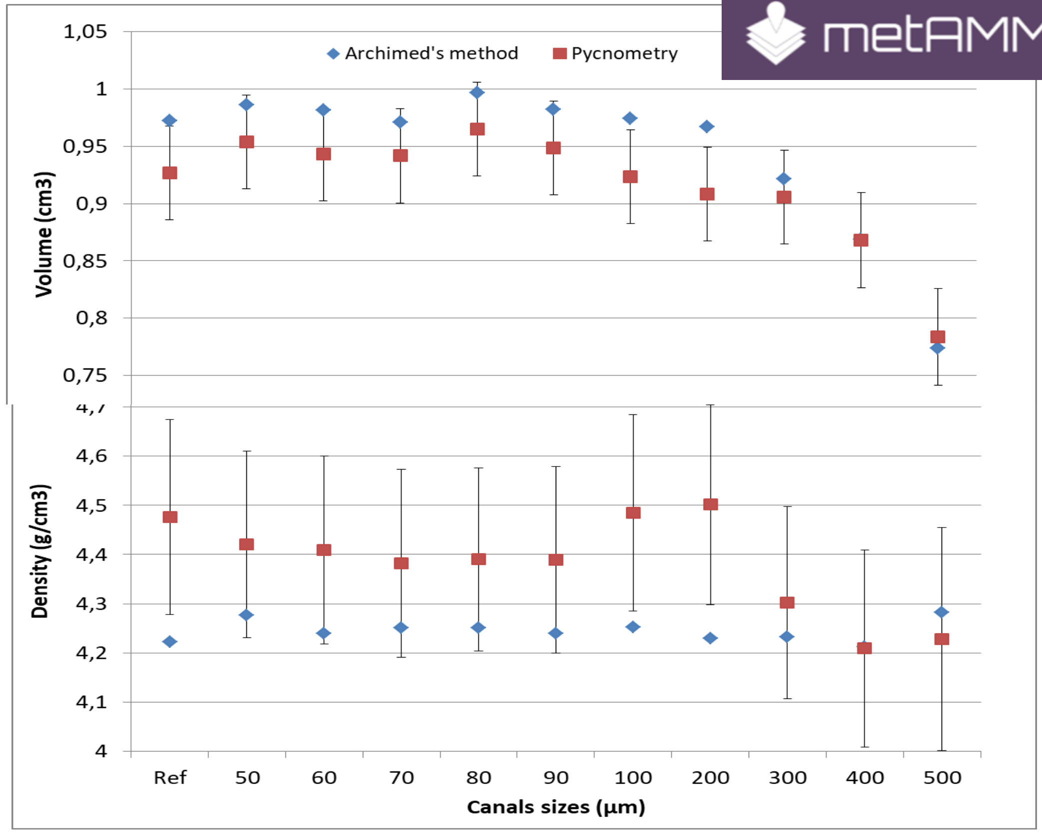
Investigated volumetric NDT methods for AM)

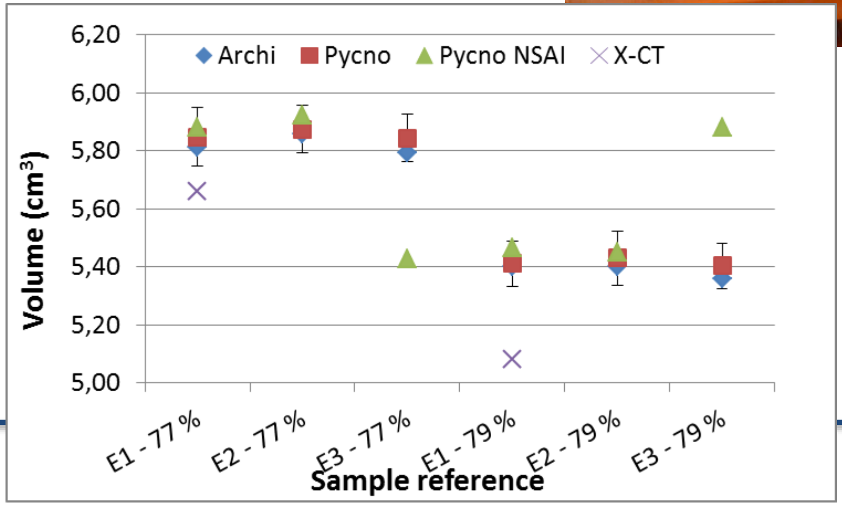
Archimedes' method and gas pycnometry

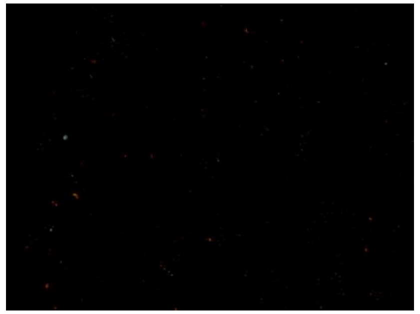




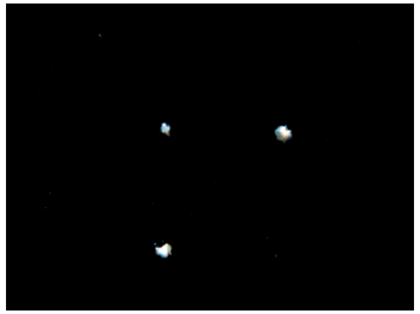
Ti dense specimens with opened canals of different sizes



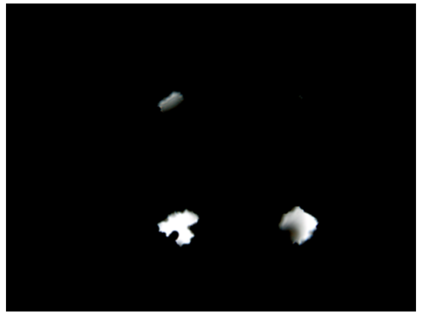




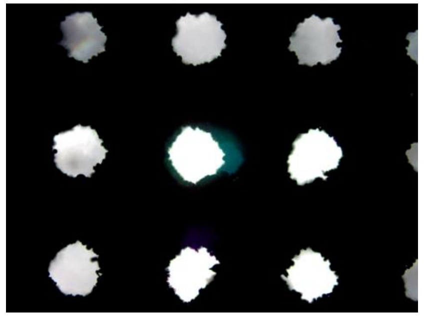
200 µm



300 µm



400 µm



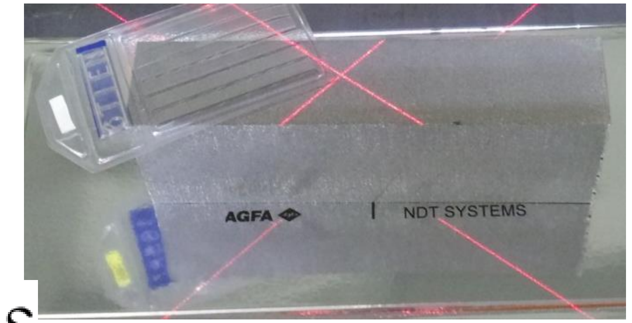
500 µm

AF. Obaton, M-Q. Lê, V. Prezza, D. Marlot, P. Delvart, A. Huskic, S. Senck, E. Mahé , C. Cayron., 'Investigation of new volumetric non-destructive techniques to characterise additive manufacturing parts', *Weld World*, vol. 62, no. 5, pp. 1049–1057, Sep. 2018, doi: 10.1007/s40194-018-0593-7.

J. Wilbig, F. Borges de Oliveira, A.-F. Obaton, M. Schwentenwein, K. Rübner, and J. Günster, 'Defect detection in additively manufactured lattices', Open Ceramics, p. 100020, Aug. 2020, doi: 10.1016/j.oceram.2020.100020.

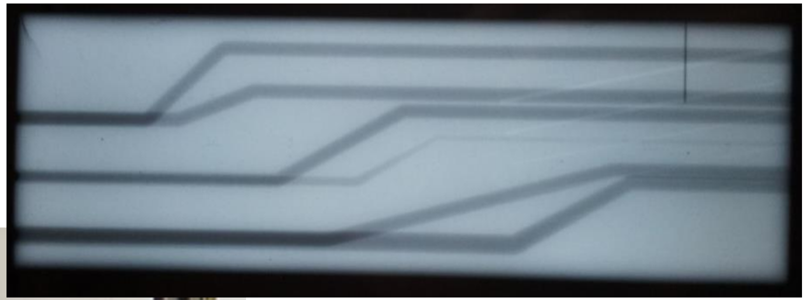
Investigated volumetric NDT methods for Additive Manufacturing (AM)

Radiography

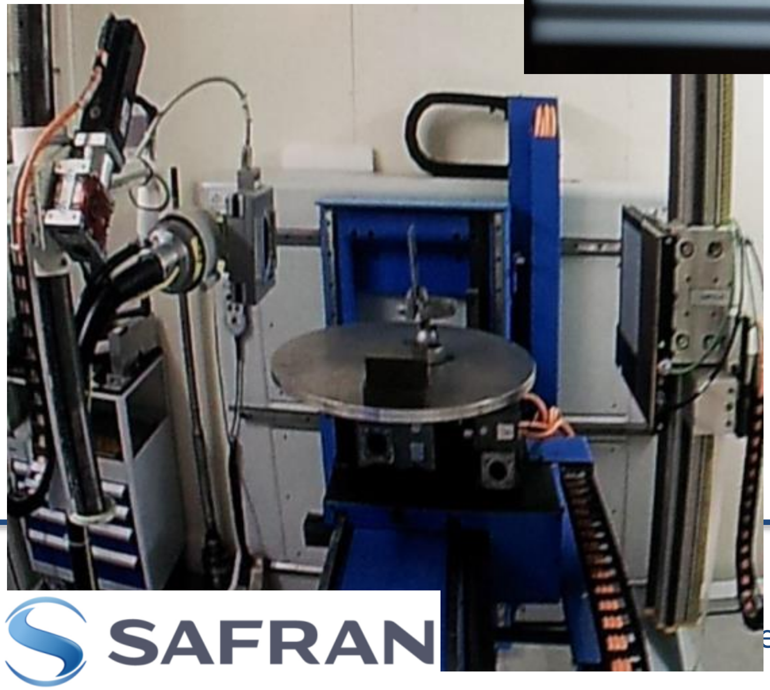


MISTRAS
ASCOT

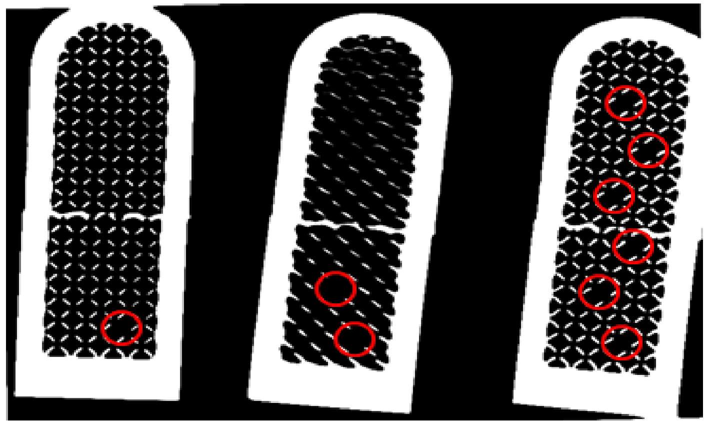
Part with channels in Ti



Computed radiography



SAFRAN



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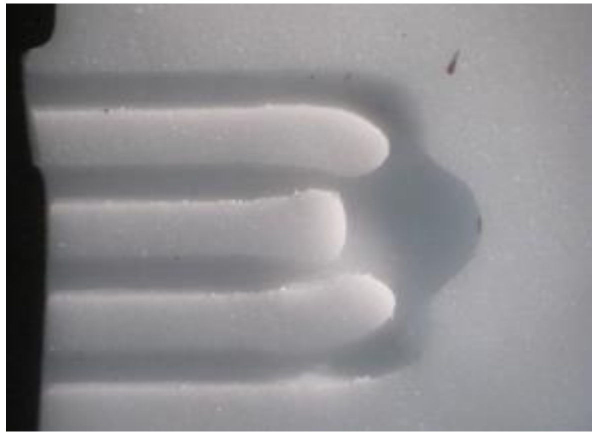
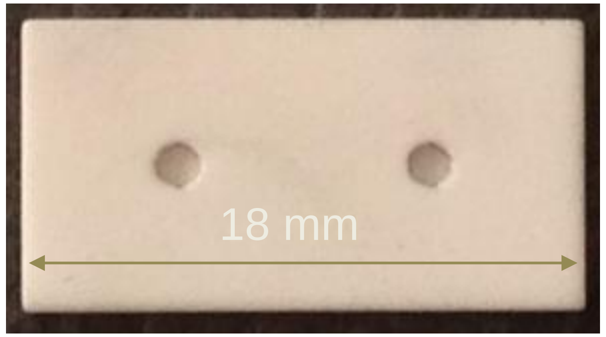
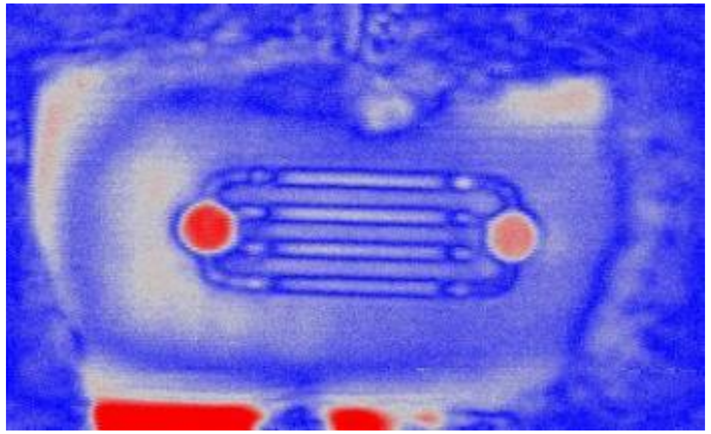


ims

THz spectrometry

Part with channels in zirconium





Investigated volumetric NDT methods for Additive Manufacturing (AM)

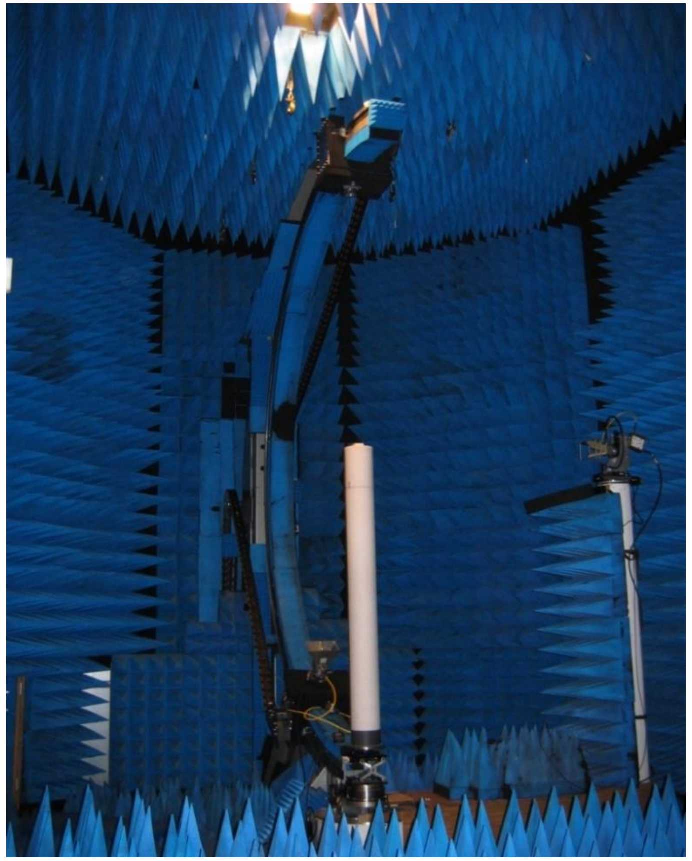
THz tomography

Polyamide 12

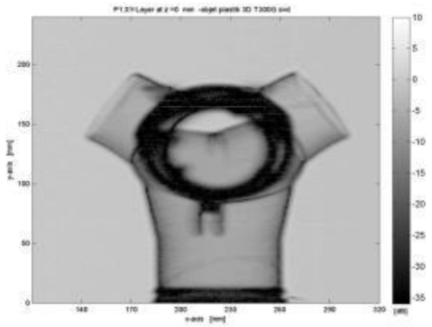
DASSAULT AVIATION

ims

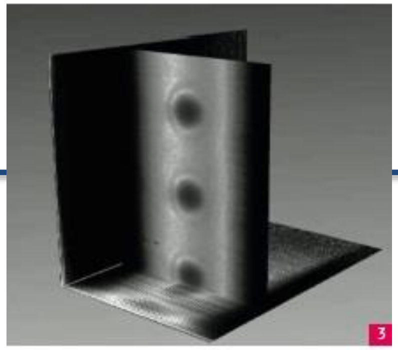
Microwave tomography



INSTITUT FRESNEL



Ceramic part



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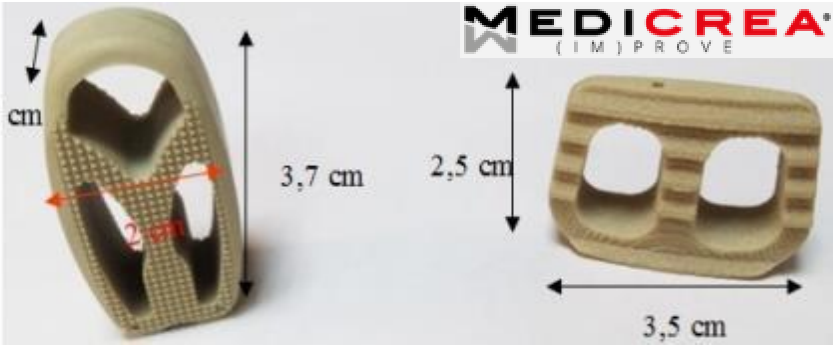
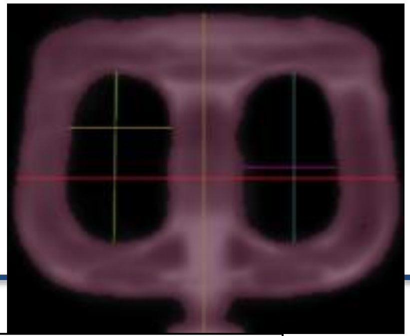


Spinal implants in peek



A-F. Obaton, M. Costin, P. Mounaix, J-M. Geffrin, C. Eyraud, C. Souvignet, J-M. Moschetta, 'Metrological Evaluation of Tomography Methods Applied to Objects Fabricated by Additive Manufacturing, *International symposium on Digital Industrial radiology and Computed Tomography DIR2015*, Ghent, Belgium, 22-25 June 2015. NDT.net issue Vol.20 No.8.

J.B. Perraud, A.F. Obaton, J. Bou-Sleiman, B. Recur, H. Balacey, F. Darrack, J.P. Guillet and P. Mounaix, "THz imaging and tomography as efficient instruments for testing polymer additive manufacturing objects", Applied Optics, Vol. 55, Issue 13, pp. 3462-3467 (2016). doi: 10.1364/AO.55.003462.

Investigated volumetric NDT methods for Additive Manufacturing (AM)

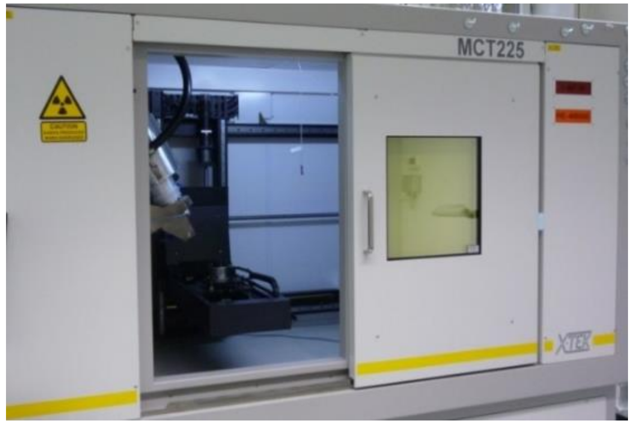
PTB

EMPIR EURAMET

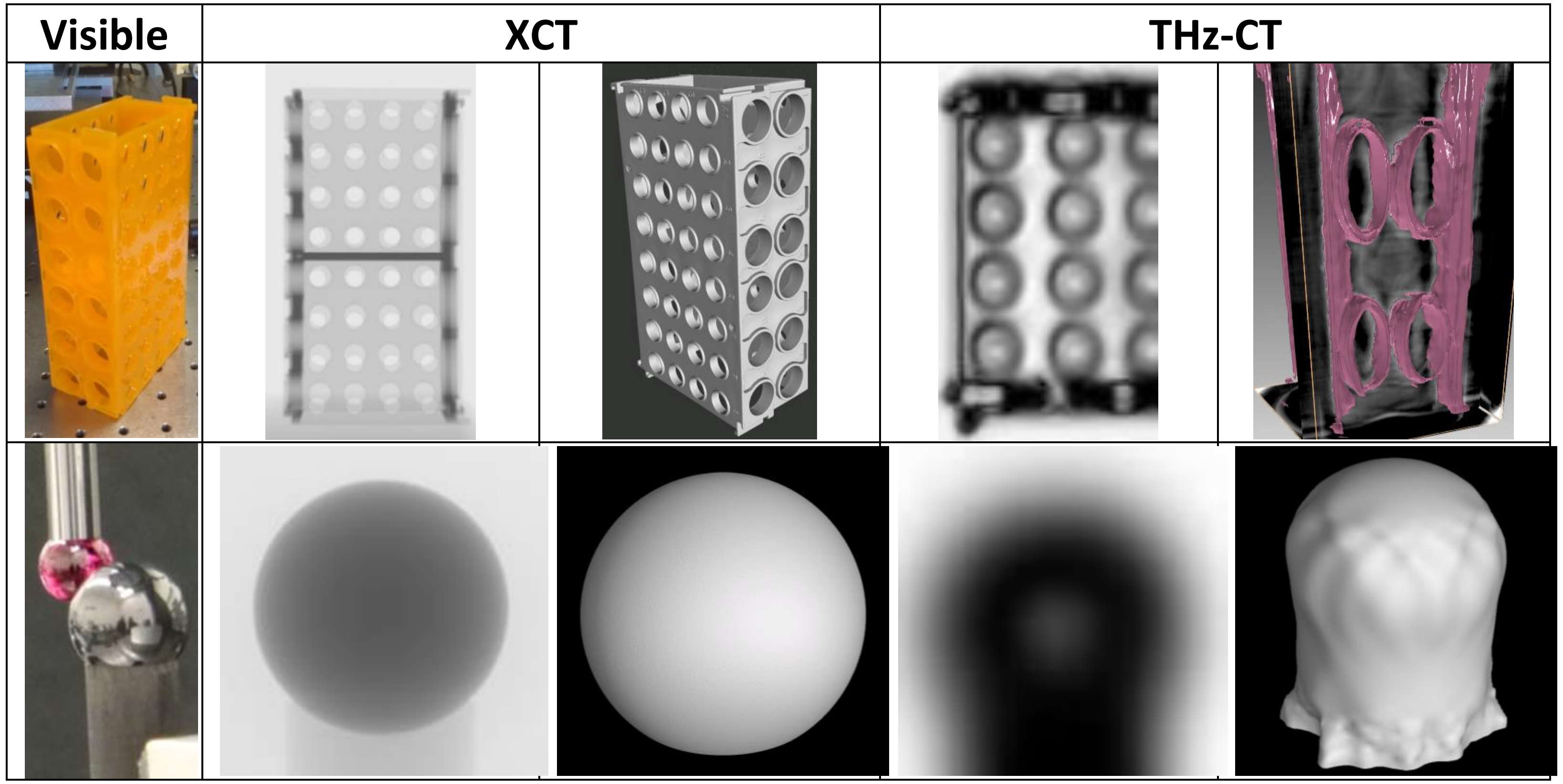
The EMPIR initiative is co-funded by the European Union's Horizon 2020 research and innovation programme and the EMPIR Participating States

metAMMI

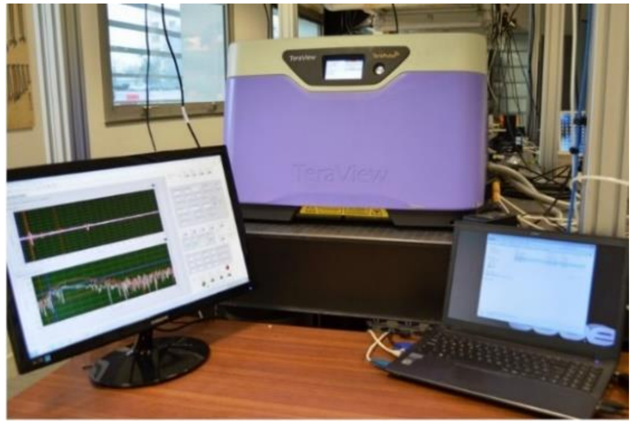
ims



XCT



Top: Polymer part, bottom: silicon nitride spheres (∅ 8 mm)



THz-CT

A.-F. Obaton, 'Overview of the EMPIR project: Metrology for additively manufactured medical implants', presented at the Joint Special Interest Group meeting between euspen and ASPE Advancing Precision in Additive Manufacturing, Ecole Centrale de Nantes, France, Sep. 2019, [Online]. Available: https://www.euspen.eu/knowledge-base/AM19106.pdf.

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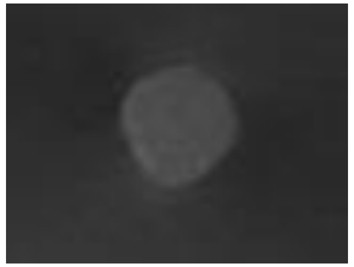
Study of operator effect on ImageJ

Focus on studies performed with XCT methods

COFREND
Confédération Française pour les Essais Non Destructifs
French Confederation for Non-destructive Testing

Volume measurement (in voxel) of 6 spherical defects with diameter from 300 µm to 800 µm

Procedure: Define the threshold of grey level



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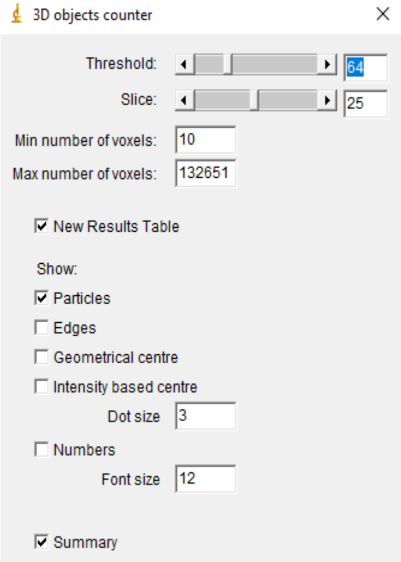

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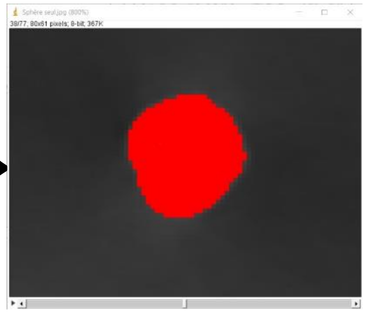
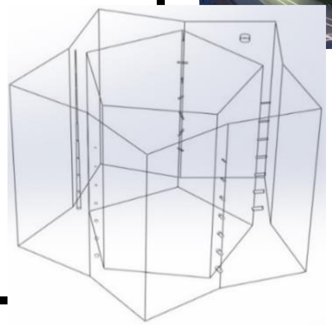
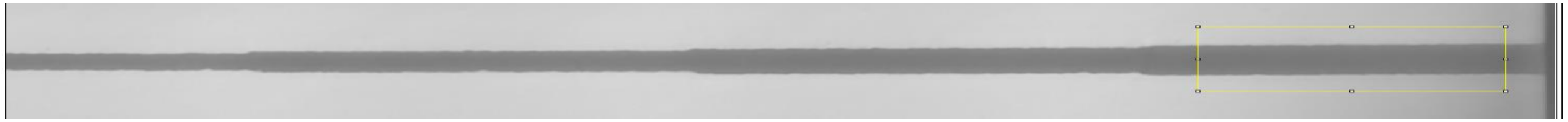




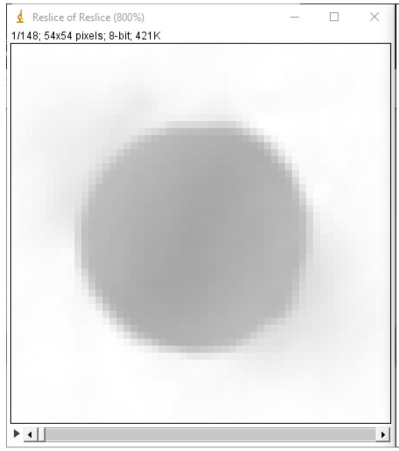
NOVITOM
ADVANCED 3D MICRO-IMAGING

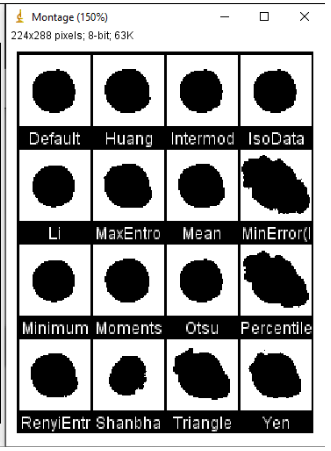
$$\sigma_{op}^2 = \sigma_{Repro}^2 - \sigma_{repeta}^2$$

Area measurement (in pixel) of each slice of 6, 2 mm long, cylinders with diameter trough 300 µm to 800 µm



Procedure: Choice of 3 filters ⇒ binarization + auto threshold





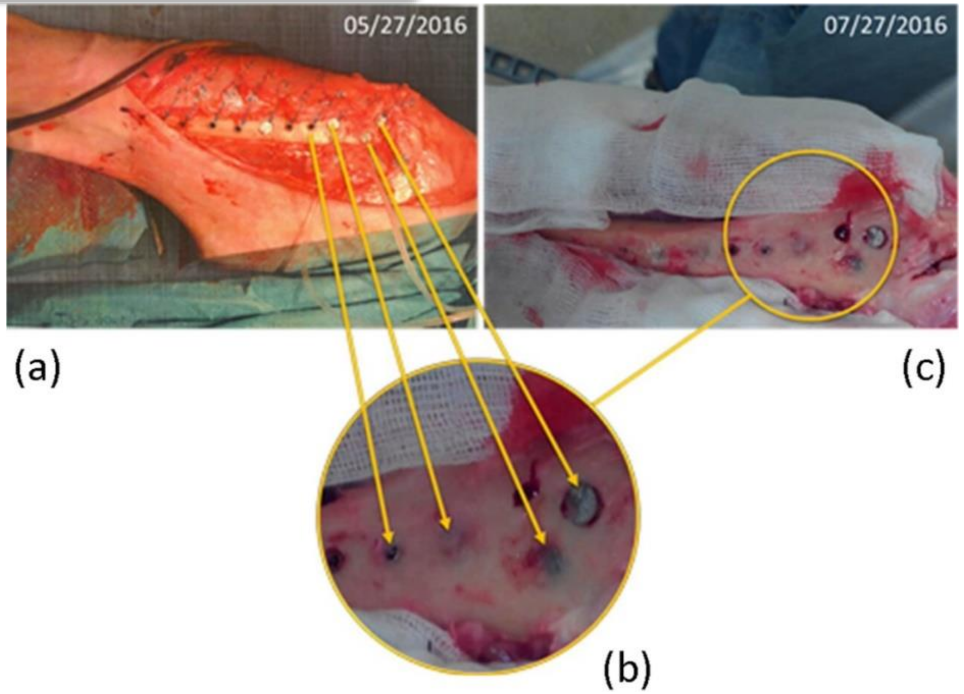
- ➢ Sphere’s volume calculation shows a large contribution of the operator effect on the reproducibility
- ➢ Cylinder’s area calculation shows that filter’s choice is the principal contributor to the reproducibility
- ➢ Values are consistent with VGStudioMax. However , ImageJ overestimated the values compare to VGStudioMax

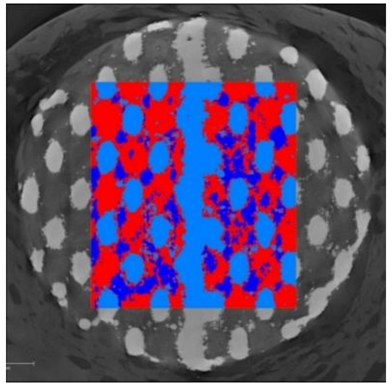
C. Cayron, A. De Soete, Y. Gaillard, C. Yardin, N. Coutant, R. Nanjareddy, P. Bouvet, A.-F. Obaton, “Comparison of dimensional measurements from images acquired by synchrotron tomography with VGSTUDIO MAX and ImageJ”, Joint Special Interest Group meeting between euspen and ASPE Advancing Precision in Additive Inspire AG, St. Gallen, Switzerland 2021.

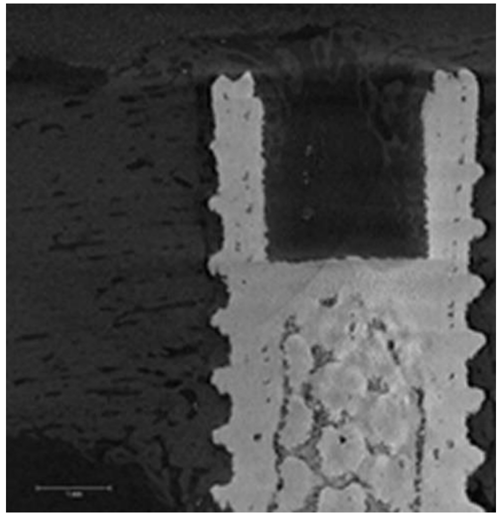
Focus on studies performed with XCT methods

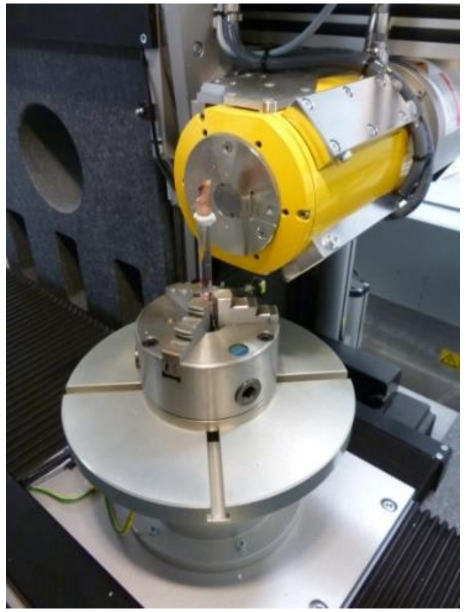
A-F Obaton was a guest researcher at BAM (Berlin) for 2 months in 2016

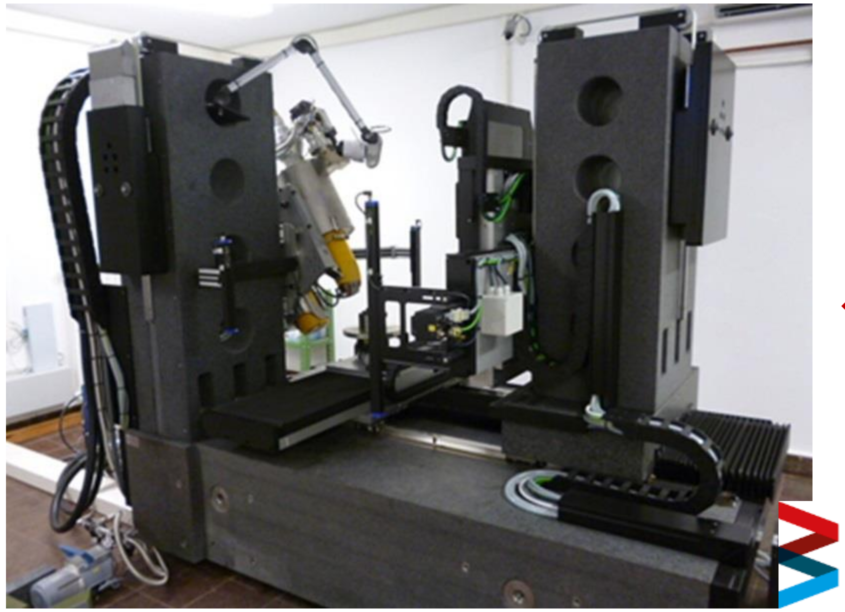
Study of bone penetration in Ti lattices







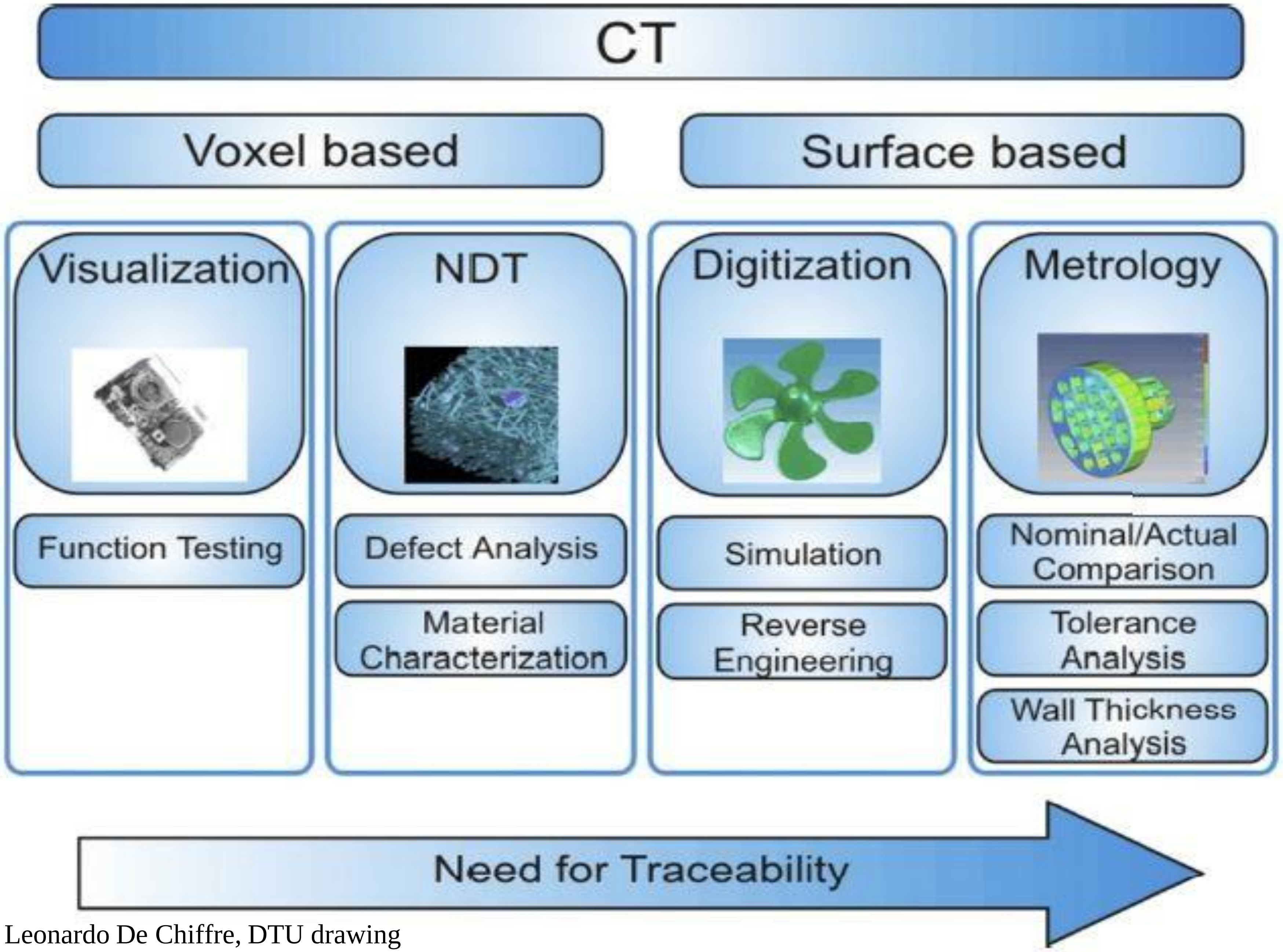




A-F Obaton was a guest researcher at BAM (Berlin) for 2 months in 2016

A-F. Obaton, J. Fain, M. Djemaï, D. Meinel, F. Léonard, E. Mahé, B. Lécuelle, J-J. Fouchet, G. Bruno, 'In vivo XCT bone characterization of lattice structured implants fabricated by additive manufacturing: a case report', *Heliyon*, vol. 3, no. 8, Aug. 2017, doi: 10.1016/j.heliyon.2017.e00374.

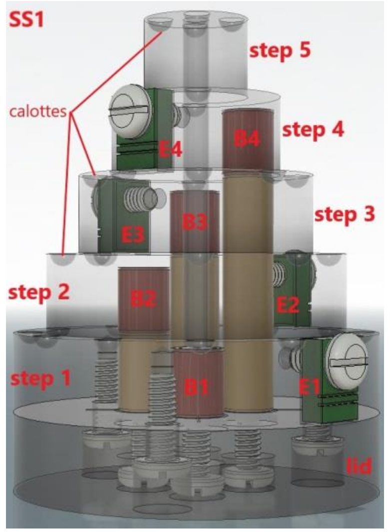
Focus on studies performed with XCT methods

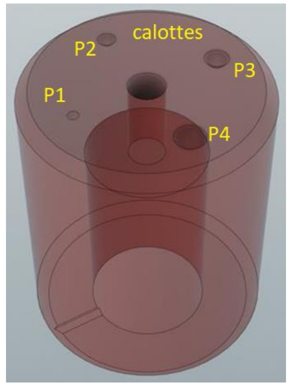


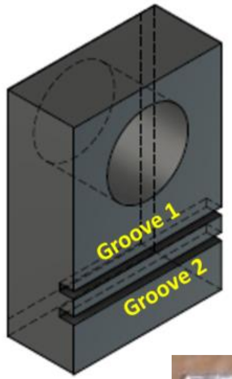
Leonardo De Chiffre, DTU drawing

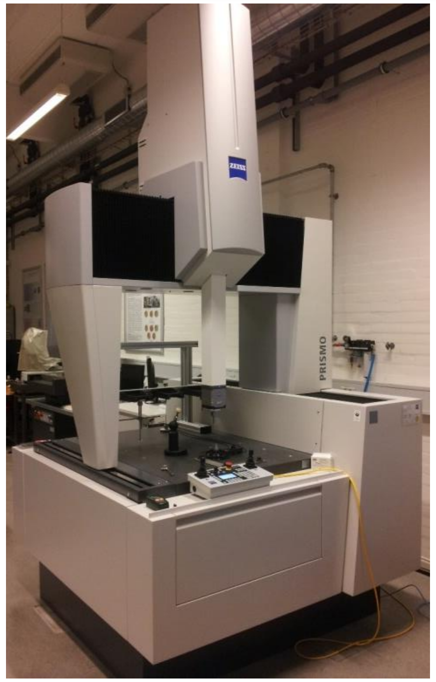
Focus on studies performed with XCT methods

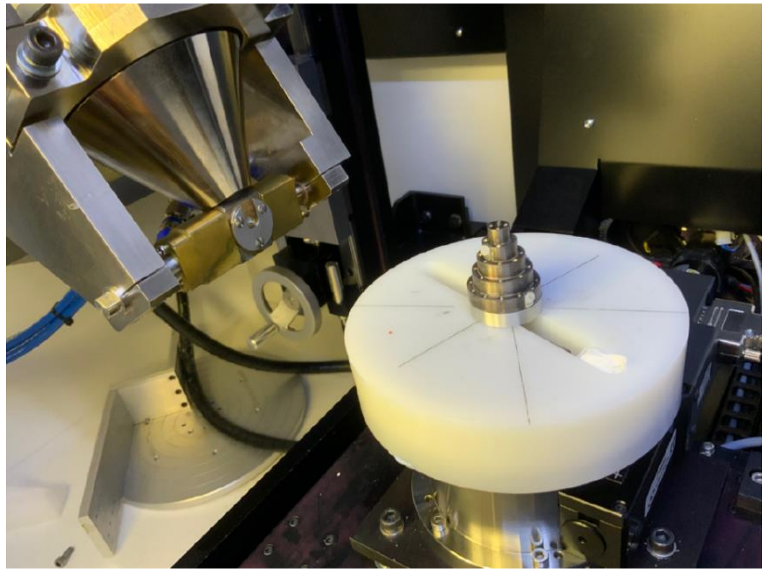
Design and fabrication of 3 standards in ABS, Al and SS representing complex AM parts and coordination of a round robin on XCT measurements











The EMPIR initiative is co-funded by the European Union's Horizon 2020 research and innovation programme and the EMPIR Participating States

A-F Obaton was a guest researcher at DTU (Denmark) for 4 months in 2020

DTU Technical University of Denmark

A-F. Obaton, C. Yardin, K. Liltorp, D. Quagliotti, L. De Chiffre, "Comparison campaign of XCT systems using machined standards representative of additively manufactured parts", in *ndt.net*, Wels, Austria, Feb. 2022, Forthcoming.

A.-F. Obaton, C. Gottlieb Klingaa, C. Rivet, K. Mohaghegh, S. Baier, J. Lasson Andreasen, L. Carli, L. De Chiffre, 'Reference standards for XCT measurements of additively manufactured parts', in *ndt.net*, Wels, Austria, Feb. 2020, vol. id152, [Online]. Available: https://www.ndt.net/article/ctc2020/papers/ICT2020_paper_id152.pdf.

ZEISS novo nordisk DANISH TECHNOLOGICAL INSTITUTE NPL National Physical Laboratory messtronik list cea tech mtc University of Nottingham UK | CHINA | MALAYSIA le cnam LABORATOIRE NATIONAL DE MÉTROLOGIE ET D'ESSAIS LNE

Focus on studies performed with XCT methods

Benefits of the method

- deals with complex shapes
- deals with rough surfaces
- defect detection and location
- high spatial resolution
- defect dimensioning

Drawbacks of the method

- limited in size
- limited in density
- expensive
- time-consuming
- large files, difficile to handle

XCT: reference method for AM parts but alternative methods to XCT are required

1. Joint group JG59 “NDT for AM parts” of the ISO-TC261/ASTMF42 standardization group on AM
2. Part designed and additively manufactured to investigate NDT methods especially for AM
3. Investigated NDT methods for AM
4. Focus on studies performed with XCT methods
5. **Focus on studies performed with resonant ultrasound spectroscopy (RUS) methods**
6. LNE projects

Focus on studies performed with resonant ultrasound spectroscopy methods (RUS)

Principle of RUS methods

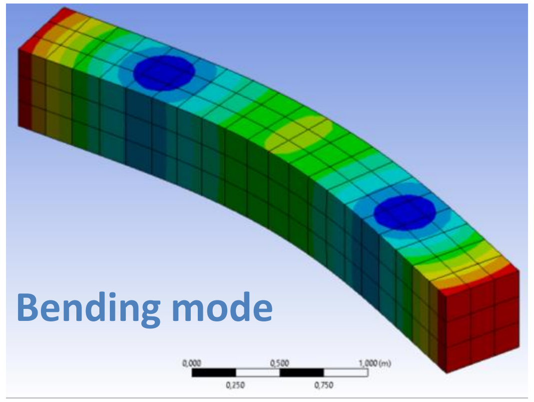
1. Mechanical impulse of the sample under test to generate its natural resonant frequencies
2. Monitoring of the vibrational response of the sample under test ⇒ frequency spectrum (resonant peaks of the vibrational modes)
3. Comparison of the spectrum of the sample under test with the spectrum of a set of reference parts (parts identical to the sample under test supposedly without defects)
4. Analysis of the frequency shifts between the peaks of the sample under test and the peaks of the reference parts
   ⇒ pass/fail tested sample

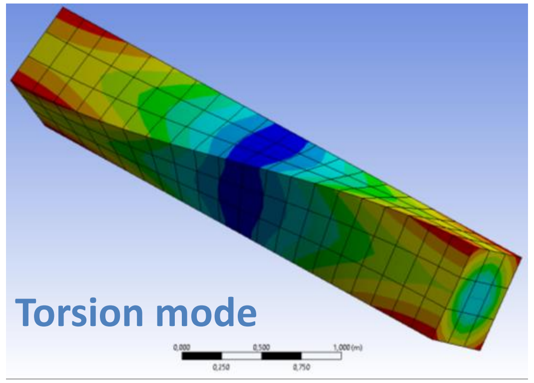
Type of RUS methods

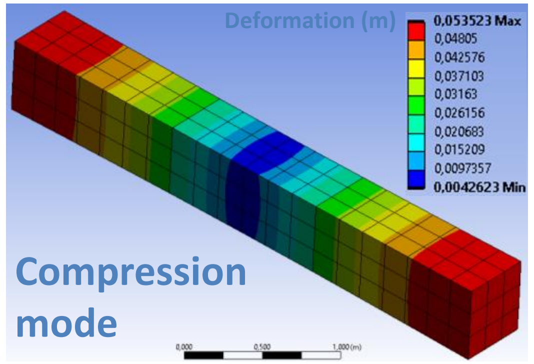
1. "Swept sine method" with a piezoelectric sensor
2. "Impulse excitation technique" (IET) with a hammer tip

Benefits of the methods

- ➢ deals with complex shapes and rough surfaces
- ➢ deals with large parts
- ➢ fast and easy to use





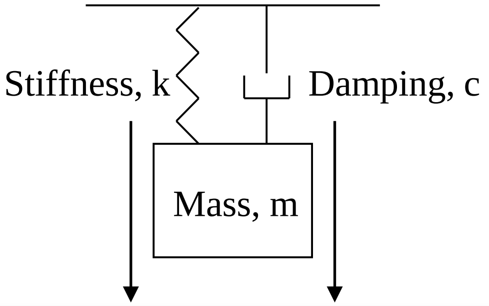


Resonant frequencies are related to:

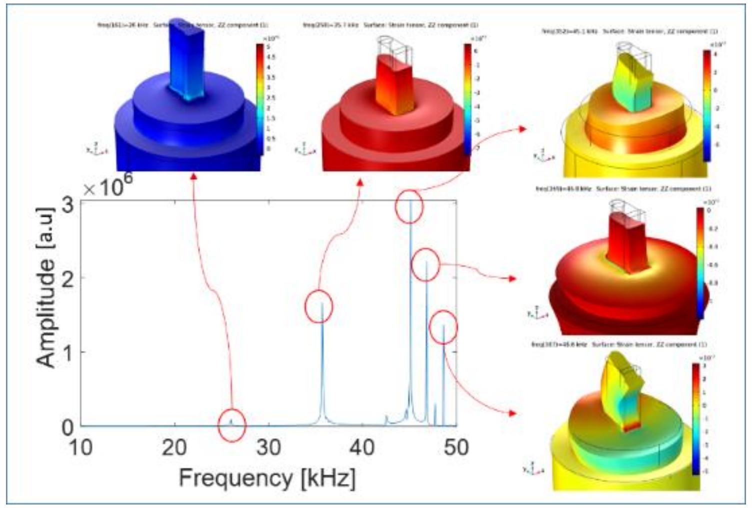
1. The geometry of the part
2. The density of the part
3. The elasticity of the part
4. The external and internal structural integrity of the part (e.g. crack)

Drawbacks of the methods

- ➢ global or full body methods
- ➢ comparison methods



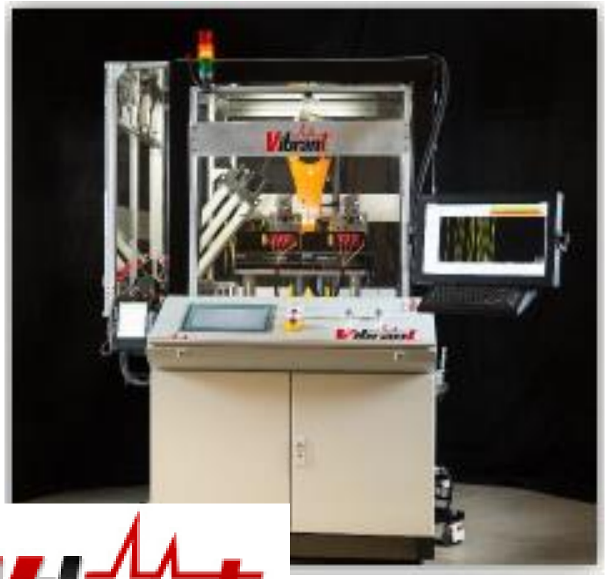
Focus on studies performed with resonant ultrasound spectroscopy methods (RUS)



GrindoSonic
THE IMPULSE EXCITATION TECHNIQUE

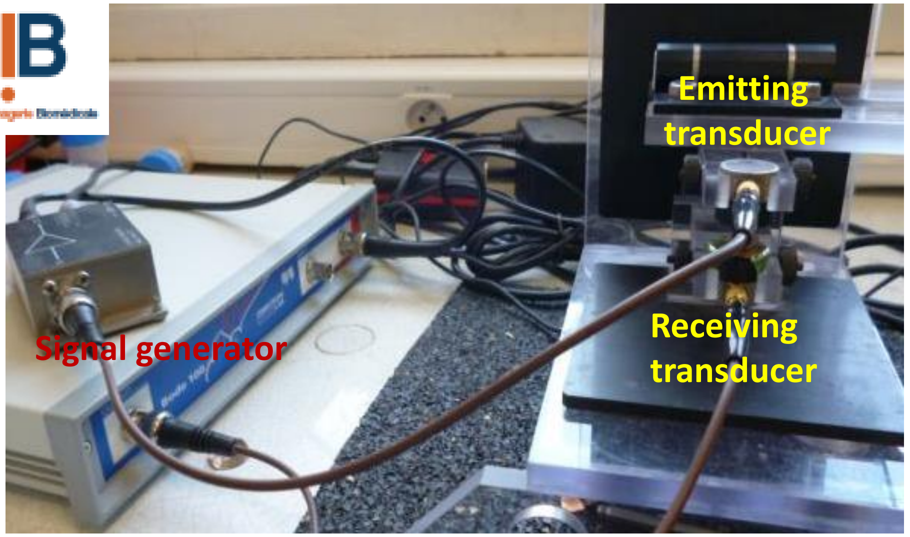
Polytec

THE MODAL SHOP
MTS SYSTEMS CORPORATION

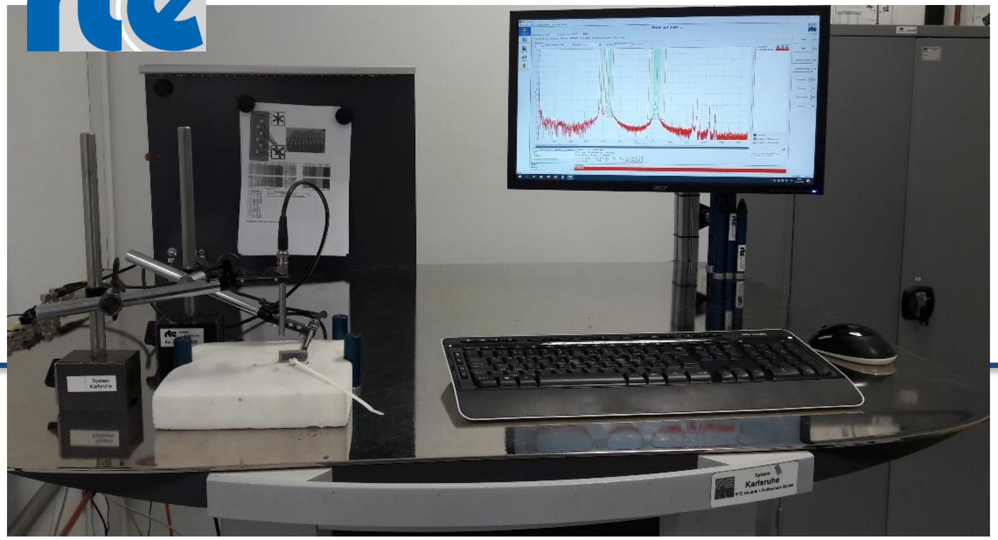


Vibrant

LIB
Laboratoire d'Imagerie Biomédicale



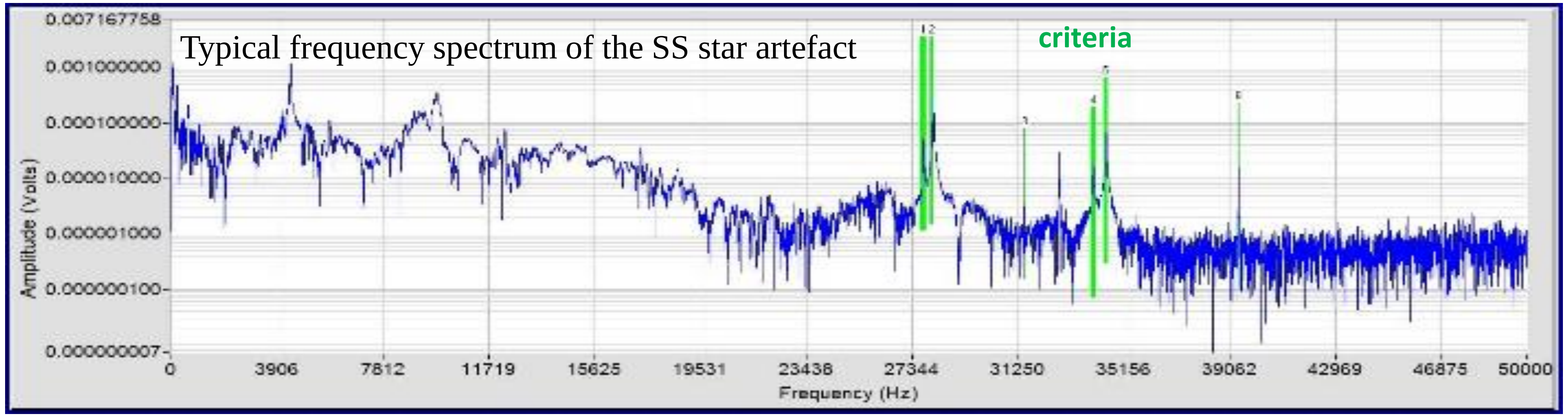
rte



A-F. Obaton, A. Van den Bossche, O. Burnet, B. Butsch, I. Zouggarh, F. Soulard , and W. Johnson, “Novel or Improved NDE Inspection Capabilities for Additively Manufactured Parts”, *ASTM International*, Forthcoming (accepted 22 Feb 2021).

RUS tests on SS star artefacts with different number of defects

	Build 1		Build 2	
	Pass	Fail	Pass	Fail
Reference parts	20	0	19	1
Parts with defects	0	24	0	24



Data were collected between 500 Hz and 50 kHz and in between 500 Hz and 94 kHz.

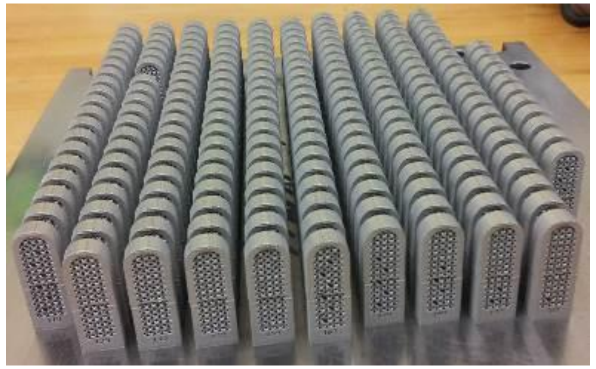
- RUS enabled to sort the samples with internal features (defects) from the reference samples
- RUS was not able to sort the parts according to the number of internal features

A-F Obaton was a guest researcher at NIST (Gaithersburg) from Nov. 2017 until Nov. 2018 and in August 2019.

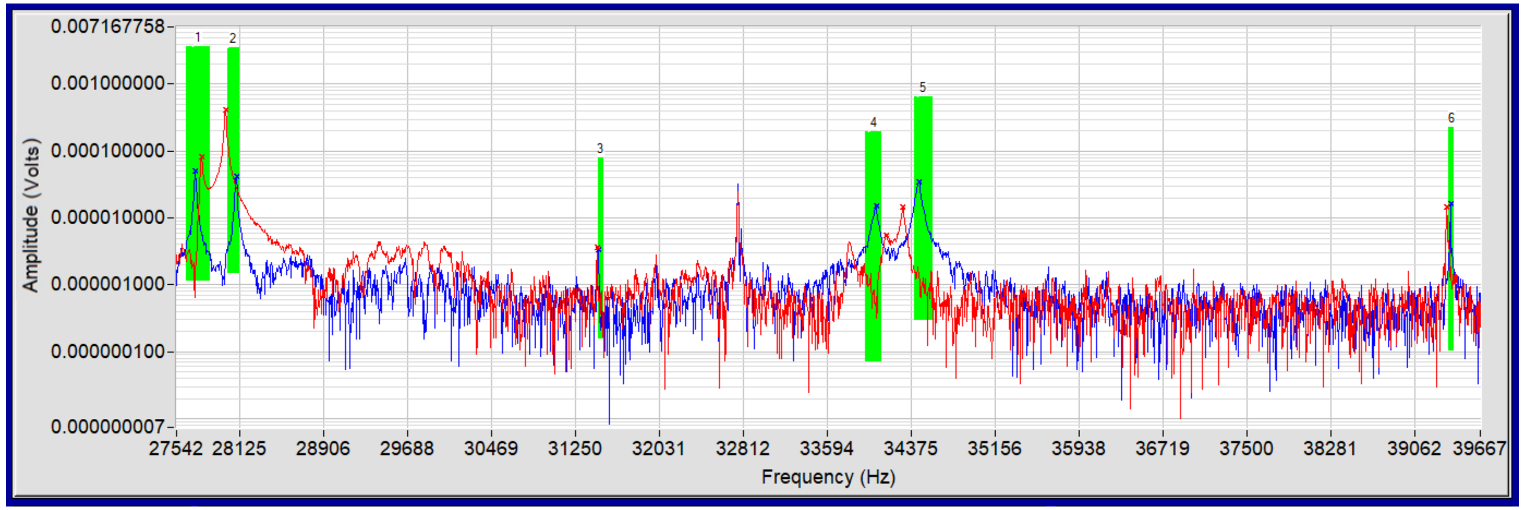
A.-F. Obaton, B. Butsch, E. Carcreff, N. Laroche, J. Tarr, and A. Donmez, 'Efficient volumetric non-destructive testing methods for additively manufactured parts', Weld World, Jun. 2020, doi: 10.1007/s40194-020-00932-0.

RUS tests on CoCr lattice structures with different number of missing struts

THE MODAL SHOP
MTS SYSTEMS CORPORATION



	ref	1 out	2 out	4 out	6 out	8 out	10 out	12 out	1 in	2 in	4 in	6 in
ref		fail	fail	fail	fail	fail	fail	fail	fail	fail	fail	fail
1 out	fail		pass	fail	fail	fail	fail	fail	pass	pass	pass	pass
2 out	fail	pass		fail	fail	fail	fail	fail	pass	pass	pass	pass
4 out	fail	fail	fail		fail	fail	fail	fail	fail	fail	fail	fail
6 out	fail	fail	fail	fail		pass	pass	pass	fail	fail	fail	fail
8 out	fail	fail	fail	fail	pass		pass	fail	fail	fail	fail	fail
10 out	fail	fail	fail	fail	pass	pass		pass	fail	fail	fail	fail
12 out	fail	fail	fail	fail	pass	fail	pass		fail	fail	fail	fail
1 in	fail	pass	pass	fail	fail	fail	fail	fail		pass	pass	pass
2 in	fail	pass	pass	fail	fail	fail	fail	fail	pass		pass	pass
4 in	fail	pass	pass	fail	fail	fail	fail	fail	pass	pass		pass
6 in	fail	pass	pass	fail	fail	fail	fail	fail	pass	pass	pass	



- RUS enabled to sort the lattices with missing struts from the one without missing strut
- RUS was able to sort the parts according to the number of missing struts but not systematically

A-F Obaton was a guest researcher at NIST (Gaithersburg) from Nov. 2017 until Nov. 2018 and in August 2019.

A-F. Obaton, Y. Wang, B. Butsch, Q. A Huang, "Non-Destructive Resonant Acoustic Testing and Defect Classification of Additively Manufactured Lattice Structures", Weld World, **65**, 361–371, 2021, https://doi.org/10.1007/s40194-020-01034-7.

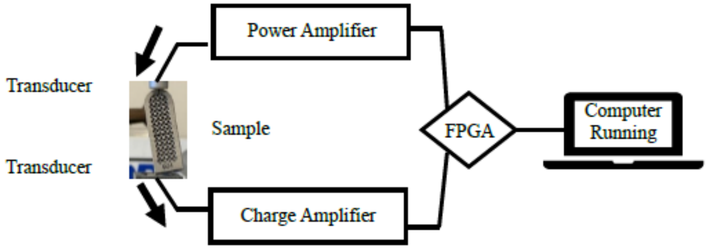
Machine learning analysis on the RUS data

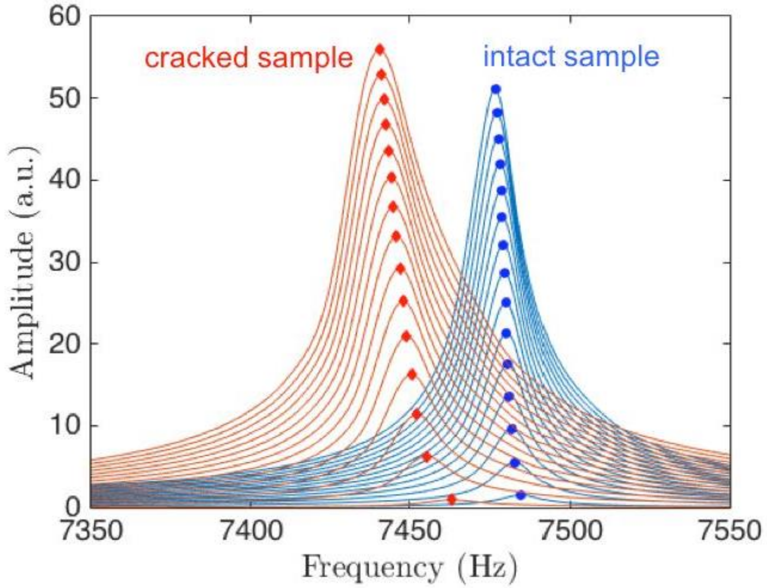
Objective of the ML models:

Screen parts with simulated defects from identical reference parts supposedly flawless and classify the parts according to the number of defects in the parts with little or no human inputs

A-F. Obaton, C. Ruiz, B. Butsch, D. Stickler and Q. Huang, "Complex AM part quality evaluation though machine learning enhanced resonant ultrasound spectroscopy method", ASTM International, ICAM2021, Forthcoming.

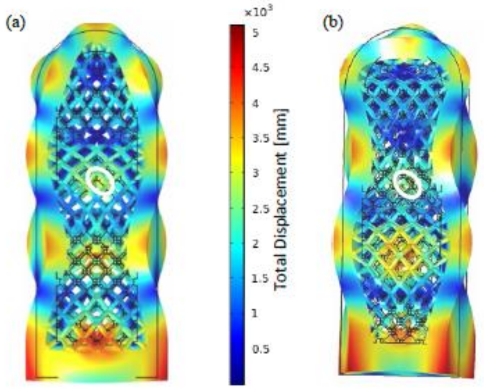
Focus on studies performed with RUS: non-linear RUS

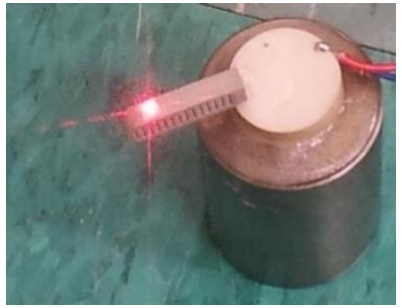


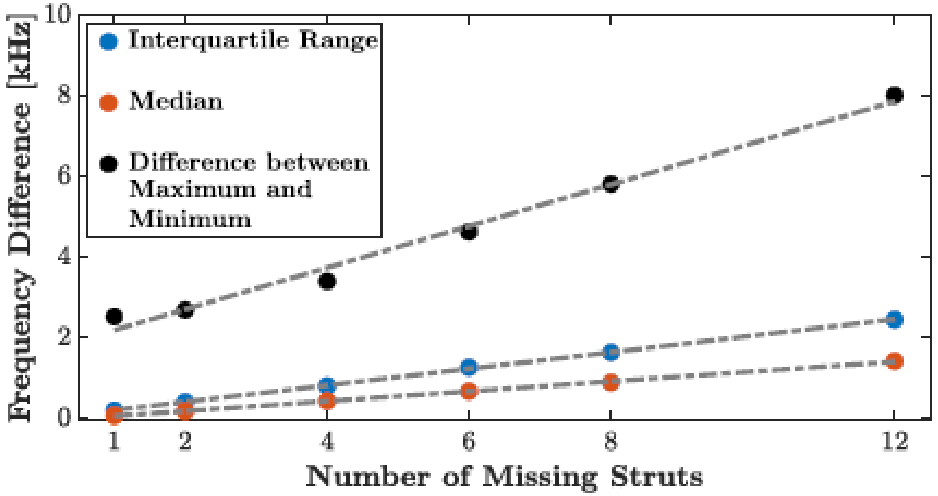


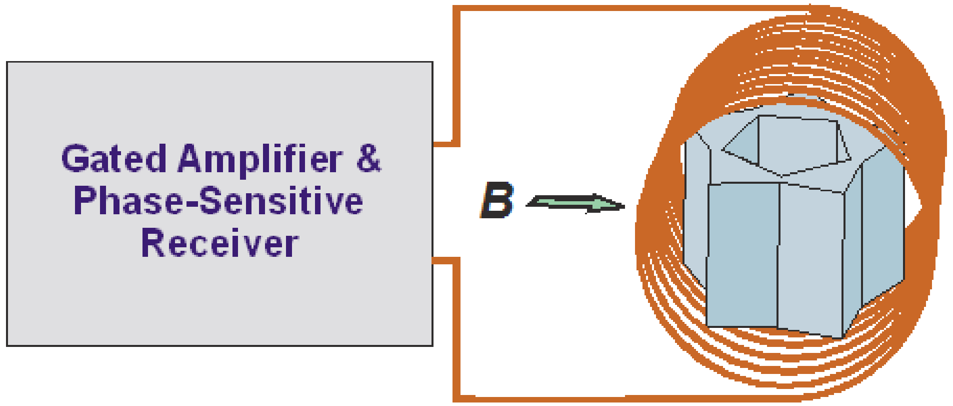
NIST

PennState









S. McGuigan, A. Arguelles, A-F. Obaton, A. Donmez, J. Rivière, S. Parisa, “Resonant Ultrasound Spectroscopy for Quality Control of Geometrically Complex Additively Manufactured Components”, *Additive Manufacturing*, Vol. 39, 101808, 10.1016/j.addma.2020.101808, https://doi.org/10.1016/j.addma.2020.101808

ACADEMIA NDT INTERNATIONAL

Science, Technology and Diagnostics in Non-Destructive Testing

1. Joint group JG59 "NDT for AM parts" of the ISO-TC261/ASTMF42 standardization group on AM
2. Part designed and additively manufactured to investigate NDT methods especially for AM
3. Investigated NDT methods for AM
4. Focus on studies performed with XCT methods
5. Focus on studies performed with resonant ultrasound spectroscopy (RUS) methods
6. **LNE projects**

LNE projects

European JPR : "MetAMMI"
Metrology for AM medical implants and guides (06/2015-05/2019)

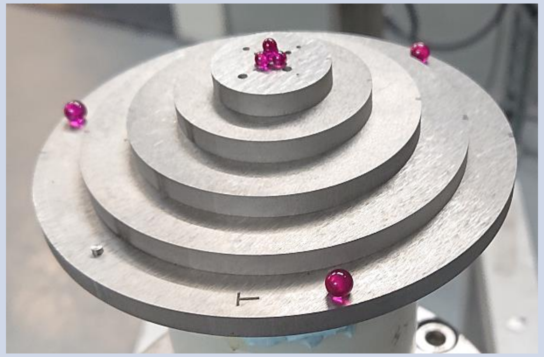
LNE coordination

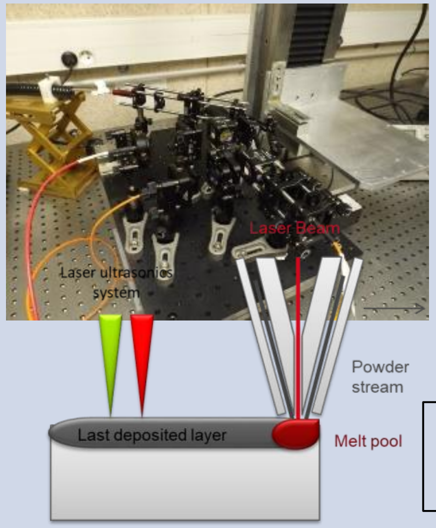
metAMMI

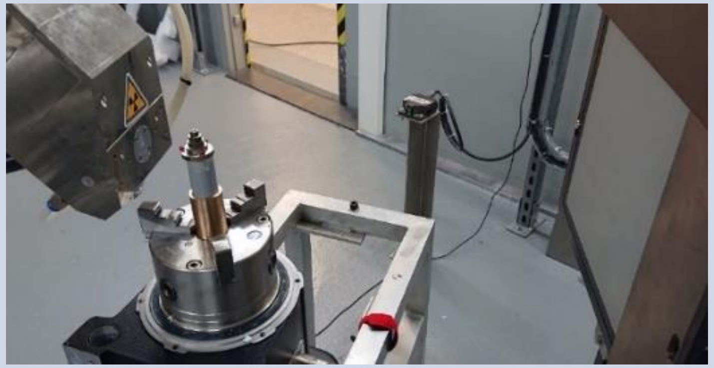
A.-F. Obaton, "Overview of the EMPIR project: Metrology for additively manufactured medical implants", Euspen and ASPE Advancing Precision in Additive Manufacturing, https://www.euspen.eu/knowledge-base/AM19106.pdf.

National partner-oriented research: "I AM SURE"
In and off process AM part inspections: quality control and metrology (11/2015-05/2020)

BeAM BE ADDITIVE MANUFACTURING · LNE · THALES · POLY-SHAPE · VLM Façonnage numérique · AIRBUS GROUP · NAVAL GROUP · list ceatech · cetim · AFPR



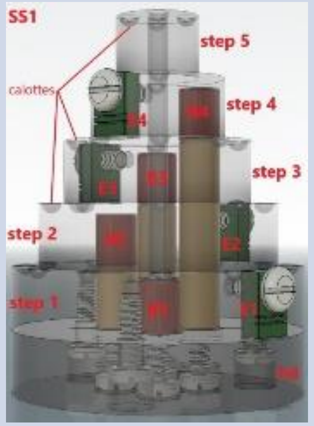


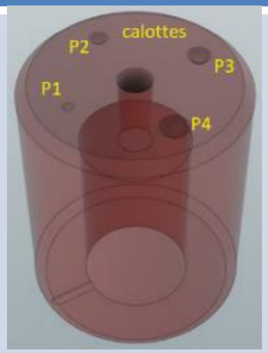


C. Millon, A. Vanhoye, A-F. Obaton, J-D. Penot, "Development of laser ultrasonics inspection for online monitoring of additive manufacturing", Welding in the World, Vol. 62, Issue 3, pp. 653-661, 2018, https://doi.org/10.1007/s40194-018-0567-9

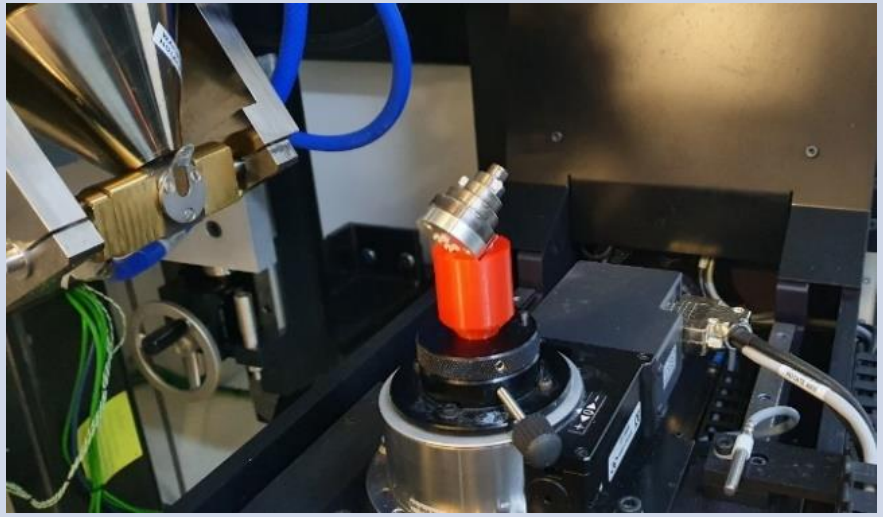
LNE projects

JRP: "AdvanCT" Advanced CT for dimensional and surface measurements in industry (06/2018-11/2021)





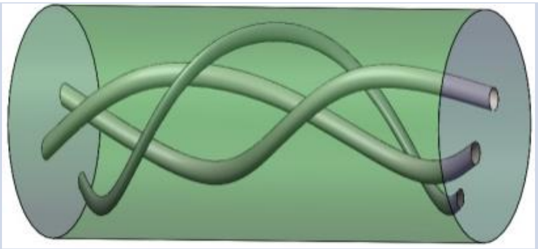
DTU Technical University of Denmark



A-F. Obaton, C. Gottlieb Klingaa, C. Rivet, K. Mohaghegh, S. Baier, J. Lasson L. Carli, L. De Chiffre, “Reference Standards for XCT Measurements of Additively Manufactured Parts”, ndt.net, Vol. id152, 2020, https://www.ndt.net/article/ctc2020/papers/ICT2020_paper_id152.pdf

National partner-oriented research: "FA-CANALSAFE®" ND inspection of channels (07/2019-09/2021)

GrindoSonic THE IMPULSE EXCITATION TECHNIQUE



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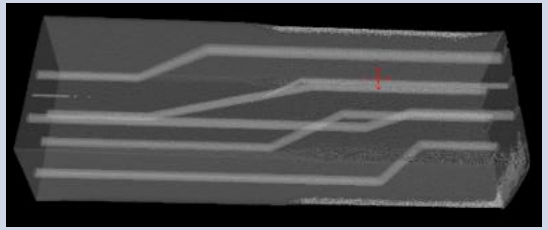
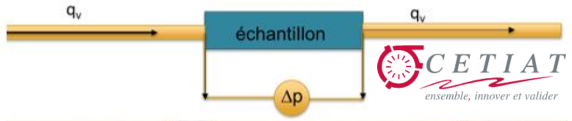
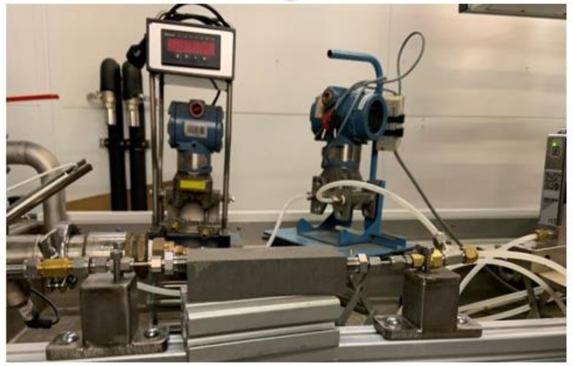
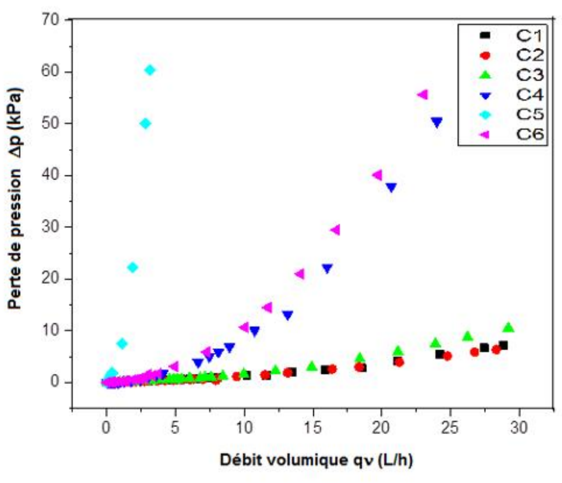




CETIAT ensemble, innover et valider





arianeGroup

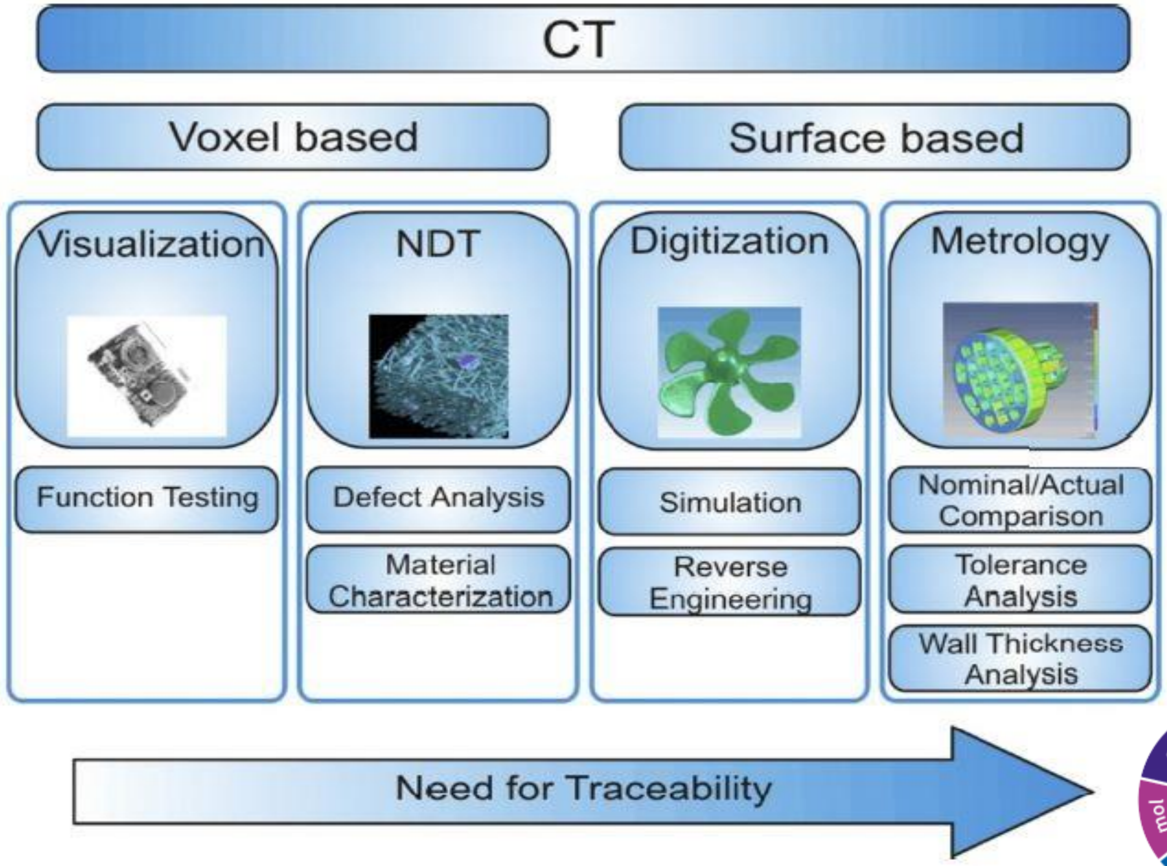
THALES

SAFRAN

High involvement in the French Confederation for Non-destructive Testing

COFREND
Confédération Française pour les Essais Non Destructifs
French Confederation for Non-destructive Testing

XCT group



PhD thesis
CETIM/INSA/LNE

NDT for AM group

Artificial Intelligence (AI) group

PhD student on
Metrological study of the influence of LPBF processing parameters on parts dimensional accuracy

Lucas Fournet-Fayard, 2^{nd} year PhD student

Study of the dimensional accuracy of the manufactured parts according to the AM process parameters, assessment of:

- Geometry and dimensional properties (distortions, dimensional deviations,…)
- Roughness

Study of the origins of the deviations:

- Thermo-mechanical study
- Correlation with dimensional measurements

L. Fournet-Fayard, C. Cayron, I. Koutiri, V.Gunenthiram, P. Sanchez, A-F. Obaton, "Influence of the processing parameters on the dimensional accuracy of In625 lattice structures made by laser powder bed fusion", Joint Special Interest Group meeting between euspen and ASPE Advancing Precision in Additive Manufacturing Inspire AG, St. Gallen, Switzerland 2021.

ACADEMIA NDT INTERNATIONAL

Science, Technology and Diagnostics in Non-Destructive Testing

Thank you for your attention

Dr/Habil. Anne-Françoise Obaton
Researcher in metrology for Additive Manufacturing (AM)
National Metrology Institute (NMI) in France
Laboratoire national de métrologie et d’essais (LNE)
anne-francoise.obaton@lne.fr

LABORATOIRE NATIONAL DE MÉTROLOGIE ET D’ESSAIS