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X-ray microtomography examination of titanium-niobium-zirconium orthopedic implants prototypes fabricated by laser powder bed fusion

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X-ray Microtomography Examination of Titanium-Niobium-Zirconium Orthopedic Implants Prototypes Fabricated by Laser Powder Bed Fusion

XIX Brazilian Materials Research Society Meeting (XIX B-MRS)

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Introduction

1. Introduction
2. Materials and methods
3. Results
    Tomography
    a. Metrology
    b. Defect detection
    c. Porosity analysis
4. Conclusion

Materials and methods

- Ti-13%Nb-13%Zr alloy orthopedic implants prototypes were fabricated by laser powder bed fusion (L-PBF)
- The alloy powder was produced at IPT, and the prototypes were fabricated at SENAI using a SLM-Cusing M2 machine
- L-shaped implants prototypes were produced with four different machining allowances, to investigate the best fit to the final dimensions and possible effects on porosity
- X-ray tomography was performed at the IPT Mechanical Metrology Laboratory
- Dimensional and geometrical characteristics were analyzed using VGStudio Max, SmartFit 3D and GOM Inspect softwares

Orthopedic implants

Implant

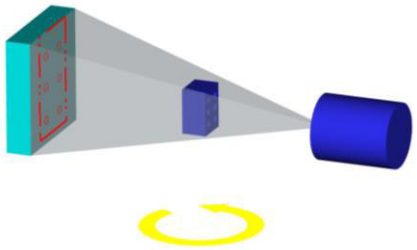
Implant with structural support

Materials and methods

- On a fully protective enclosure, the object to be inspected is rotated in the radiation field of an X-ray source
- For a large number of beam directions, the radiation intensity distribution, after passing through the object, is determined by a flat panel detector, and digitally stored as a projection
- The resulting projections of the full object rotation feed the mathematical algorithms used for reconstructing it

Parameter	Implant 001		Implant 001 (detail)		Implant 003	
	Unit	Value	Unit	Value	Unit	Value
Source Voltage	kV	300	kV	300	kV	300
Source current	µA	200	µA	200	µA	200
Integration time	s	.5	s	.5	s	.5

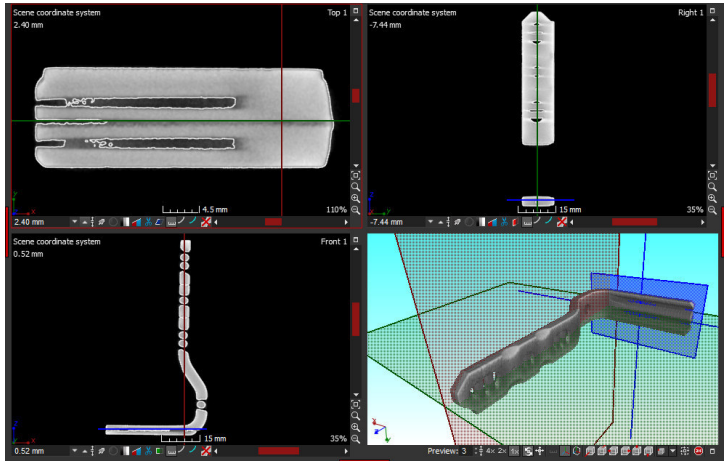
Werth TomoScope HV Compact



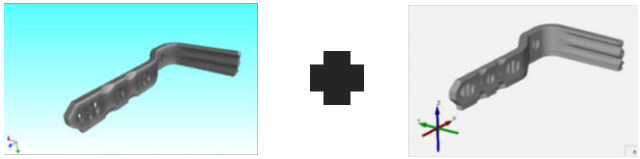
Fundamental principle of a coordinate measuring machine with X-ray computed tomography

Results - tomography

- Tomography of the implants has been performed using 75 micrometers scanning conditions
- Metrological investigation of the four different allowances



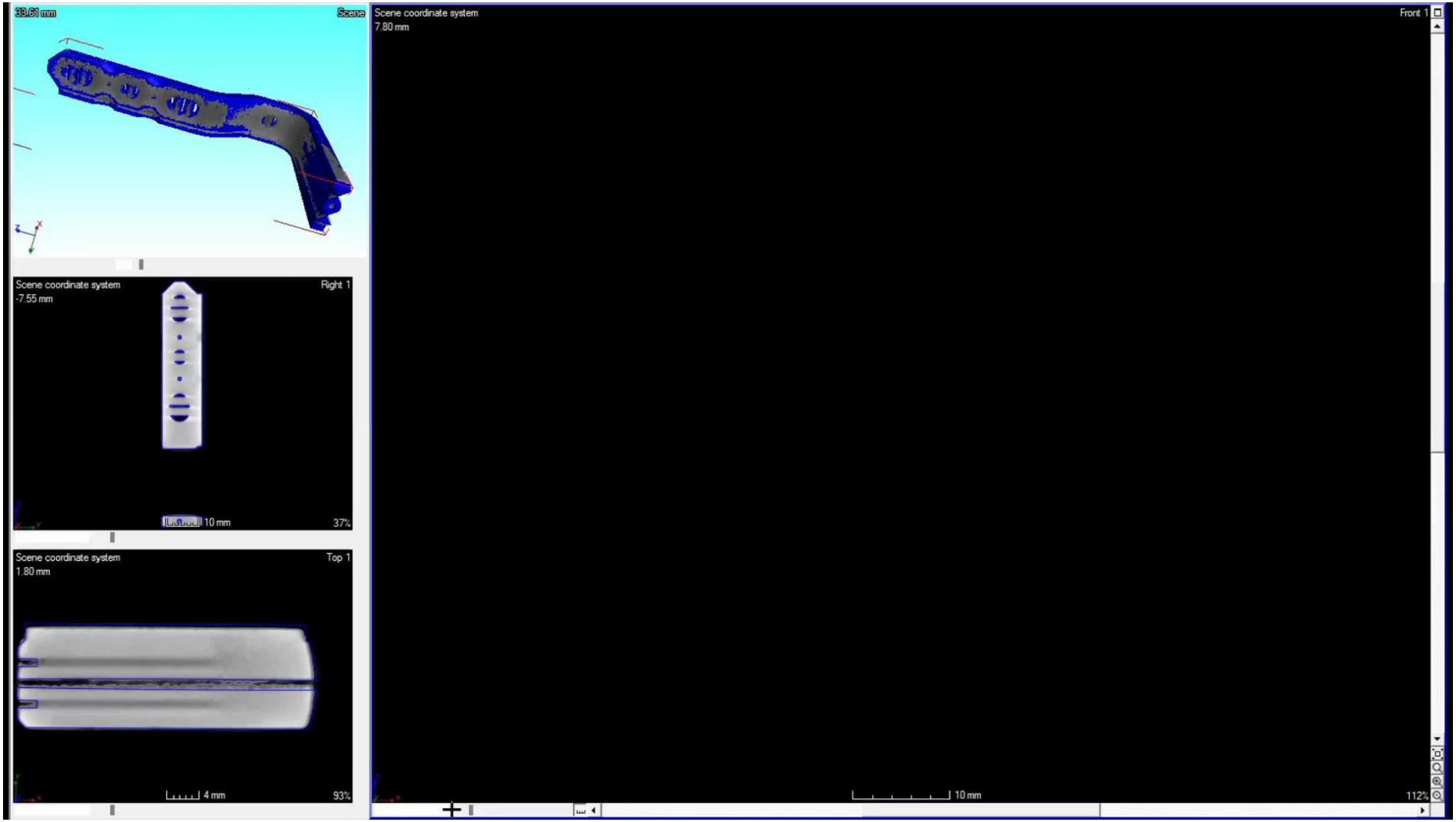
3D Tomography



Comparison of CT-generated point cloud against CAD model

Detail of the fitting

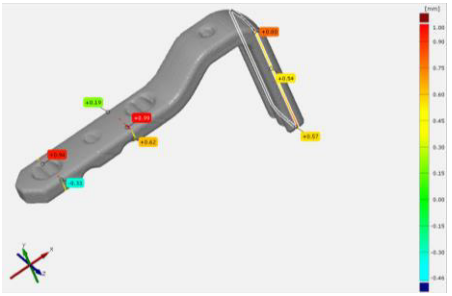
Metrology


39.61 mm
Scene
Scene coordinate system
-7.55 mm
Right 1
10 mm
37%
Scene coordinate system
1.80 mm
Top 1
4 mm
93%
Scene coordinate system
7.80 mm
Front 1
10 mm
112%

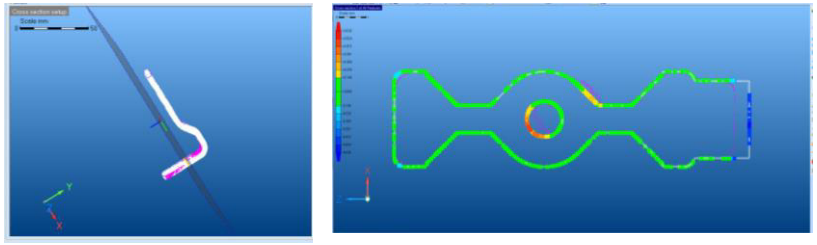
Metrology

- Best fit analysis of the four different allowances
- Examination of inner and outer geometries
- Strategies including cutting planes, in order to analyze 2D planes locally
- 2D and 3D best fitting showed that an allowance equal to .5 mm would be enough for further machining

Implant 001 3D fitting



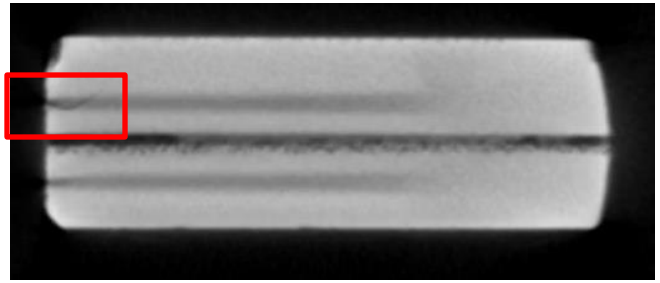
Implant 003 3D Fitting



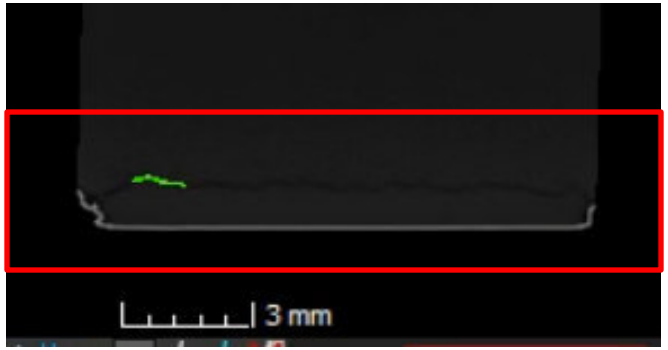
Cutting plane on the basis

Defect

- Non-destructive inspection of implants - detection of discontinuities, cracks, voids without damaging the sample
- Detection and analysis of inner defects
- Critical cracks detected on 0 mm allowance implant



Crack on the basis



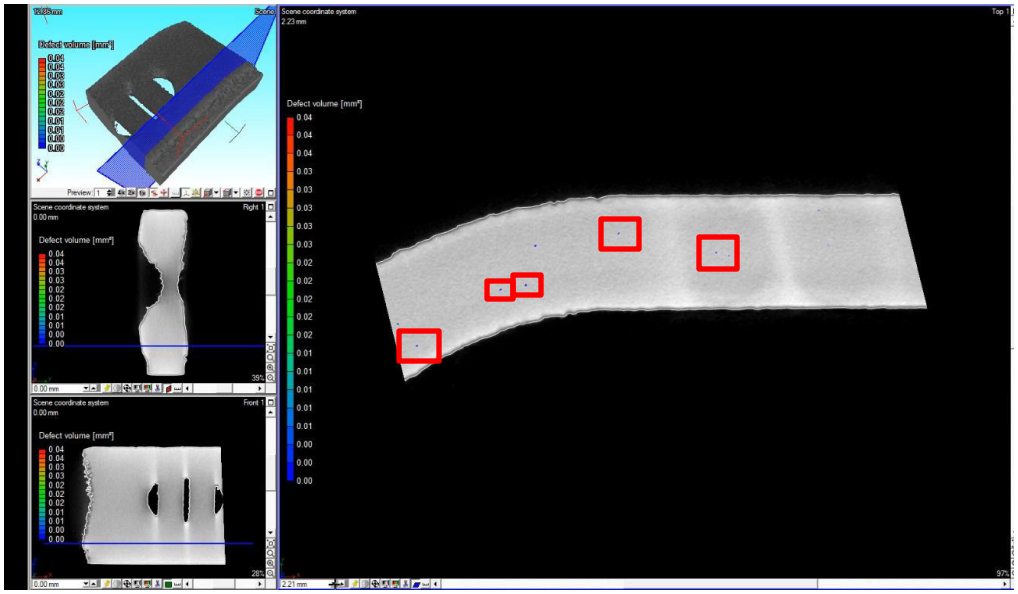
Crack on Region of Interest (ROI)

Porosity

- Region of interest has been scanned with better resolution

- Porosity was investigated using 16 micrometers slicing

- Pores could be detected at both volumetric percentual and diameter estimation of every single pore

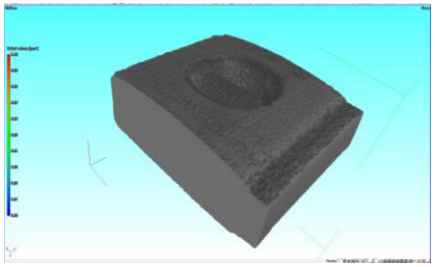


Pores detected on ROI

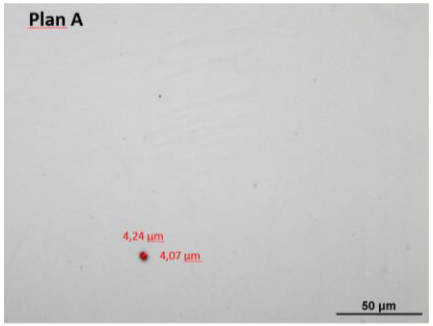
Porosity (%)
.004

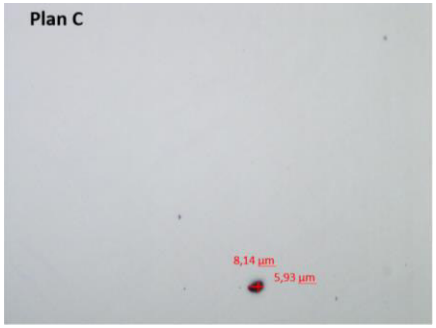
Porosity

- Tomography x optical microscopy comparison
- Results showed the complementarity between tomography and optical microscopy



Region of interest





Optical microscopy

	Optical microscopy	Tomography
Nº of pores	153	494
Porosity (%)	.0181	.0007
Diameter (µm)	3	23

Conclusion

- X-ray CT produces information about hidden structures of the sample, such as ***cracks*** and ***voids***

- Metrology (***measurement*** and evaluation ***of features***) analysis showed that an allowance starting from .5 mm would be enough for further machining

- Effective region of interest (***ROI***) of object scanned with better discrimination (16 μm). Cracks has been detected on 0 mm allowance implant. The ***porosity*** of the implant was estimated in the range of about 20 micrometers

- Entire examination of inner and outer geometries, defect and porosity analysis of implants in a non-destructive manner presented and discussed in this work

Seu desafio é nosso.

Thank you for your kind attention!

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