FT2025
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Characterization of fatigue-critical roughness parameter in electron beam powder bed fusion manufactured Ti-6Al-4V

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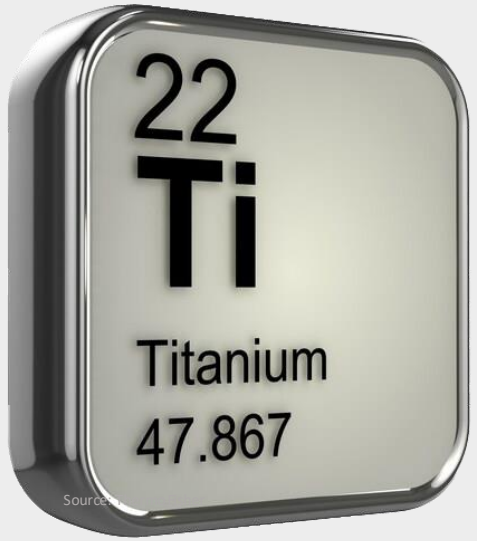
ADDITIVE INNOVATION AND MANUFACTURING

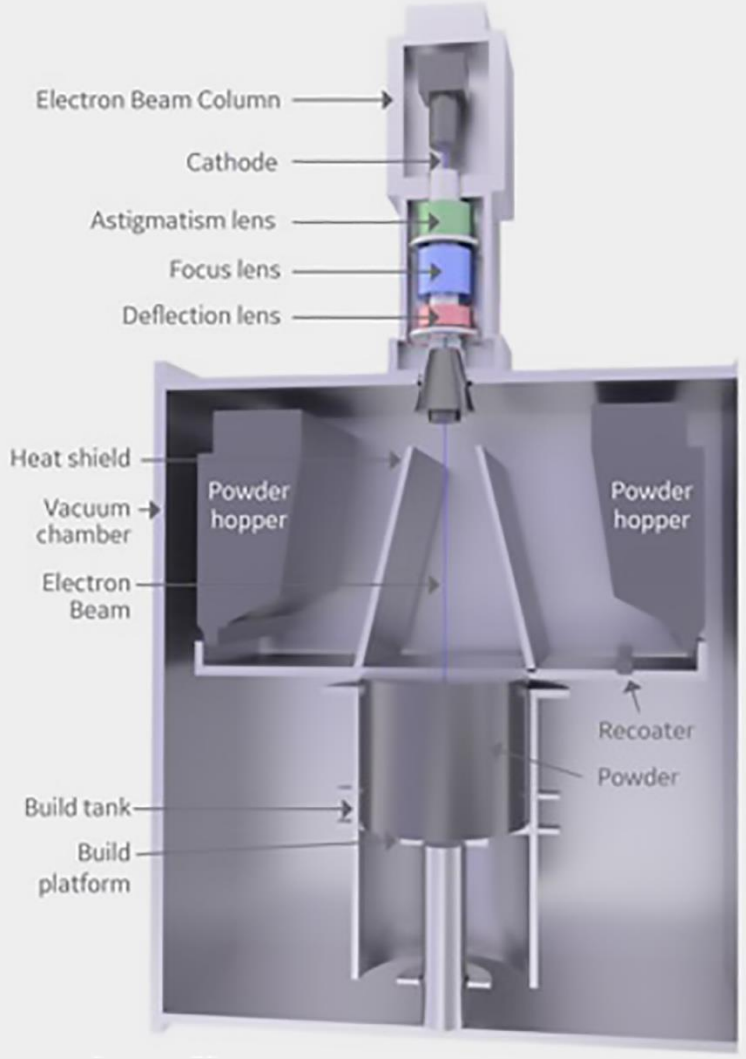
Outline

1. Introduction
2. As-built surface investigation
   - Method
   - Results
3. Summary

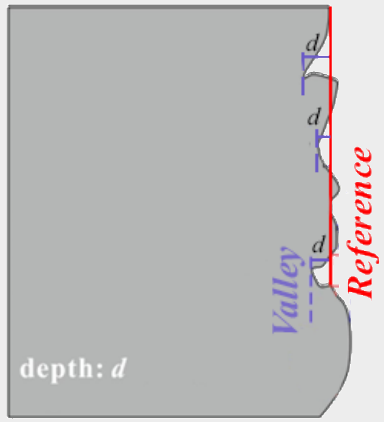


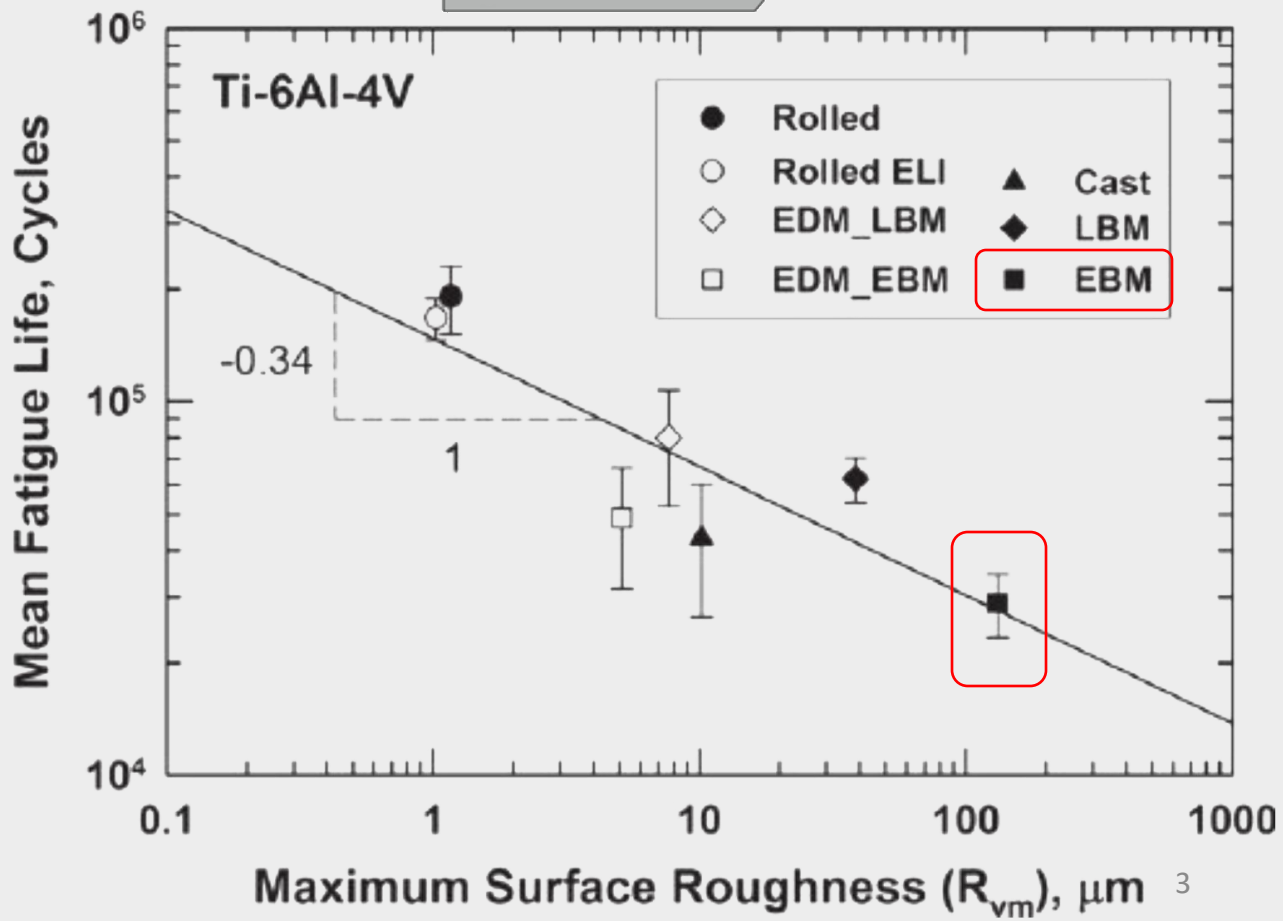
1. Introduction

Background and motivation



Source: GE





Source: DOI 10.1088/2051-672X/3/4/044006

Research Question

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As-built surface investigations

- How does the PBF-EB as-built surface roughness affect the fatigue properties in Ti-6Al-4V?

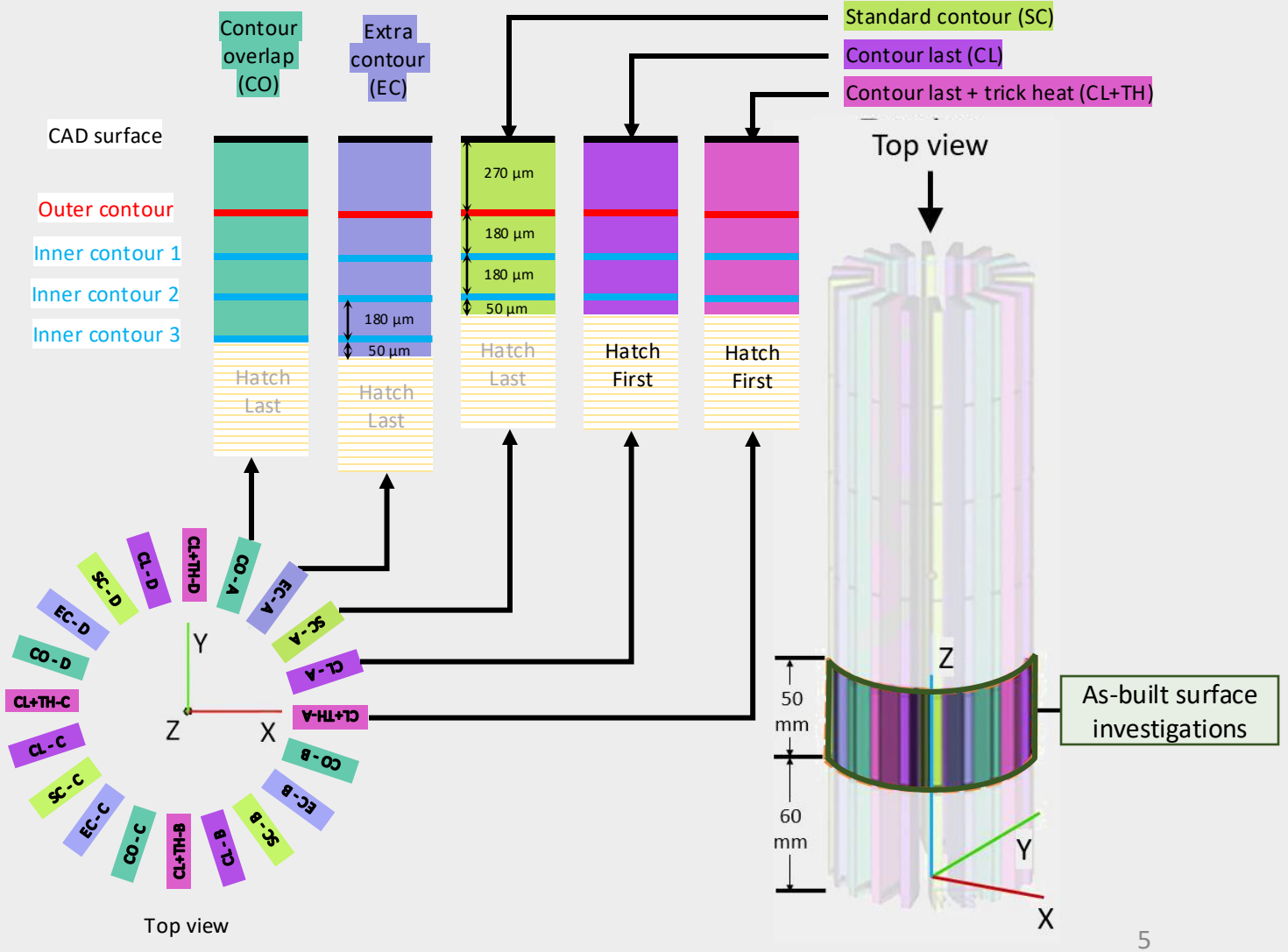
Method

Process parameter

Key process parameter for melt theme : 5.2.24

- 90 µm layer thickness.
- Plasma-atomized Ti-6Al-4V powder with 45–106 µm particle size distribution.
- No post-heat treatment.

Arcam Q20 plus PBF-EB machine



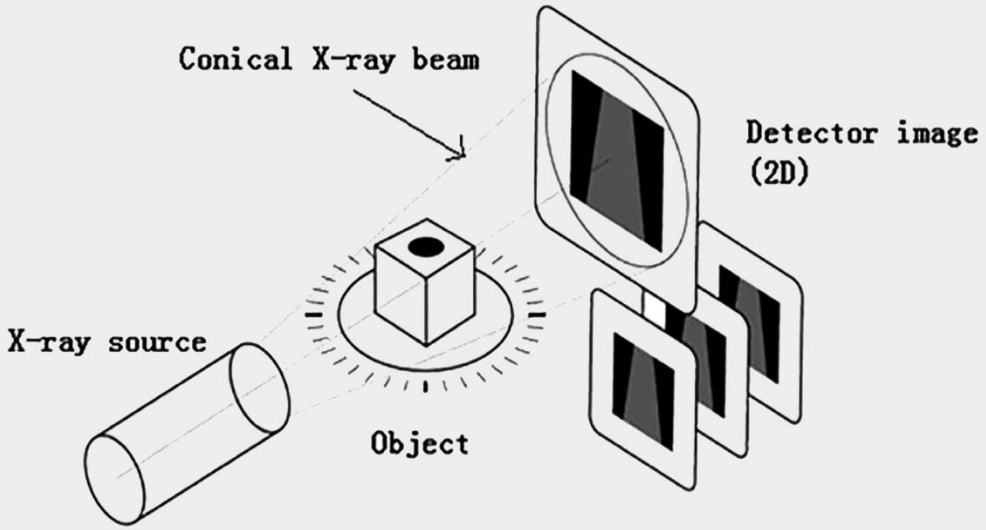
Method

Material characterization

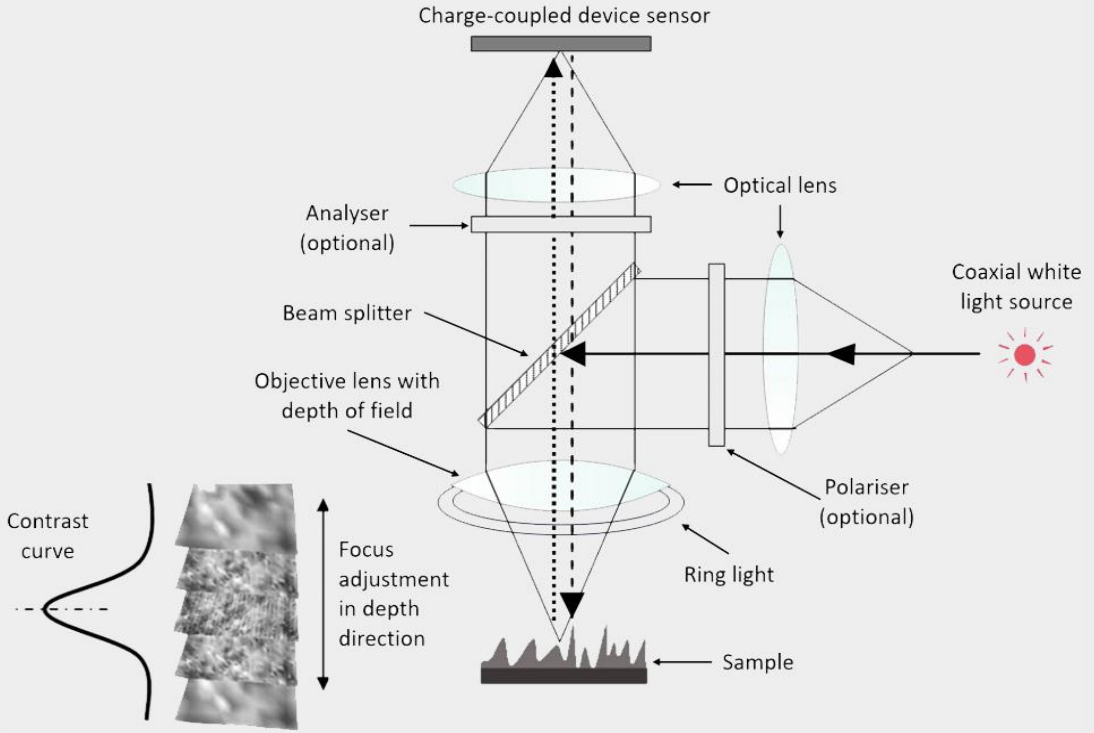
Surface characterization:

- Focus variation microscopy (FVM).
- X-ray computed tomography (XCT).
- Surface texture filtering per ISO 25178-2.

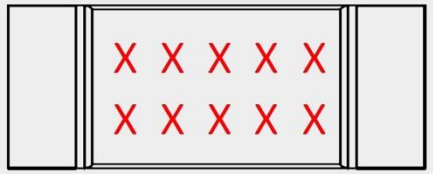
Schematic - XCT



Schematic - FVM



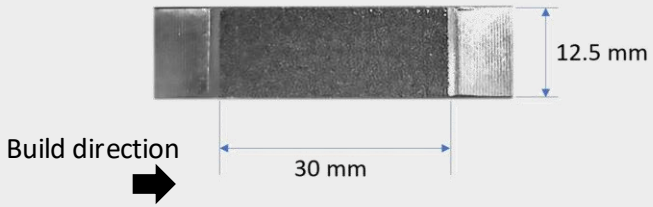
Four point bend specimen



Method

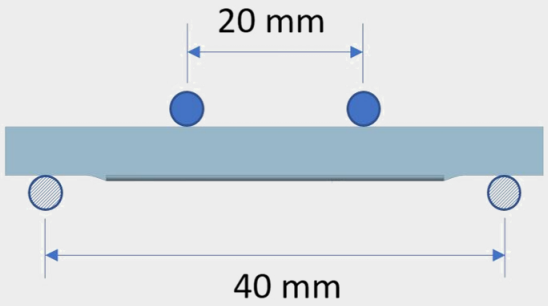
Fatigue properties

Four point bend test



σ_{max} = 591 Mpa
σ_{min} = 59.1 Mpa

R = 0.1



FCG data

Modified HIP FCG data tested at R = -1

Walker equation

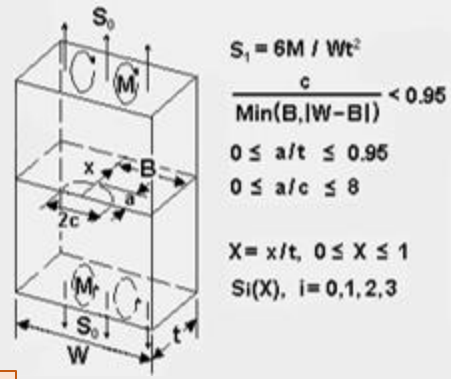
$$\frac{da}{dN} = C(\overline{\Delta K})^m = C\left(\frac{\Delta K}{(1-R)^n}\right)^m$$

n = 0.9 for R < 0
n = 0.5 for R > 0

Corrected R = 0.1

Fatigue life predictions

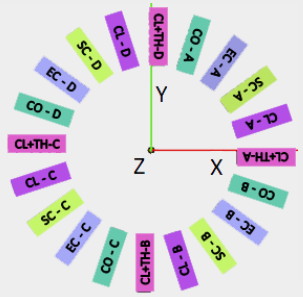
SC30



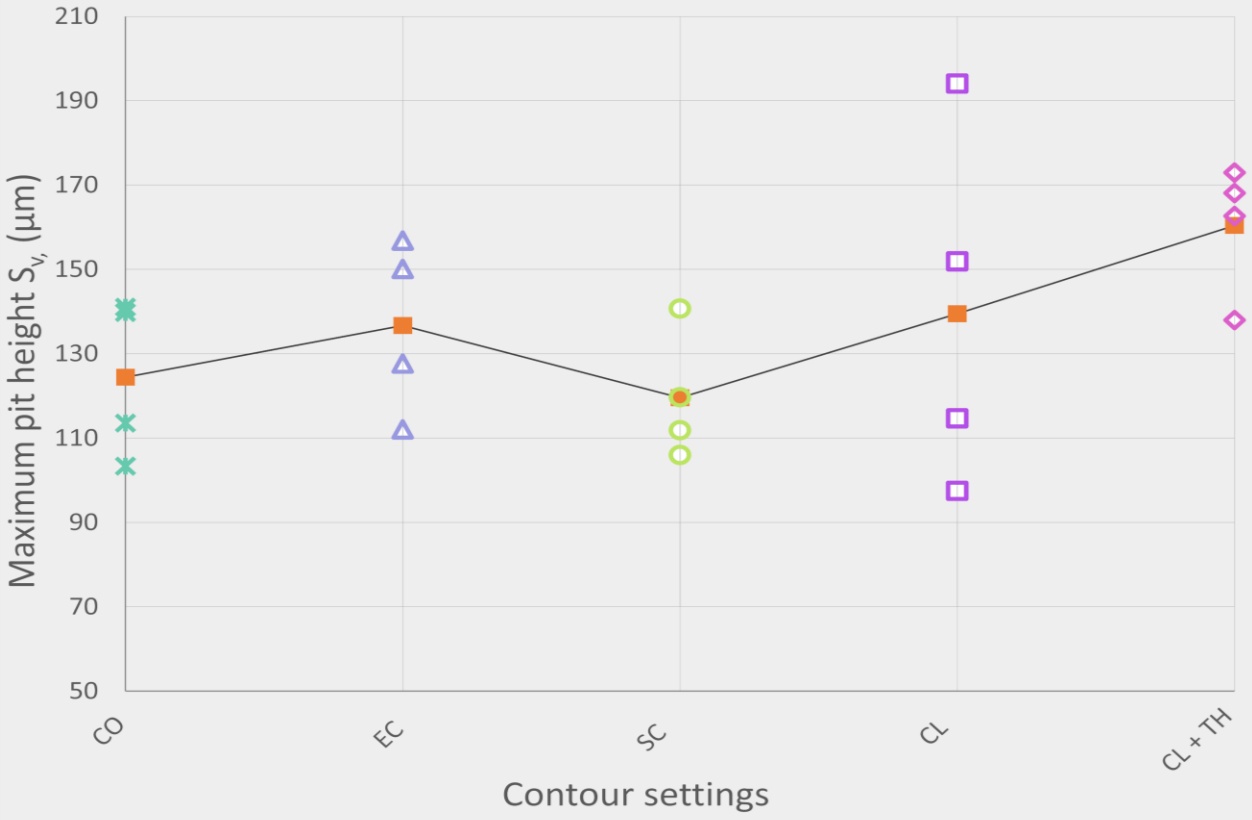
Pandian K, Neikter M, Bahbou F, Ganvir A, Hansson T, Pederson R. Fatigue behavior of low-temperature hot isostatic pressed electron beam powder bed fusion manufactured Ti-6Al-4 V, Journal of Alloys and Compounds, Volume 962, 2023, 171086, ISSN 0925-8388, https://doi.org/10.1016/j.jallcom.2023.171086.

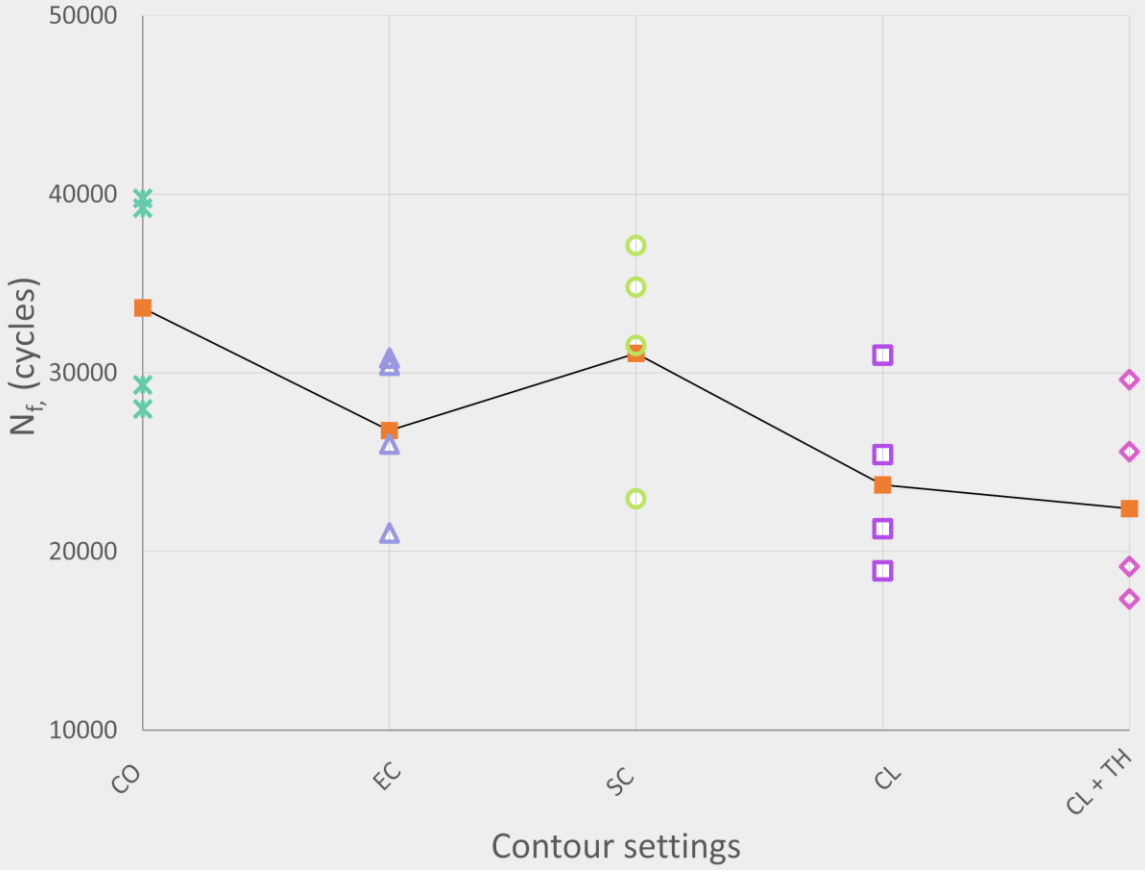
Results

Maximum pit height and fatigue life



Contour overlapping hatch
Extra contour
Standard contour
Contour last
Contour last+trick heat
Arithmetic mean
Log-normal-mean





Results

Areal roughness height parameters

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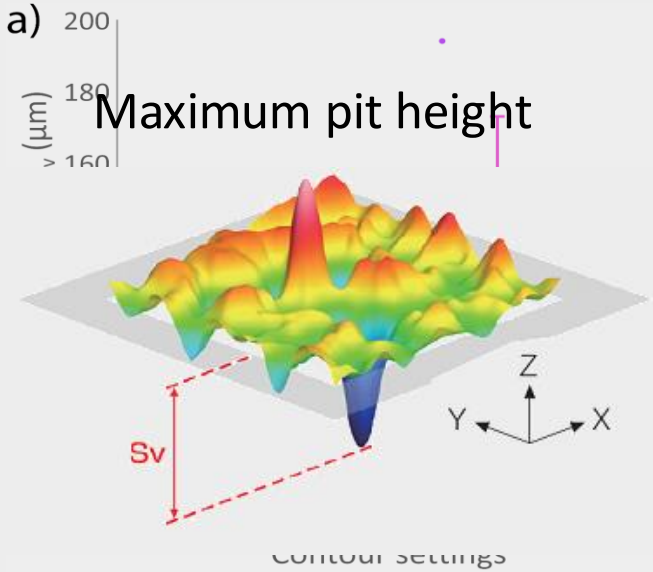
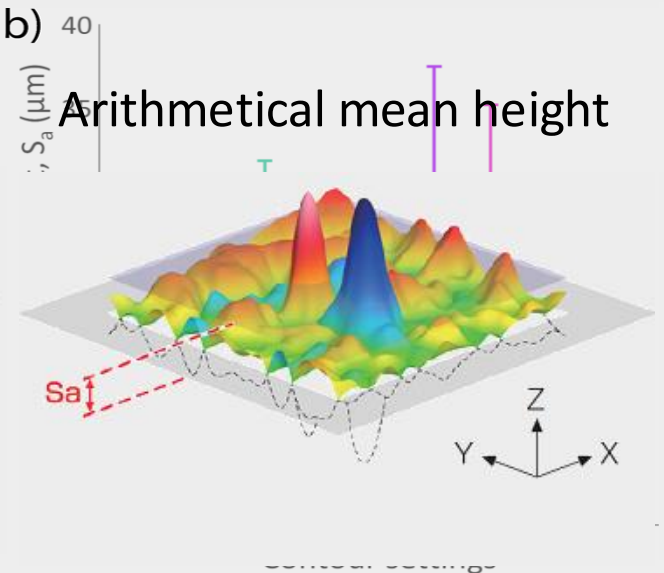
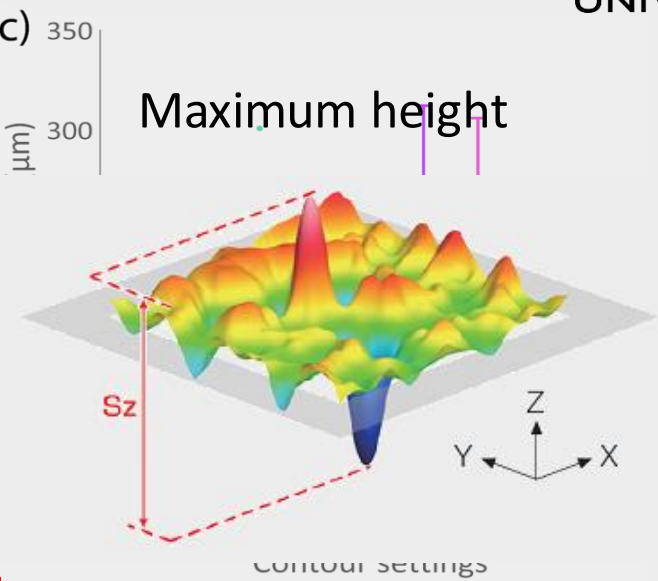
a) Maximum pit height

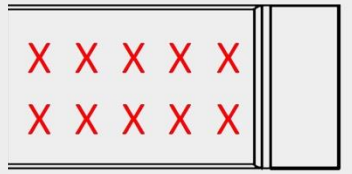


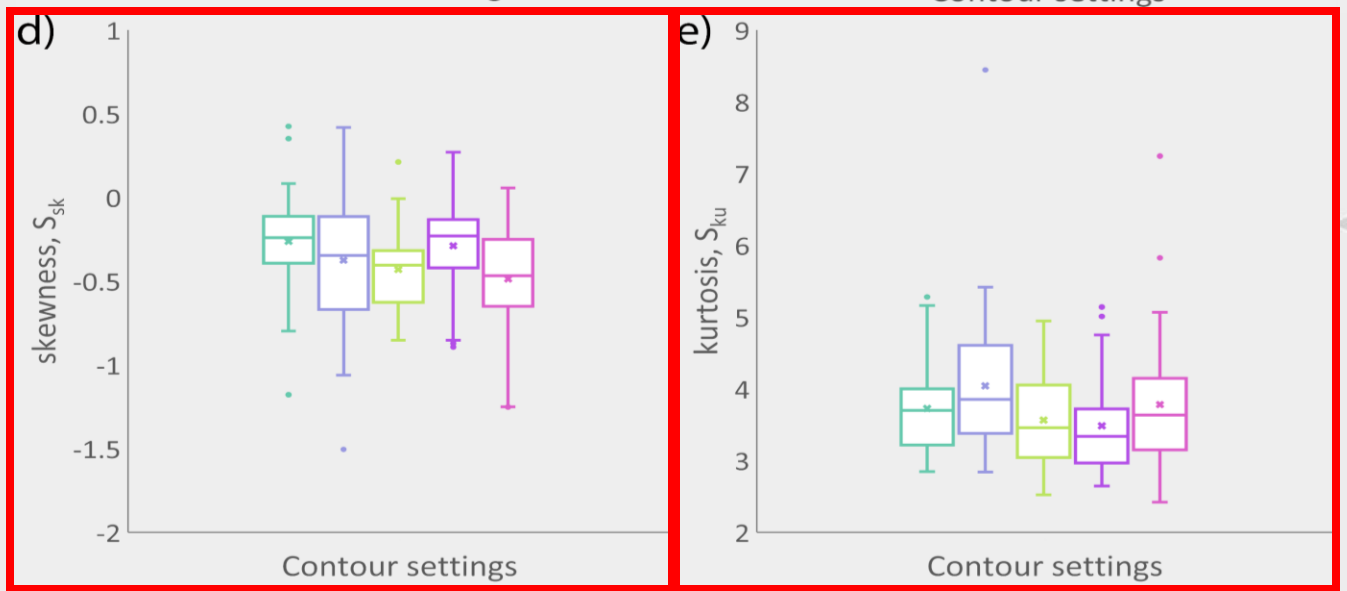
b) Arithmetical mean height



c) Maximum height

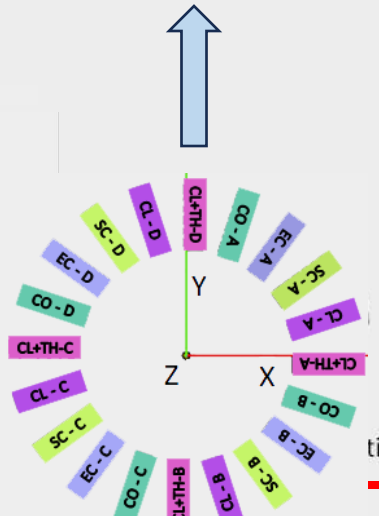






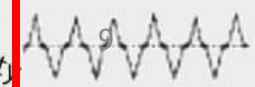
K

- Contour overlap (CO)
- Extra contour (EC)
- Standard contour (SC)
- Contour last (CL)
- Contour last + trick heat (CL+TH)



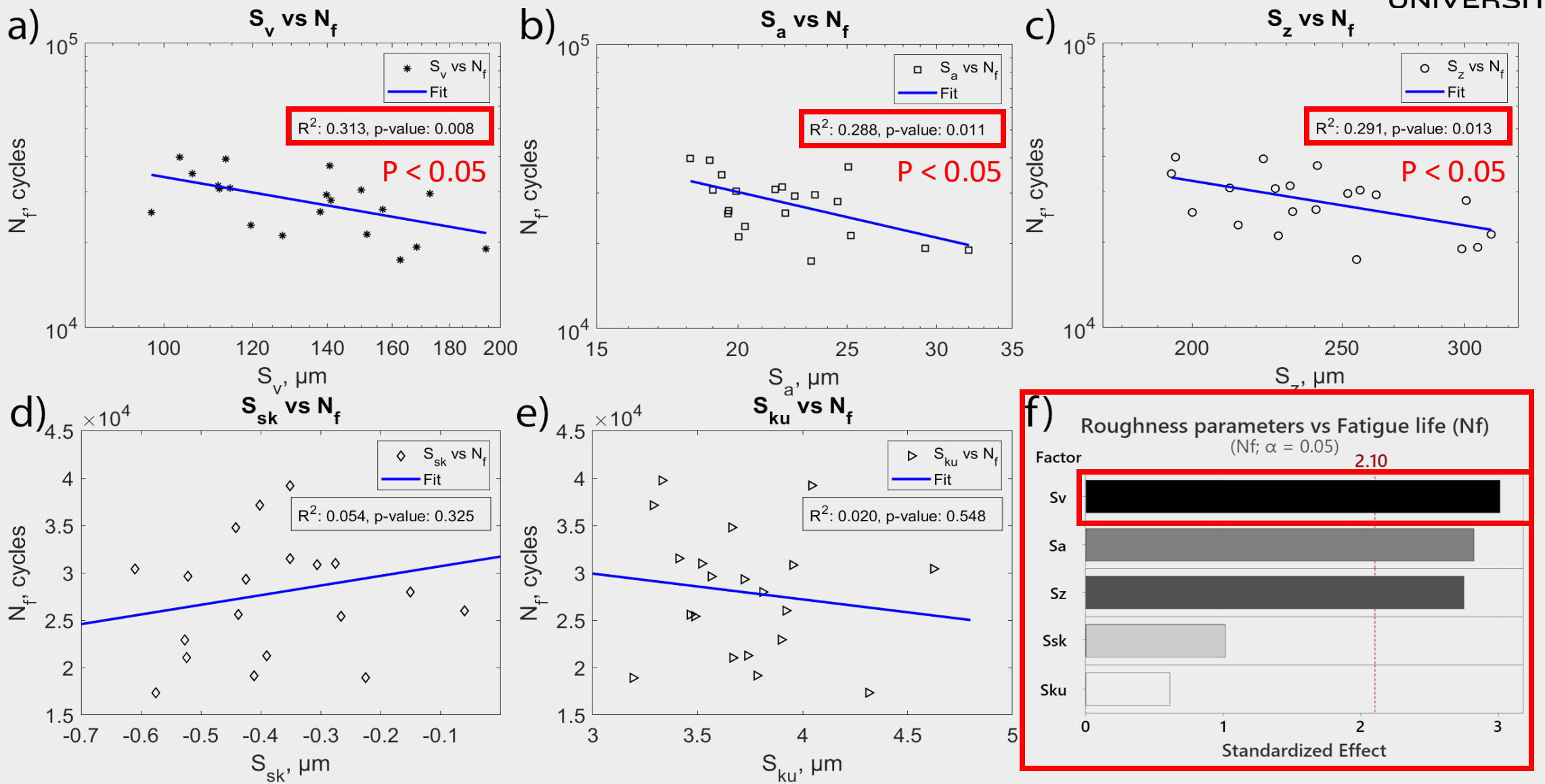
tion)

Sharp



Results

Effect of roughness parameter on fatigue



Results

Fractography

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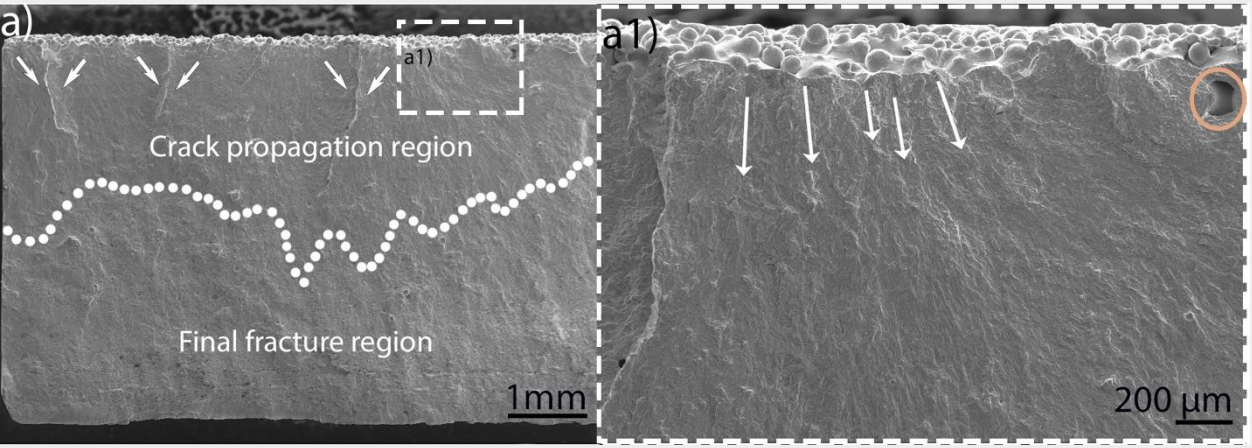
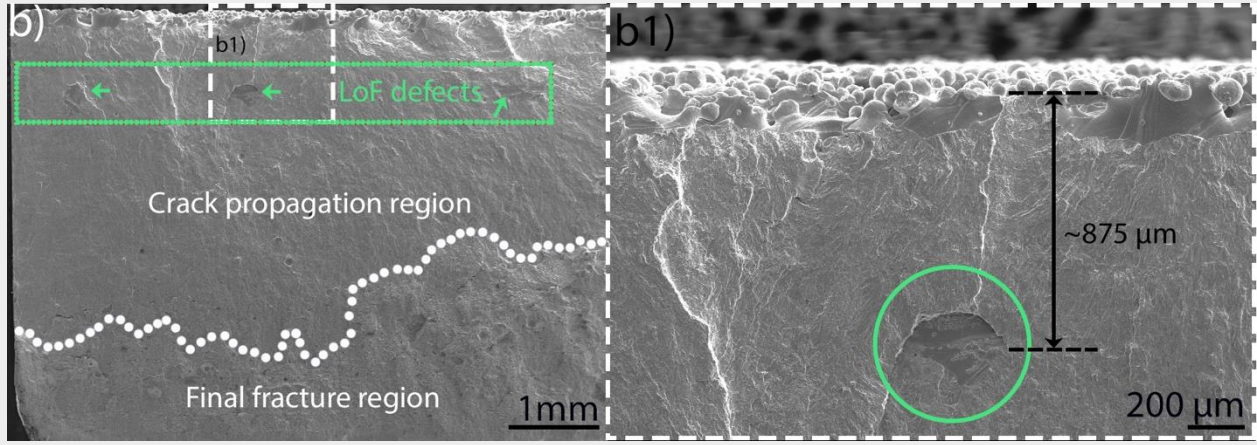
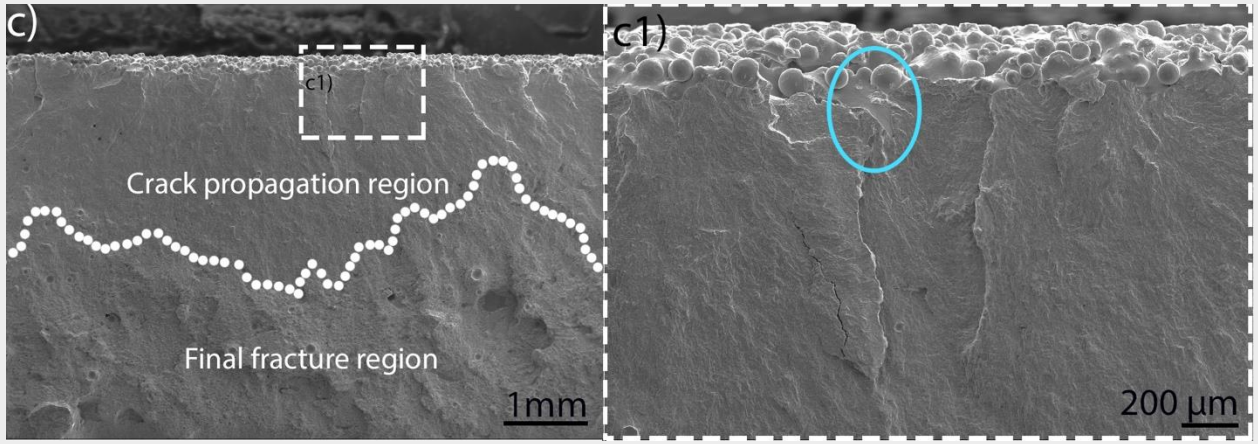
Low life - 17350 cycles



Medium life – 30987 cycles

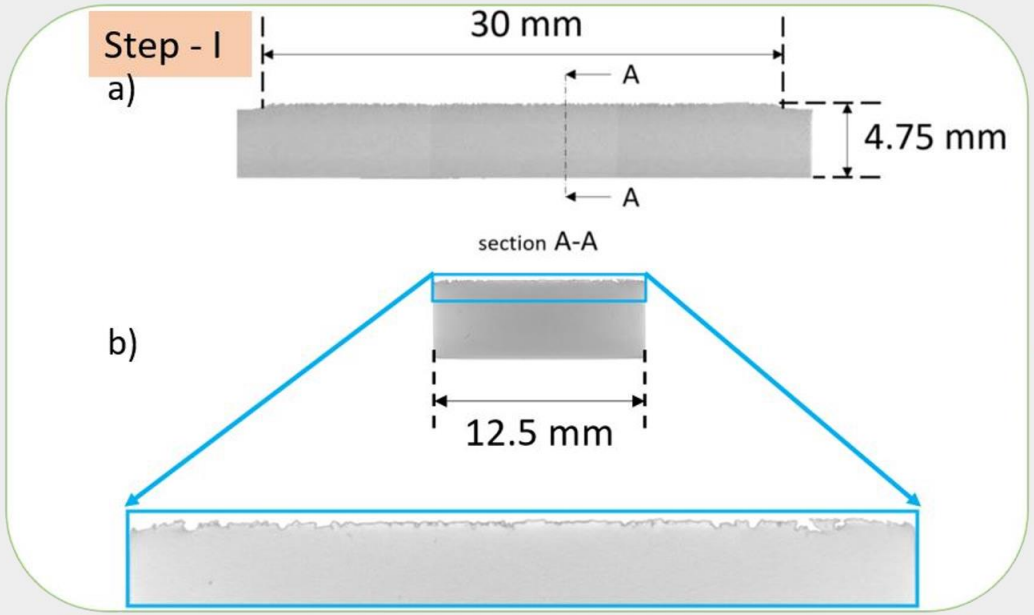


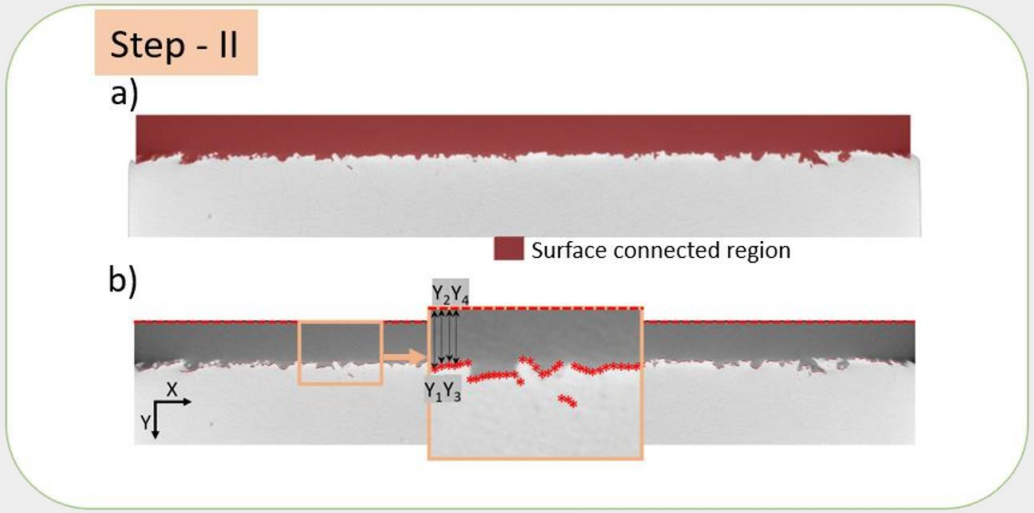
High life - 39761 cycles

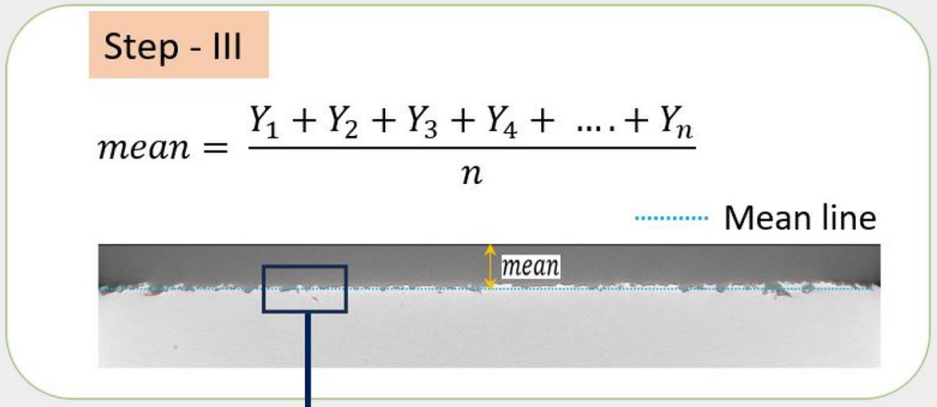


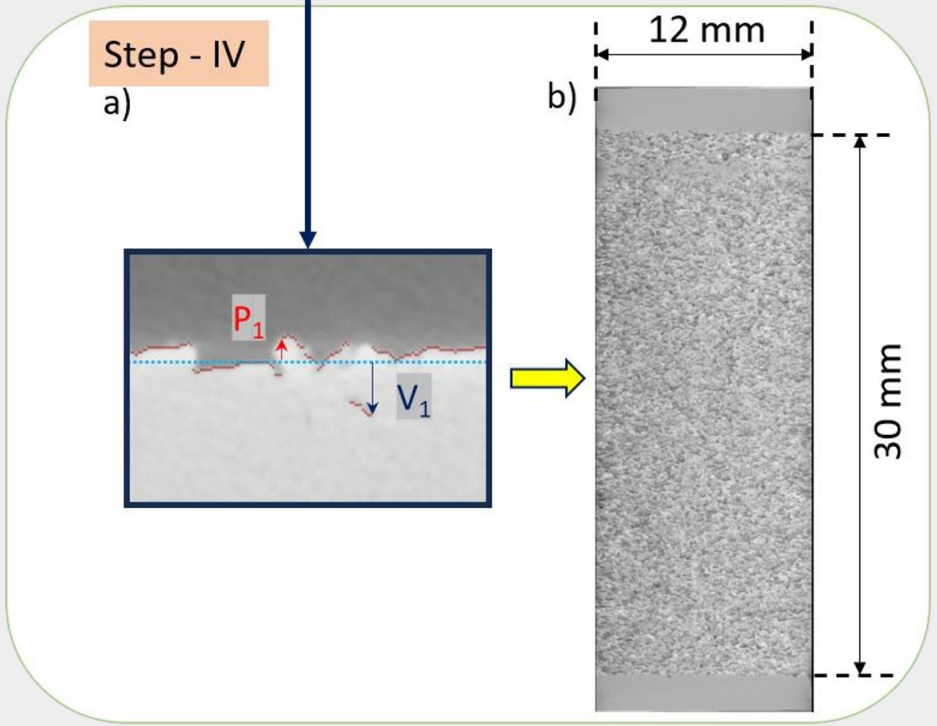
Results

Post-processing XCT data



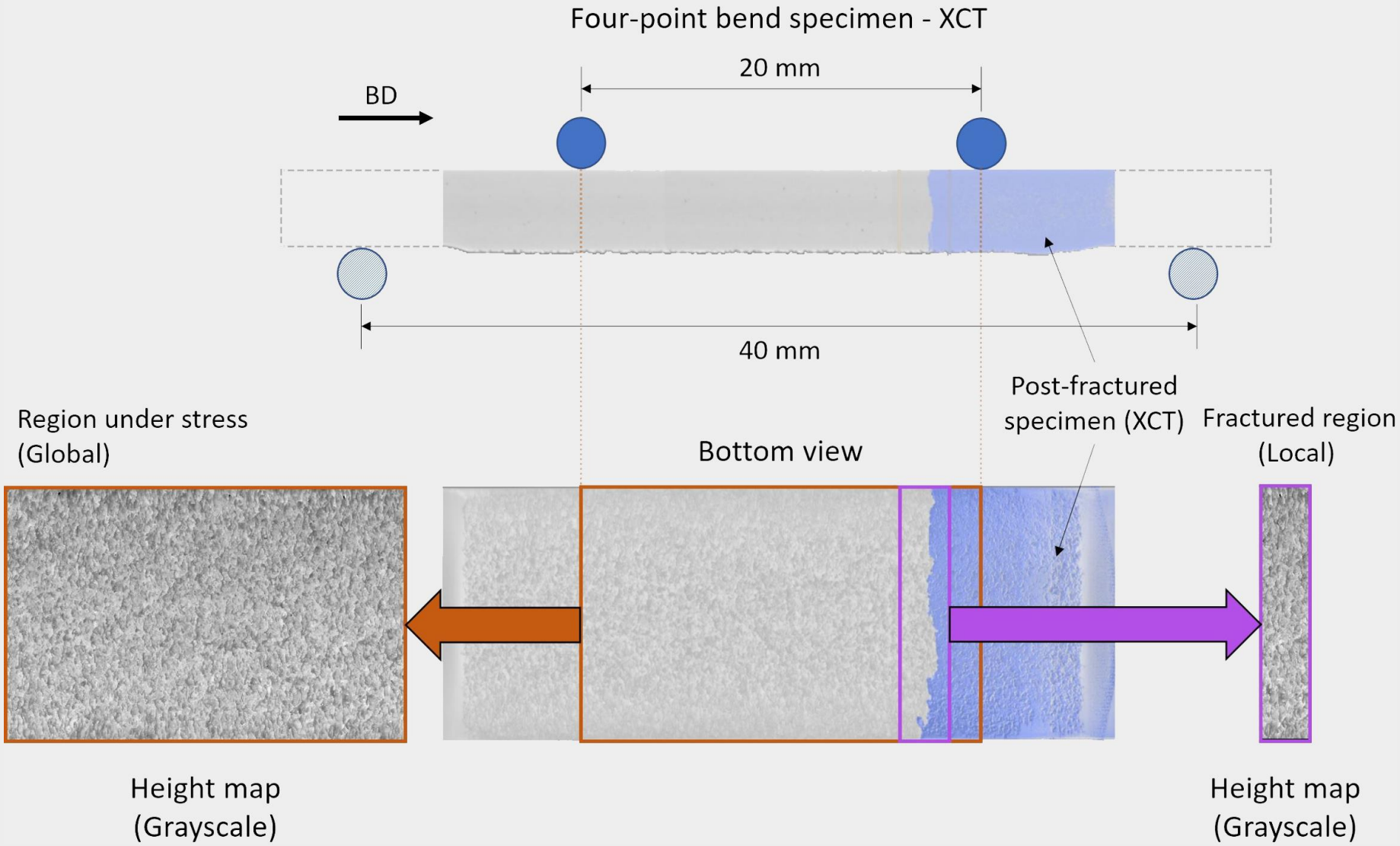






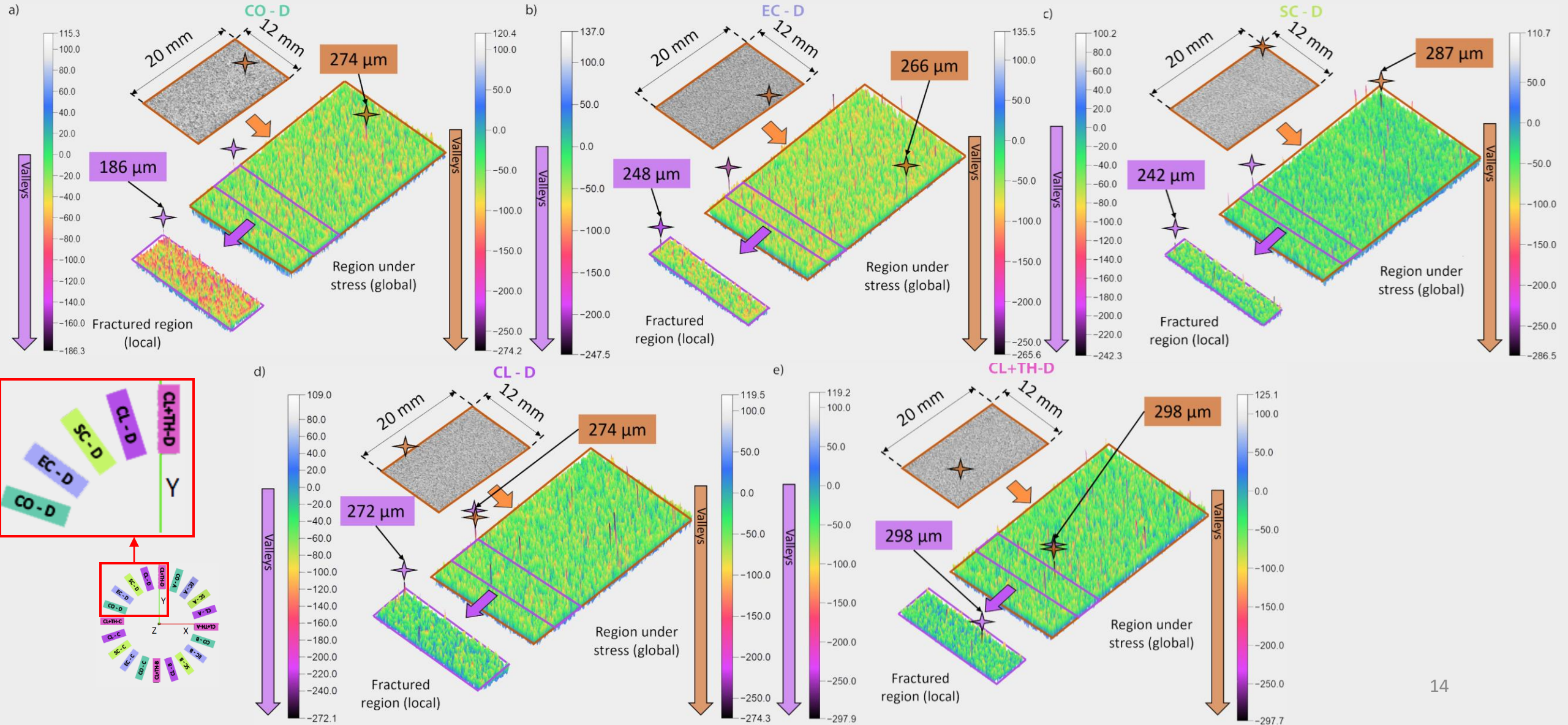
Results

Post-processing XCT data



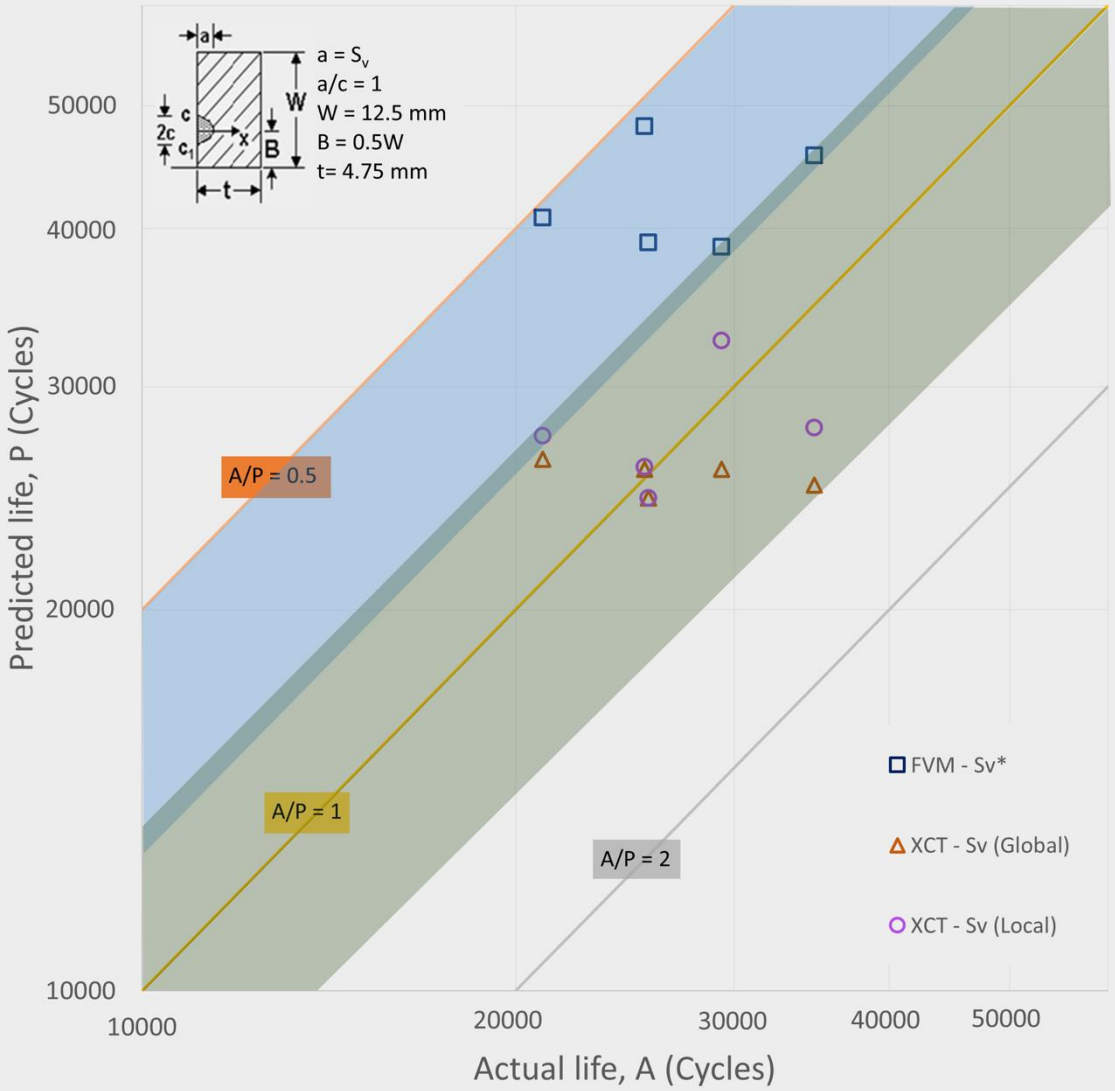
Results

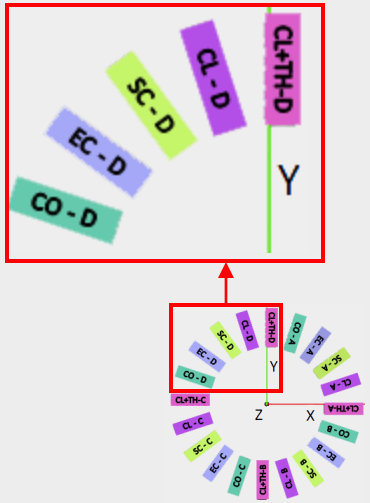
XCT based S_V



Results

Estimation of fatigue life





Specimen ID	Actual cycles to failure (A)	Initial defect size a (µm)		
		FVM S_v *	XCT S_v (Global)	XCT S_v (local)
EC – D	21043	128	266	248
CL – D	25421	97	274	272
CL+TH – D	25587	138	298	298
CO – D	29323	140	274	186
SC – D	34800	106	287	242

3. Summary

- Melting the contours before hatch showed a trend of reduced surface roughness. However, it is challenging to observe a significant effect due to the large scatter in the data.

- Maximum pit height (S_v) roughness parameter was found to be statistically significant in affecting fatigue life.

- Hidden surface-connected valley features revealed from XCT data resulted in a more conservative life predictions than estimating life using the FVM-based data.

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Thank you for your attention!