Direct Experimental Evaluation of High-cycle Fatigue Indicator Parameters in Nickel-Titanium Shape Memory Alloys

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Acknowledgements

- Resources provided by Confluent Medical Technologies, Inc.
- This work is based upon research conducted at the Center for High Energy X-ray Sciences (CHEXS) which is supported by the National Science Foundation under award DMR-1829070.

- Justin Gilbert (Confluent)
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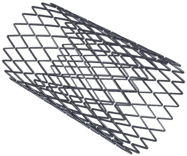
- Lot Vien (Confluent)

- Medical devices: Cyclic deformation due to cardiac rhythm.



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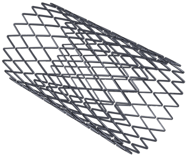

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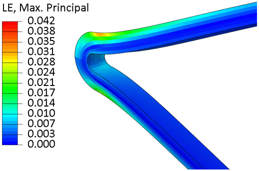

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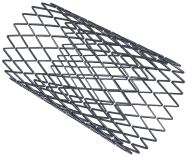
- Deformation descriptors: mean strain ($\varepsilon_{\text{mean}}$) and an alternating strain amplitude ($\varepsilon_{\text{amplitude}}$) or mean phase transformation volume (ν_{mean}) and phase transformation volume amplitude ($\nu_{\text{amplitude}}$).
- Device design: Optimize, such that the fatigue indicators are within fatigue-safe envelope.



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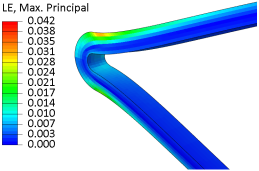

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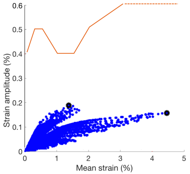

Figure 3: Strain cloud with fatigue-safety envelope.[2]

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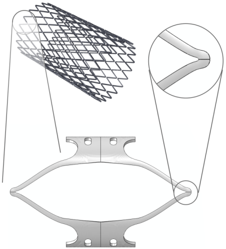
- Objective 2: By fusing DIC results with X-ray diffraction characterization, distinguish mechanisms between low-cycle and high-cycle fatigue.

DIC to Characterize Cyclic Deformation in NiTi

- Diamond specimen geometry.



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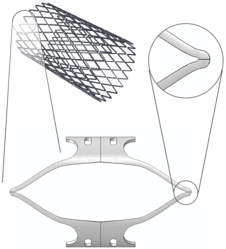

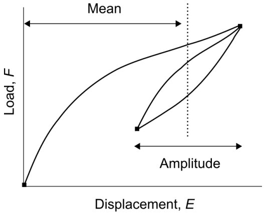

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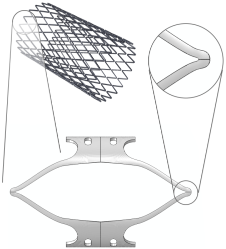

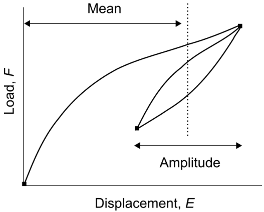

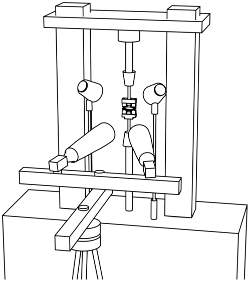

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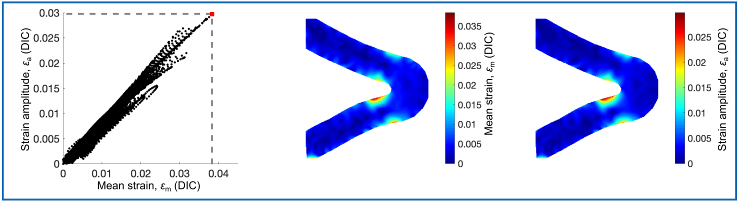

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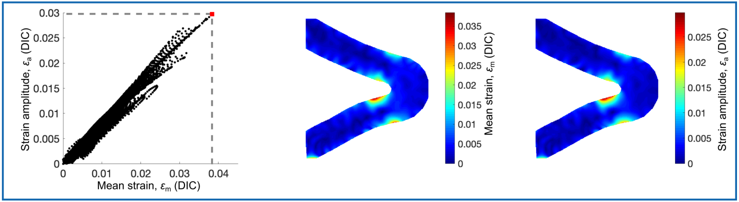
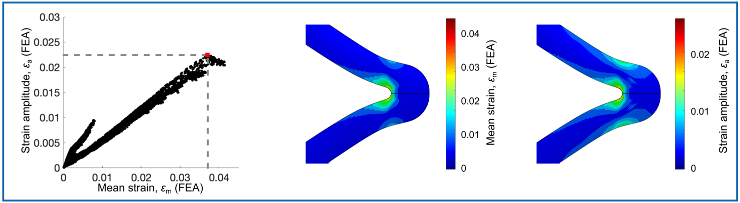


FEA



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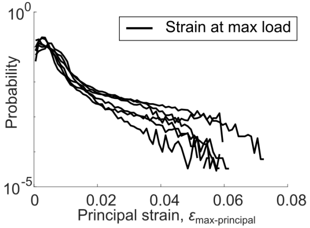
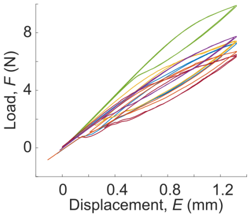
- Specimens in reality show a variability in deformation due to small differences in geometry, BC, material properties.
- DIC-based approach naturally captures this.





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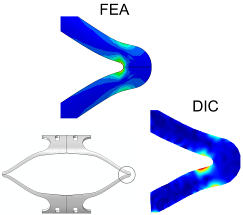

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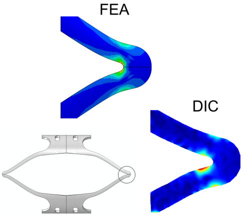

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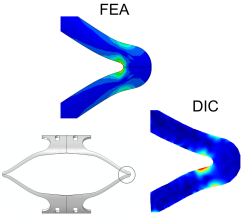

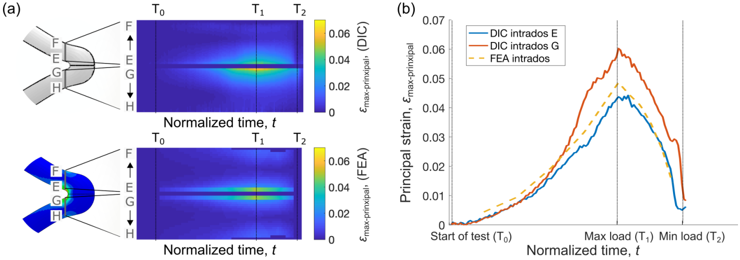

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- Approx. 30 BCs spanning typical strain ranges in medical implants.

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- Strain map: Fatigue life as a function of mean strain and strain amplitude.

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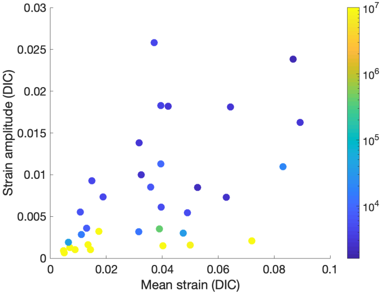

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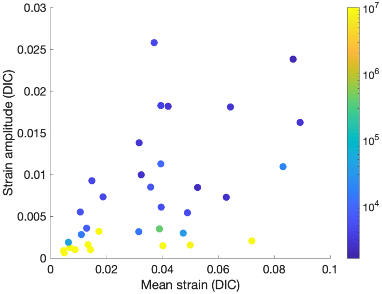

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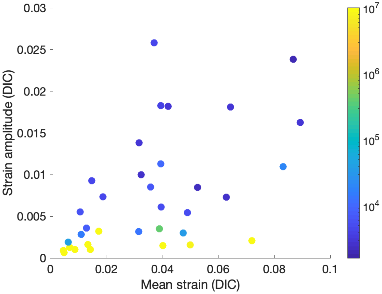

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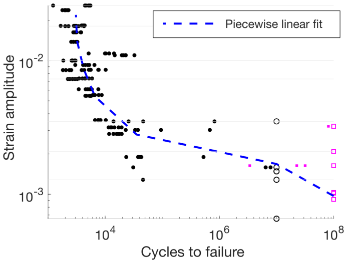

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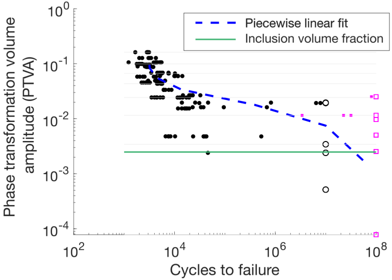

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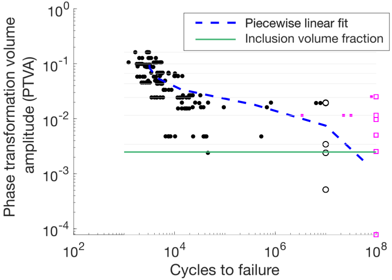
- PTVA at which the response transitions from low-cycle to high-cycle → Connected to the volume density of non-metallic inclusions.



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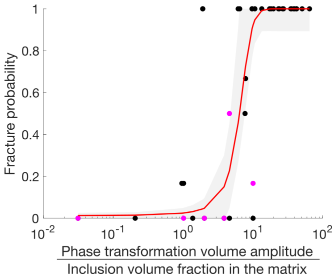
DIC + Fatigue Results: Fracture Probability

- More volume swept by the phase transformation domain → Larger fracture probability.



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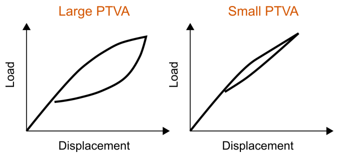

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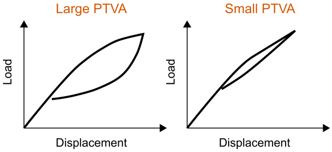

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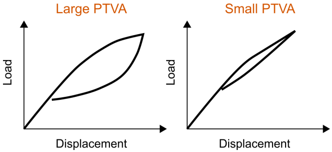

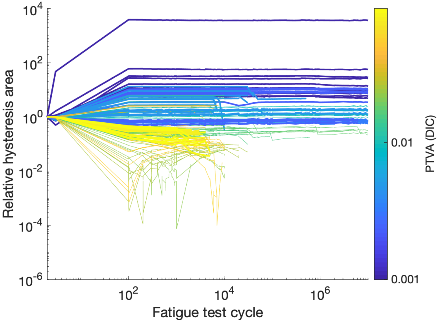

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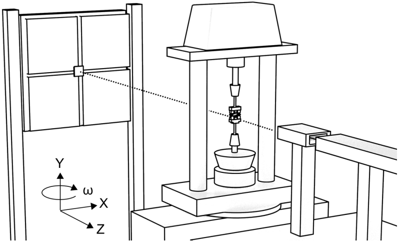

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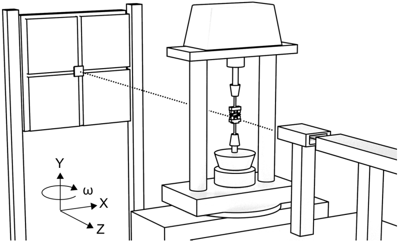

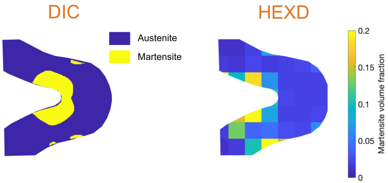

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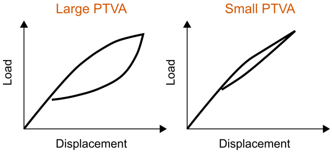

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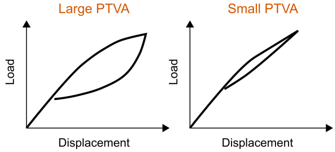

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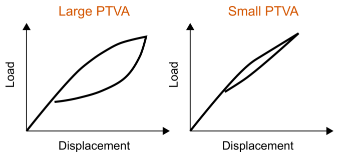

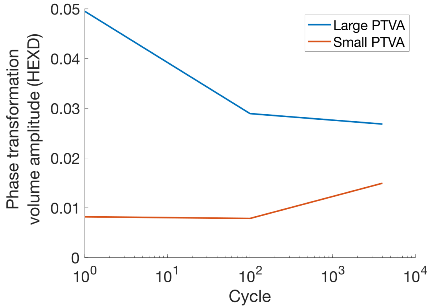

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- PTVA evolves distinctly in low-cycle and high-cycle regime.
- This insight will be used to develop a microstructure model for fatigue life in NiTi based on inclusion population details and PTVA specific to a device geometry.

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Thank you

https://bit.ly/smst2022

Fatigue Mechanisms in NiTi

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harshad.paranjape@confluentmedical.com

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