Simulation of Additive Manufacturing Processes SLS and Fatigue Damage Model

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SLS simulation & Fatigue Damage Model

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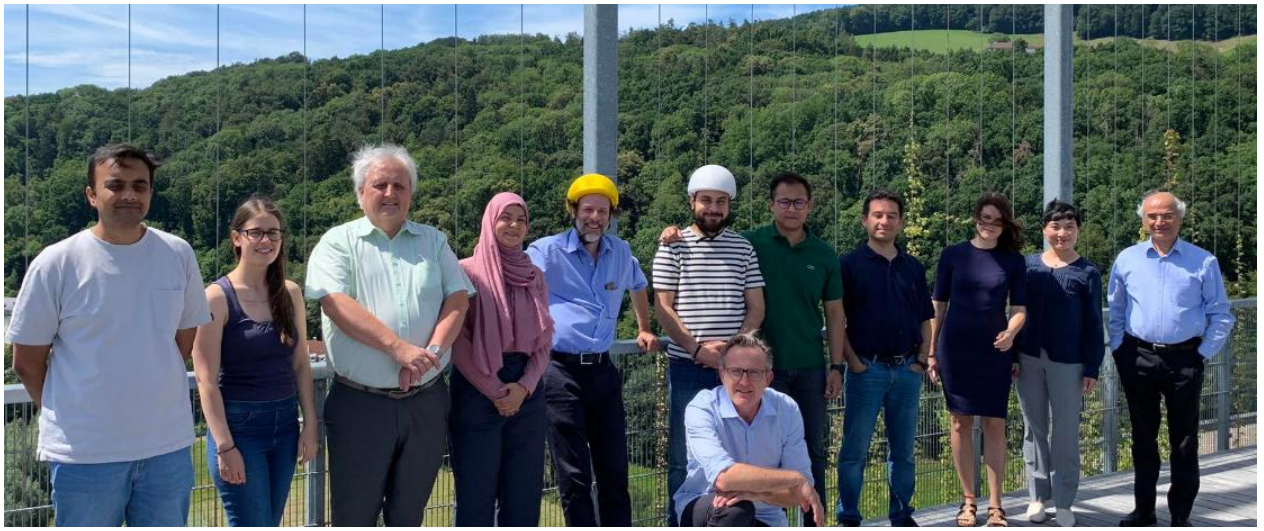
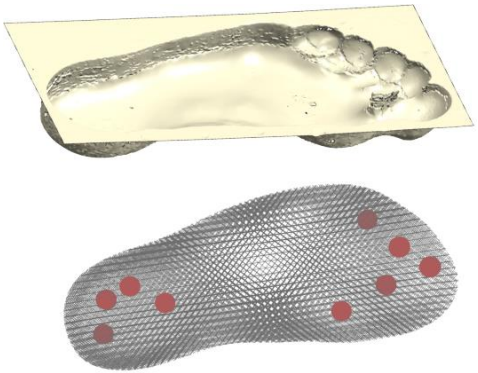
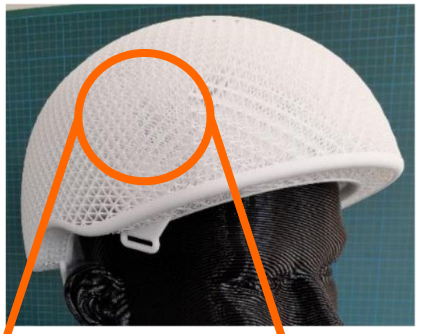
Multi-scale **O**ptimisation for **A**dditive **M**anufacturing of fatigue resistant shock-absorbing **M**eta**M**aterials

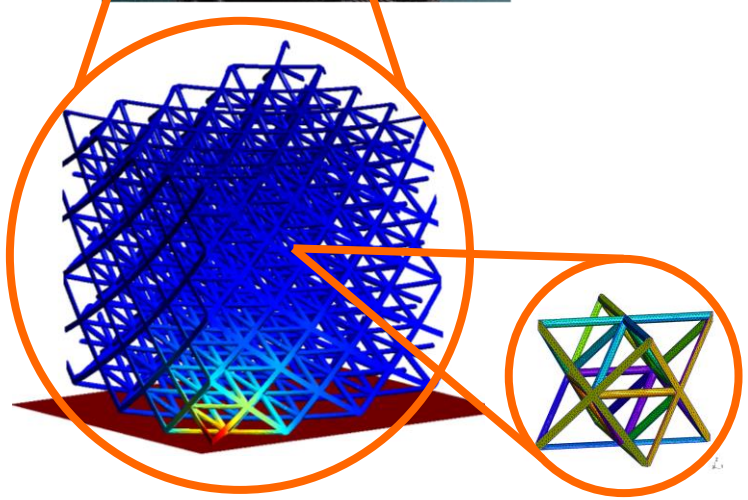


SLS simulation & Fatigue Damage Model

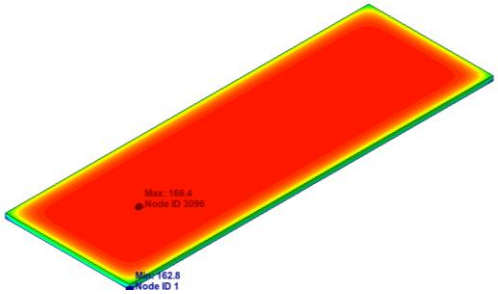
- Applications :



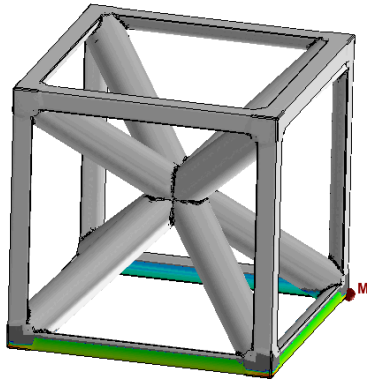




- Existing tools :
  - Python/C++ : CM3 Code - ULiège
  - Commercial : Digimat



Thermal coupling



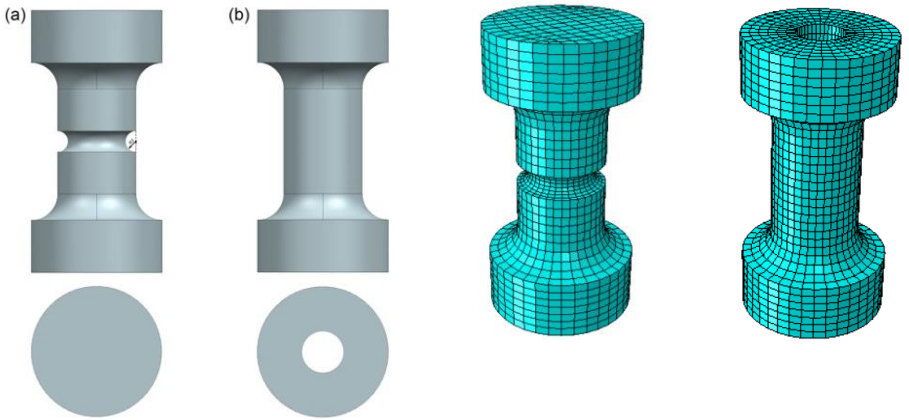
Effect on the geometry

- Scientific investigations :
  - Behavior : VEVP law, identification
  - Multi-scale : MS description, Buckling
  - Coupling : Thermo-mechanical
  - **Fatigue : Damage for HCF**

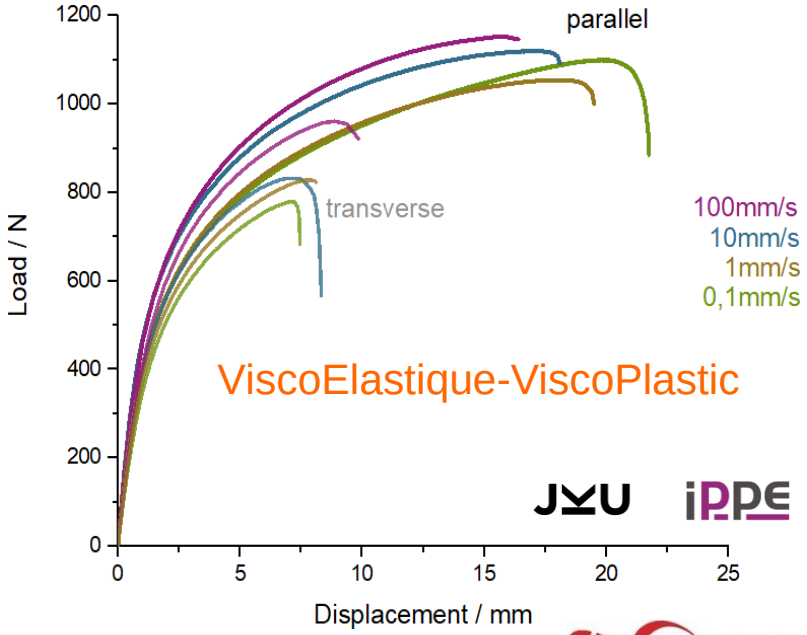
Outline

- Experimental results : fatigue tests
- Model for fatigue and computational framework :
  - Multi-scale strategy : why ?
  - VE structure for strain history : LCT
  - VE-VP local for stress history : Time-homogenization
  - Fatigue model for high cycle fatigue
- Comparison

Experimental results : fatigue tests



tension tests : material properties

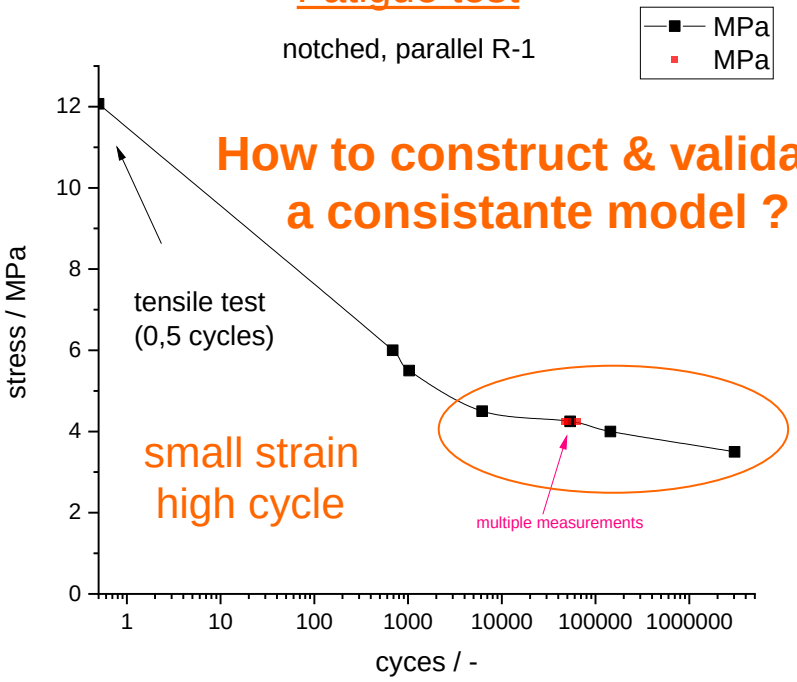


ViscoElastique-ViscoPlastic

JKU iPPE

Identification with Digimat

Fatigue test



How to construct & validate a consistante model ?

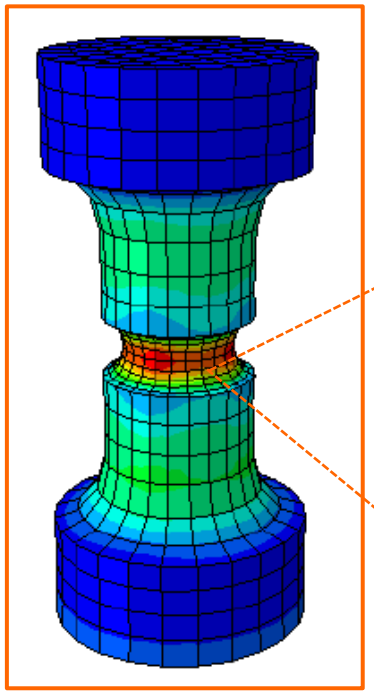
Multi-scale strategy : why ?

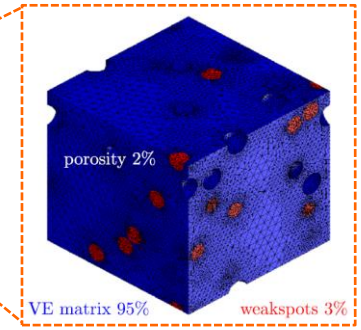
- Starting point :
  - Non trivial structure
  - Small strain - High Cycle Fatigue
  - VEVP material

    [Miled & Doghri 2011]

→ Computational-time limitation

→ Multi-scale strategy





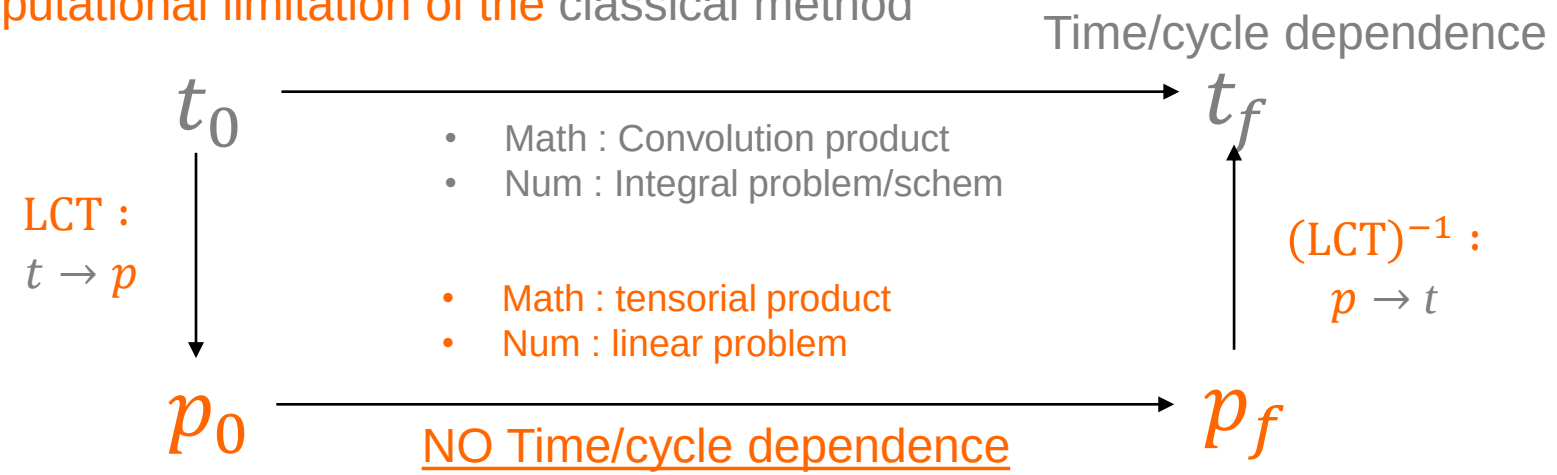
Structural scale : strain solution
Small strain : purely linear ViscoElastic
Laplace-Carson Transform

Micro scale : stress & plastic response
MS description based on the polymer
VEVP time homogenization

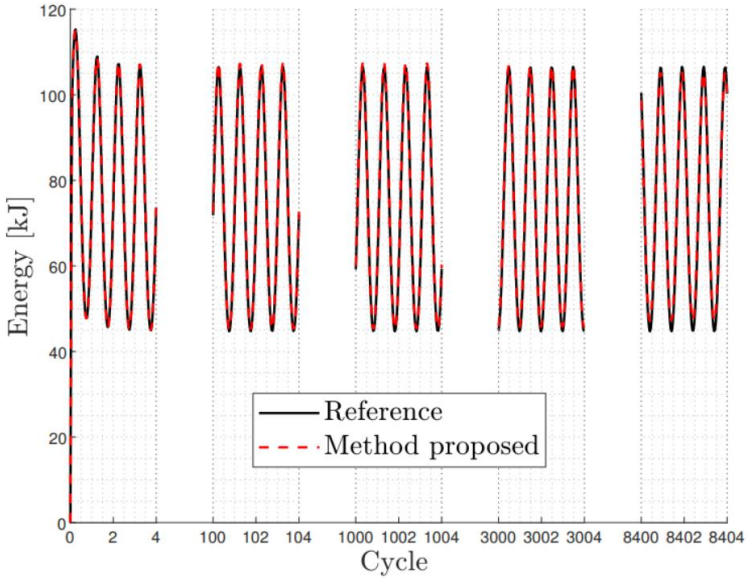
Fatigue model : state of the material
Damage at microscale
based on the accumalated plasticity

VE structure for strain history : LCT

- Computational limitation of the classical method



- Results and computational gain : [Hun & Doghri 2023]

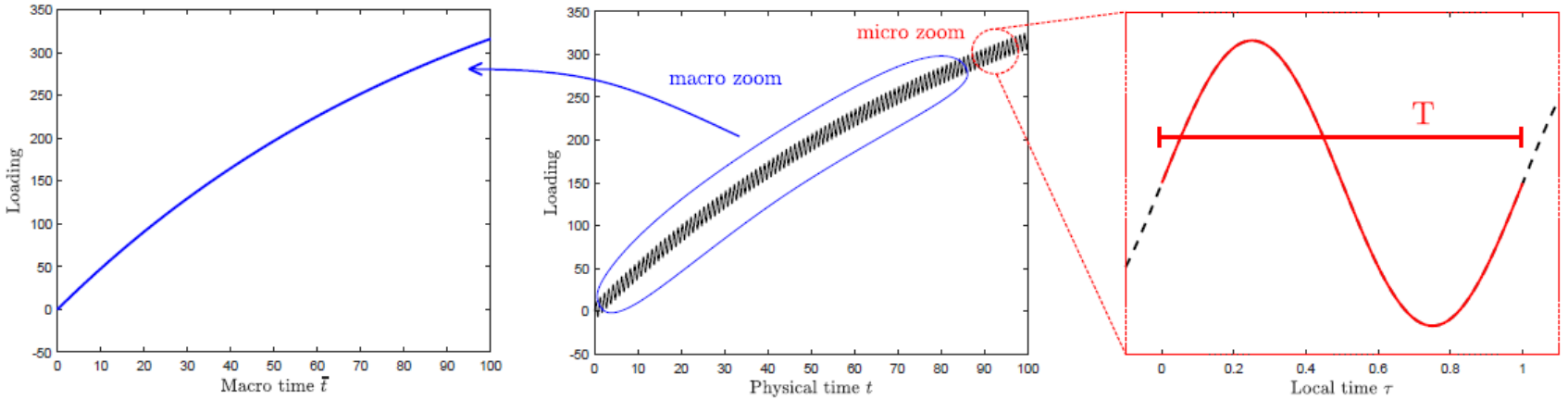


After 10 k cycles :
- Error < 2 %
- Gain = x 10 M /1 B cycles

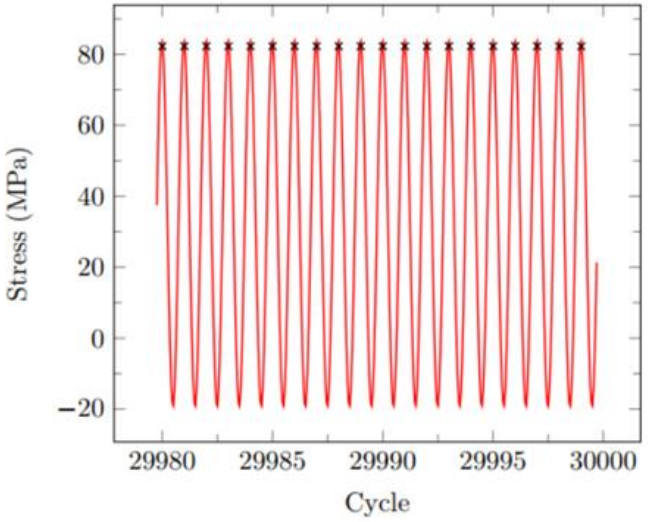
VE-VP for local stress history : Time-homogenization

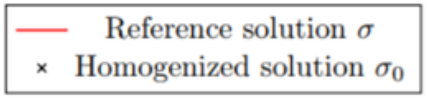
- Time homogenization : two time scales description

$$t = \bar{t} + T\tau, \text{ with } \bar{t} \in [0, T_M] \text{ and } \tau \in [0, 1],$$



- Results and computational gain : [Haouala & Doghri 2015]





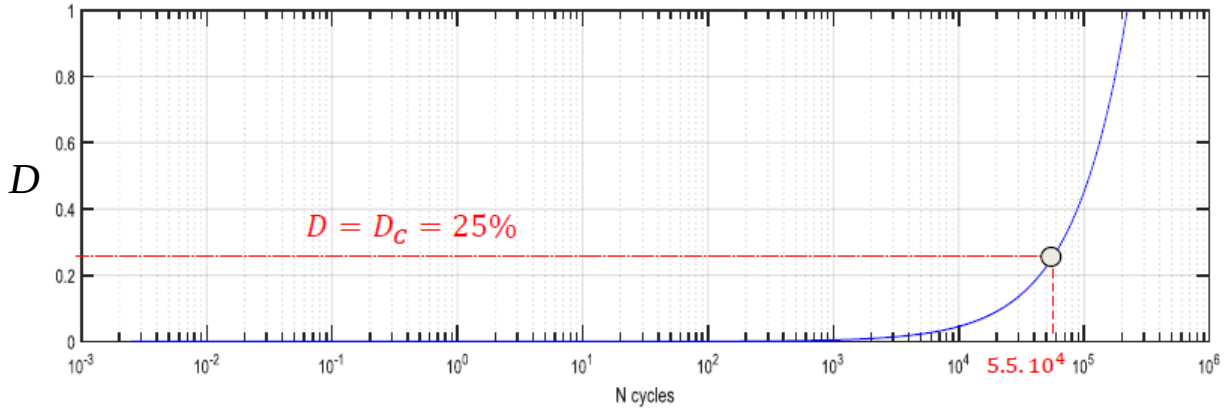
After 30 k cycles :
- *Error ~ 1.2%*
- *Gain = 97% faster*

Damage model for high cycle fatigue

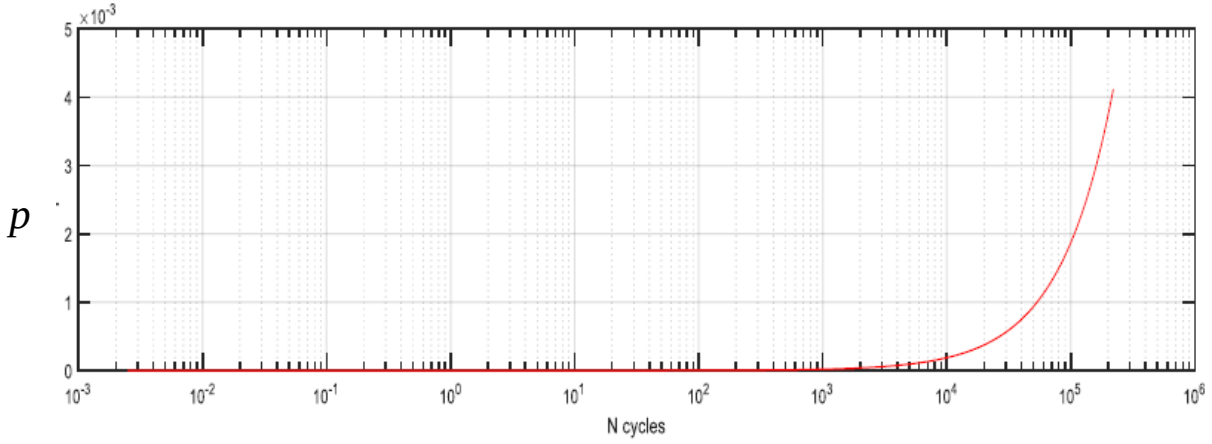
- Damage model & evolution : [Krairi & Doghri 2013]

$$\sigma(t_{n+1}) = (1 - D_n)\tilde{\sigma}(t_{n+1}) \qquad \Delta D = \left(\frac{Y}{S_D}\right)^{S_d} \Delta p$$

- D_c : critical damage value

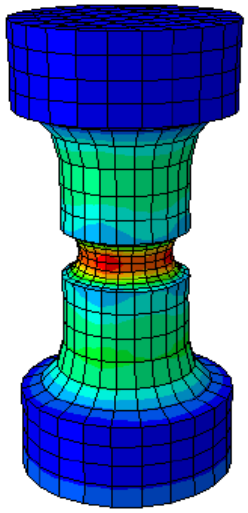


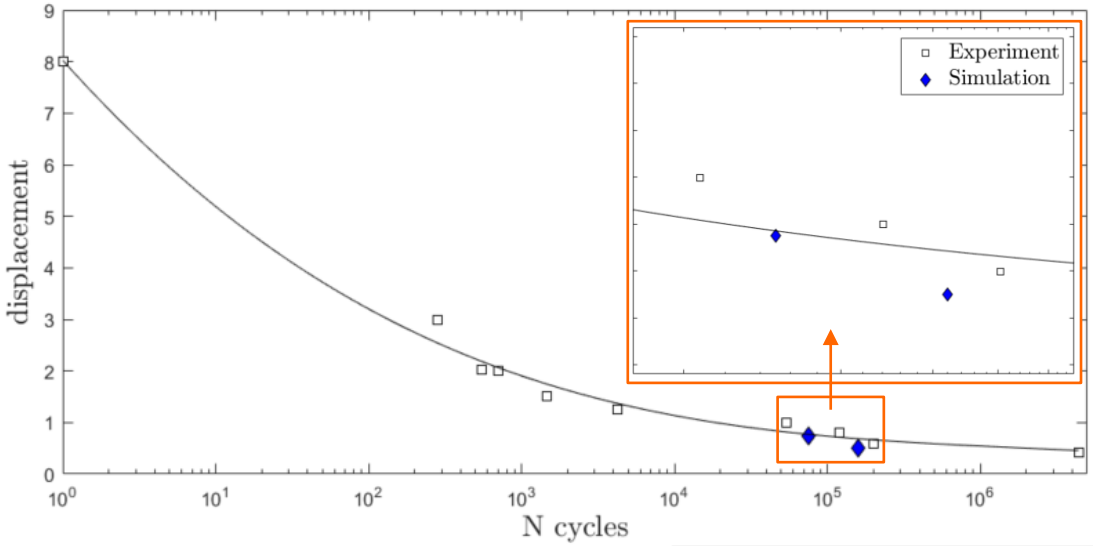
- S_d, S_D : damage parameter **<u>to identify</u>** on experiments



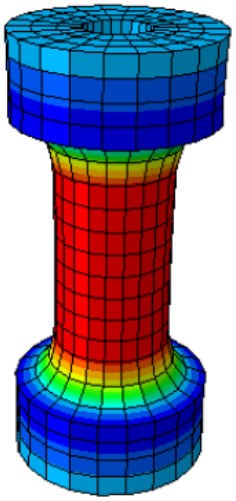
Comparison experimental & simulation

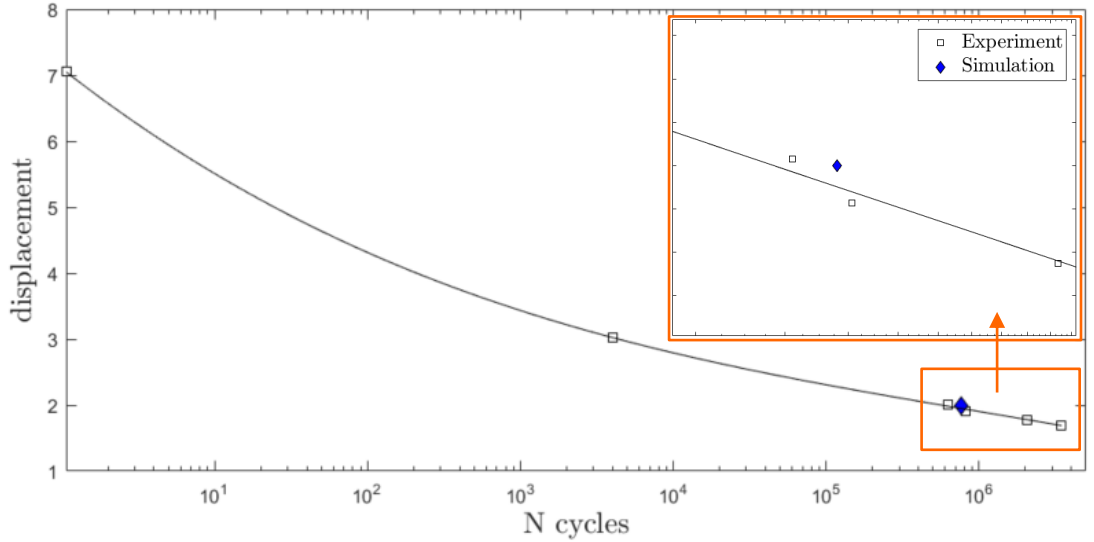
- S_d, S_D : damage parameter identified (notched)





- Validation on another geometry (perfored)





Conclusion

- Presentation of the SLS material applications
- High cycle fatigue : experiments
- High cycle fatigue : Computational framework
  - Multiscale strategy : VE structure / VEVP microstructure
  - VE structure solution : Laplace-Carson transform
  - VEVP micro solution : Two-time scale homogenization
  - Fatigue model : based on experimental
- Comparison & Validation

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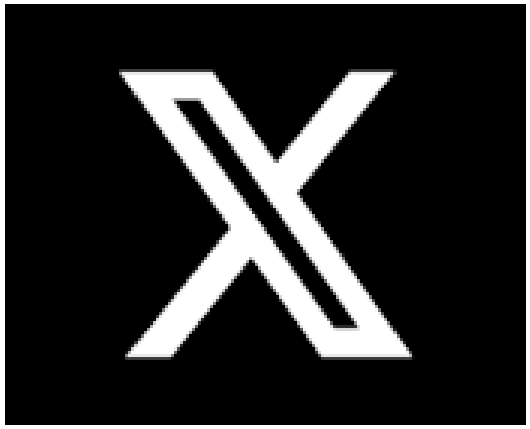
for your attention



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