


KUNSTSTOFF TECHNIK LEOBEN

WERKSTOFFKUNDE UND PRÜFUNG DER KUNSTSTOFFE


ESTIMATION OF THE LIFE TIME OF 3D-PRINTED CONTINUOUS FIBER-REINFORCED COMPONENTS

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Agenda

Introduction – Life time estimation for sfr IM

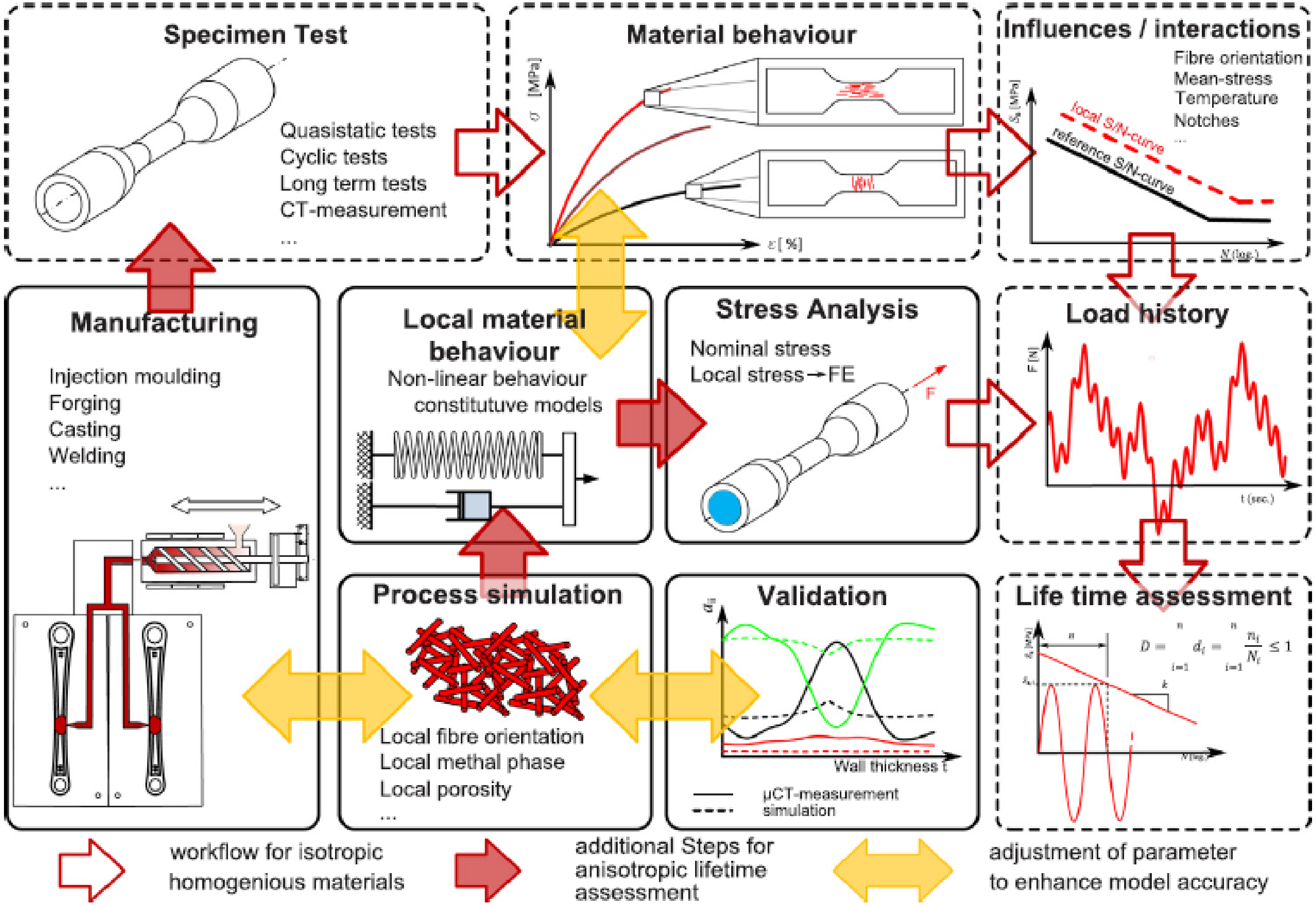
Modified/extended methodology for AM

- Process simulation
- Temperature history – welding time – strength
- Life time simulation

Conclusion and outlook

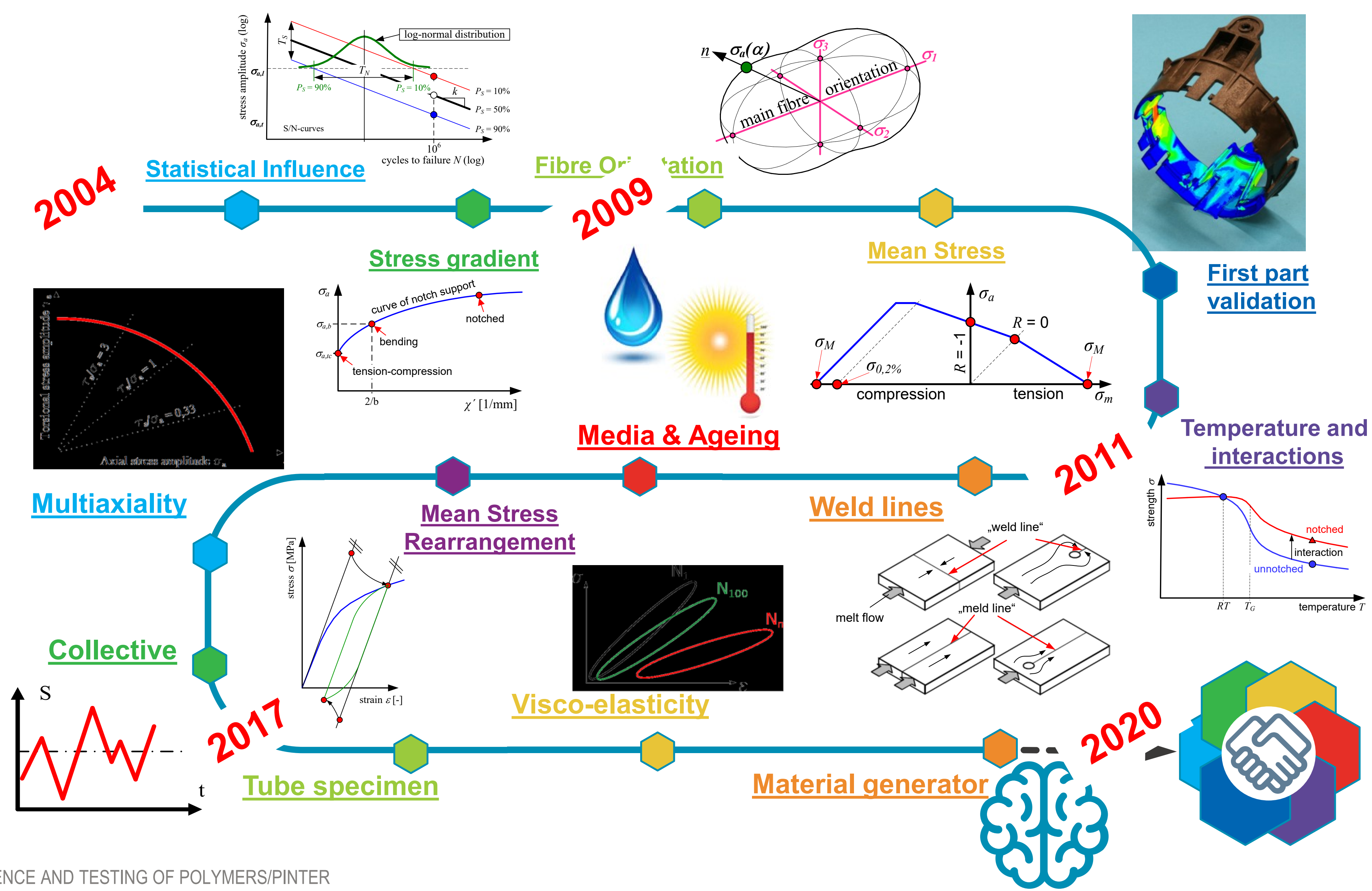
Introduction

Introduction – Life time estimation for sfr IM



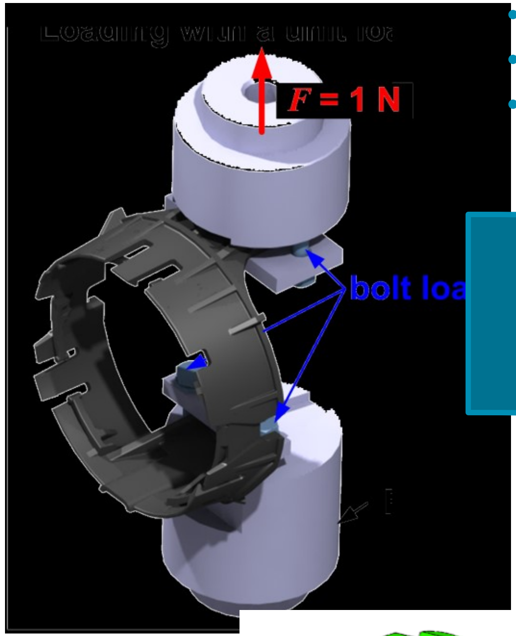
Primetzhofer et al. 2019. Lifetime assessment of anisotropic materials by the example short fibre reinforced plastic. International Journal of Fatigue 120; pp. 294–302.

Introduction – Life time estimation for sfr IM



Introduction – Life time estimation for sfr IM

CAD-Model:

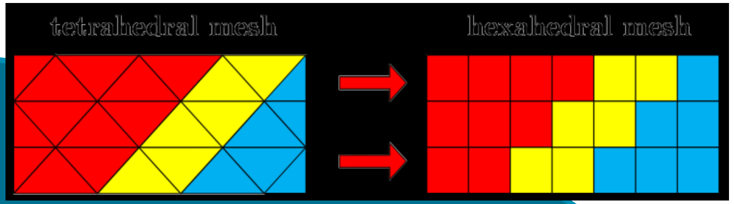


Model discretization:

- Load definition
- Boundaries
- …

Mapping: transfer of

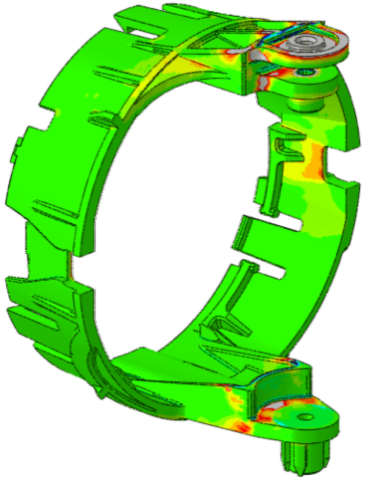
- local fibre orientation
- Residual stresses
- …

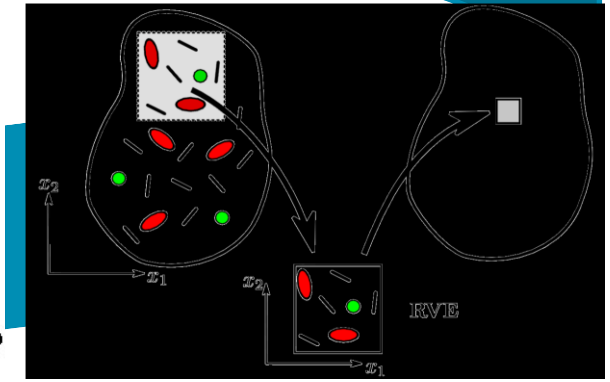


Solver

Results:

- Local stress
- Local strain
- …

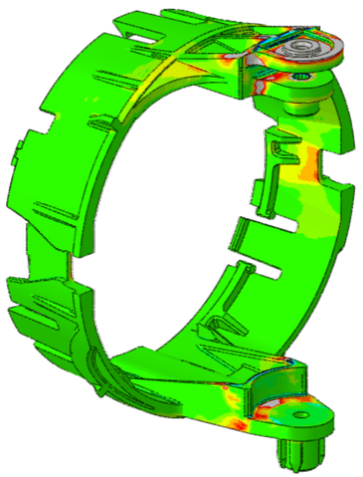




Material definition:

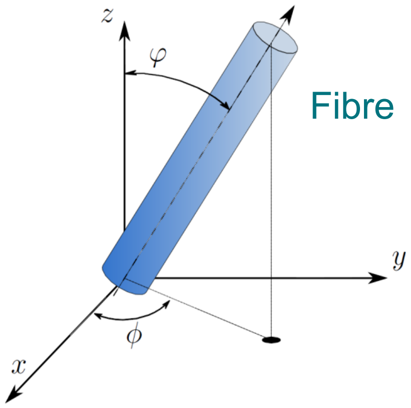
- – depending on fibre orientation
- Non-linear material behaviour

Introduction – Life time estimation for sfr IM



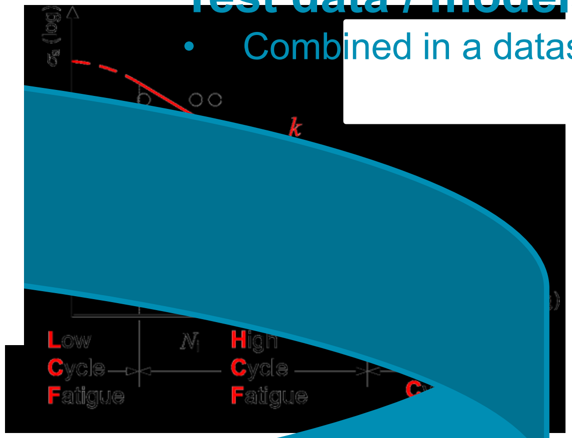
Results form FE:
- Local stress
- Local strain
- …

Fibre axis-vektor

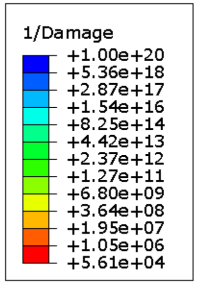


From process-simulation:
- Local fibre orientation
- Position of weld lines

Test data / models:
- Combined in a dataset

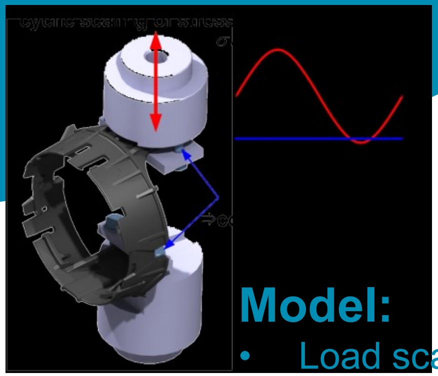


Results:
- Local damage / life time
- Local S/N curve
- …

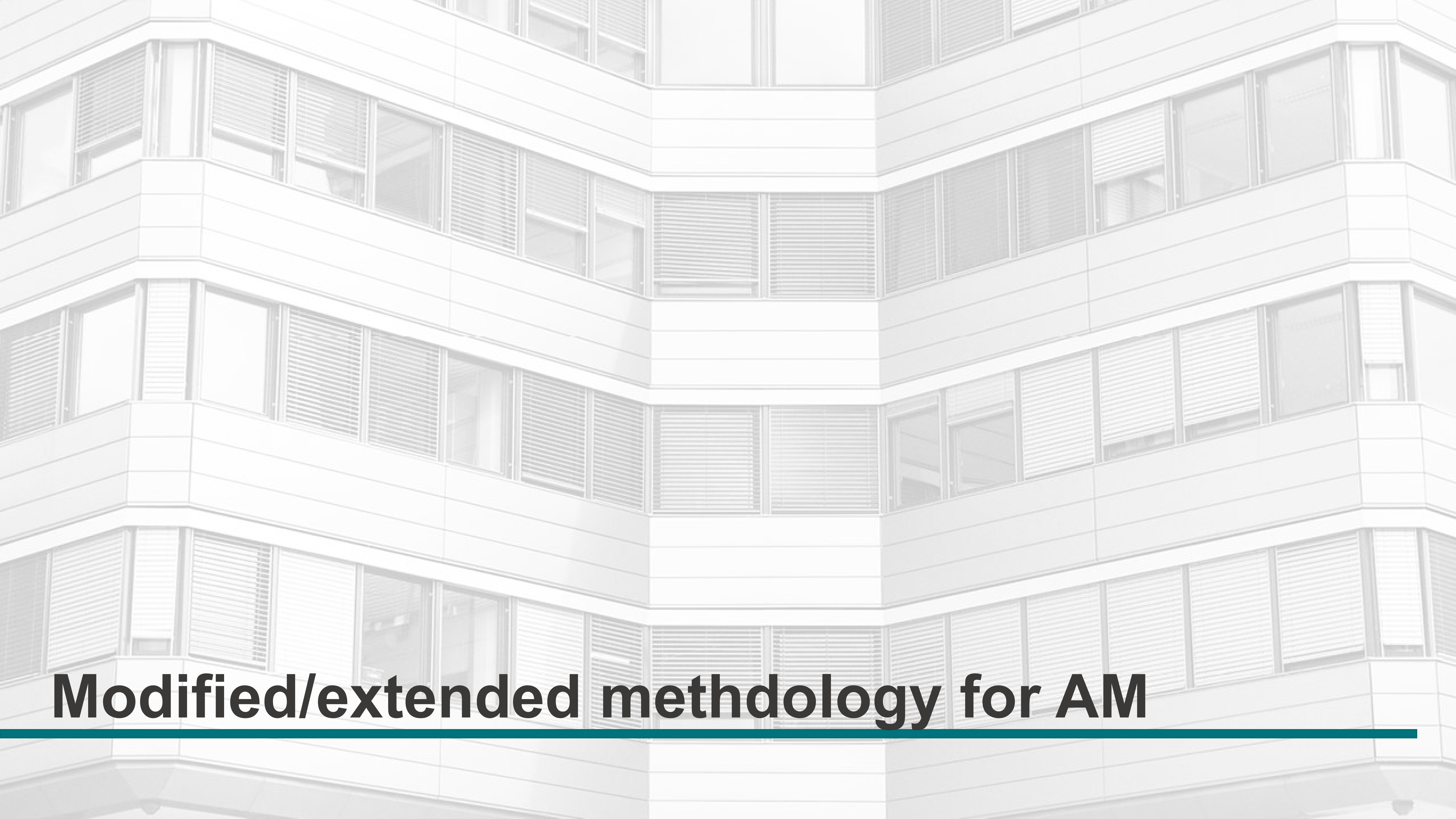


FEMFAT software
FINITE ELEMENT METHOD FATIGUE

Solver: includes
- Material models
- Damage accumulation



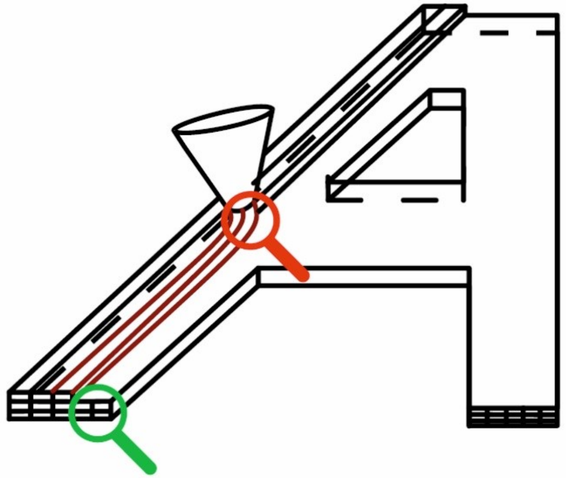
Model:
- Load scaling
- Material assingment



Modified/extended methdology for AM

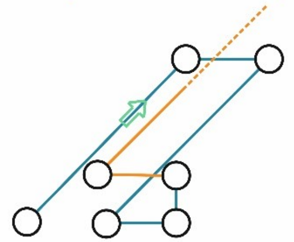
Modified/extended methodology for AM

Process simulation



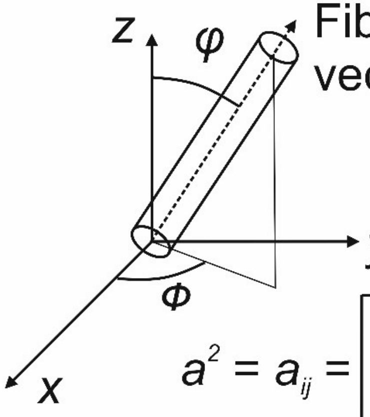
Inputs:
printing path;
part geometry;
thermal material properties;
nozzle temperature;
strand parameters; ...

Deposition path



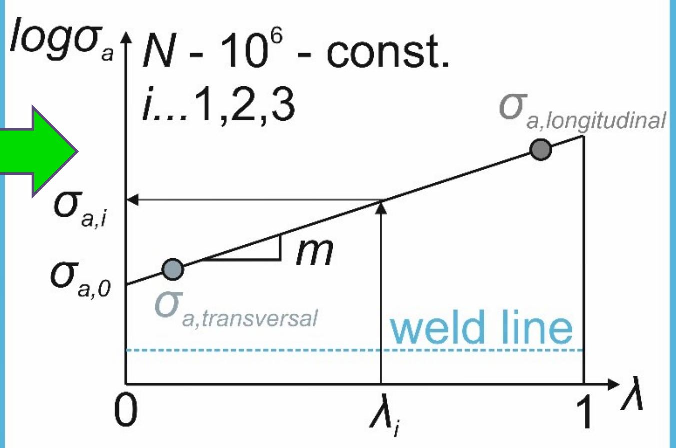
○ Waypoint coordinates
— Path
⇗ Vector between waypoints

Orientation

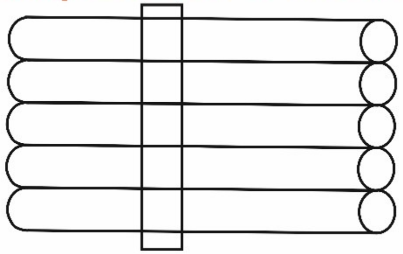


$$a^2 = a_{ij} = \begin{bmatrix} a_{xx} & a_{xy} & a_{xz} \\ & a_{yy} & a_{yz} \\ \text{sym.} & & a_{zz} \end{bmatrix}$$

Life time simulation

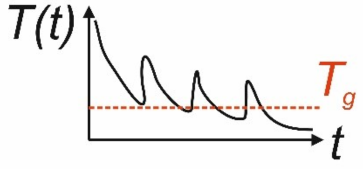


Temperature history - welding time - strength



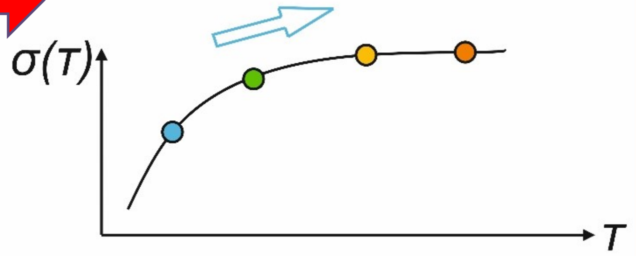
Printing of walls with different nozzle temperatures (T_{n1}, T_{n2}, T_{n3}, T_{n4})

Mechanical testing
Determination of weld strength σ

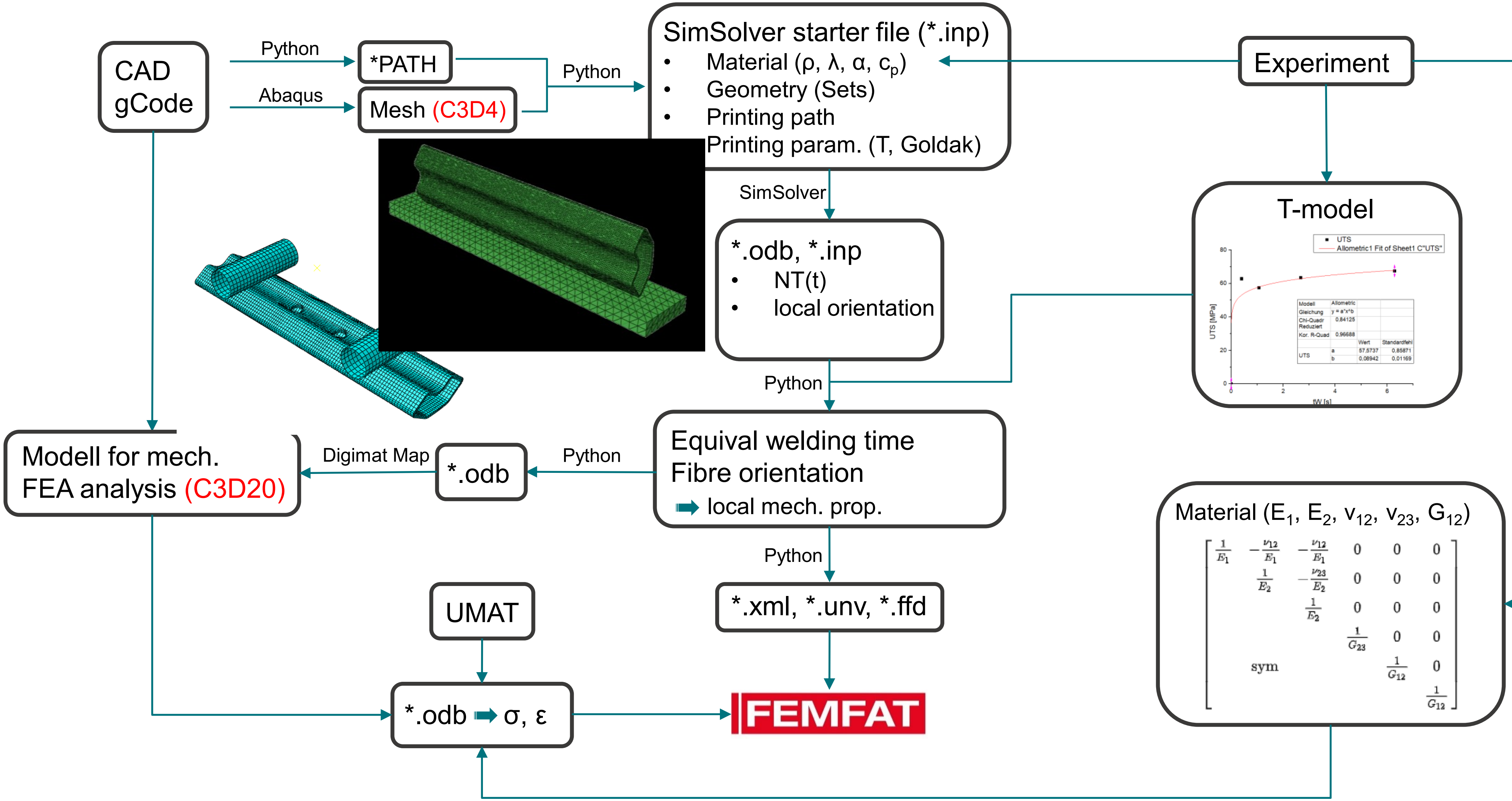


T-measurement during printing
Determination of welding time τ

higher welding time τ
higher strength σ

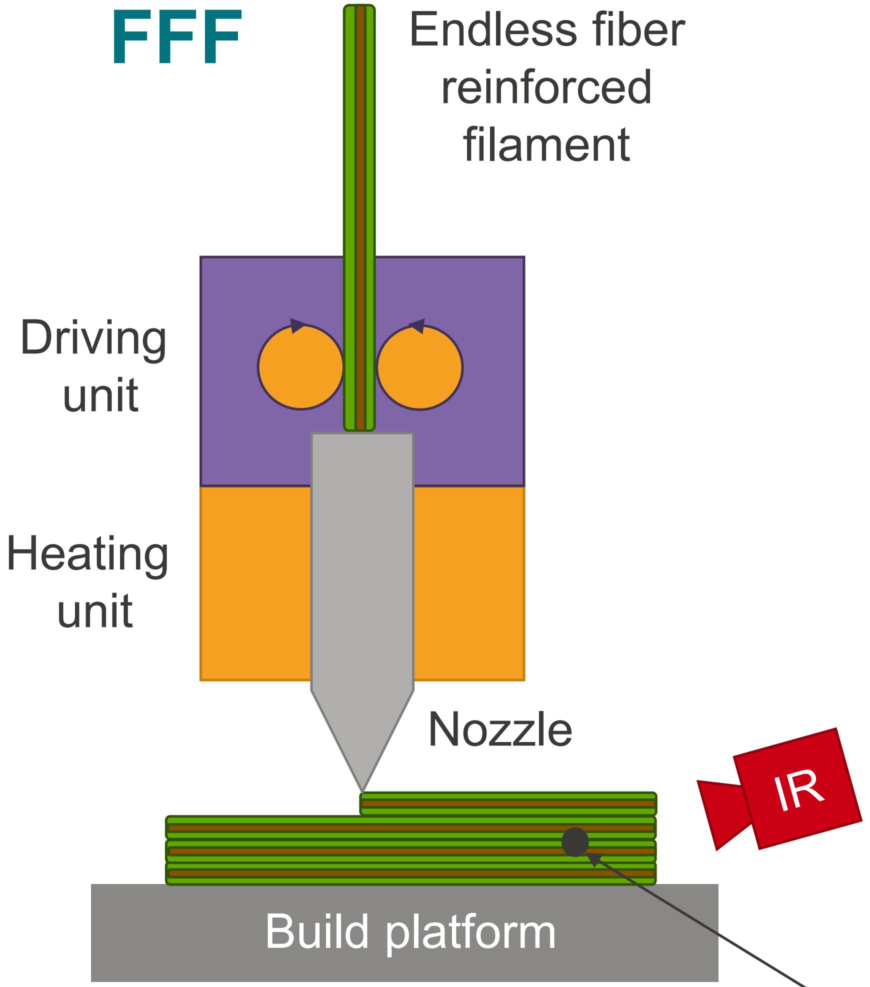


Modified/extended methodology for AM



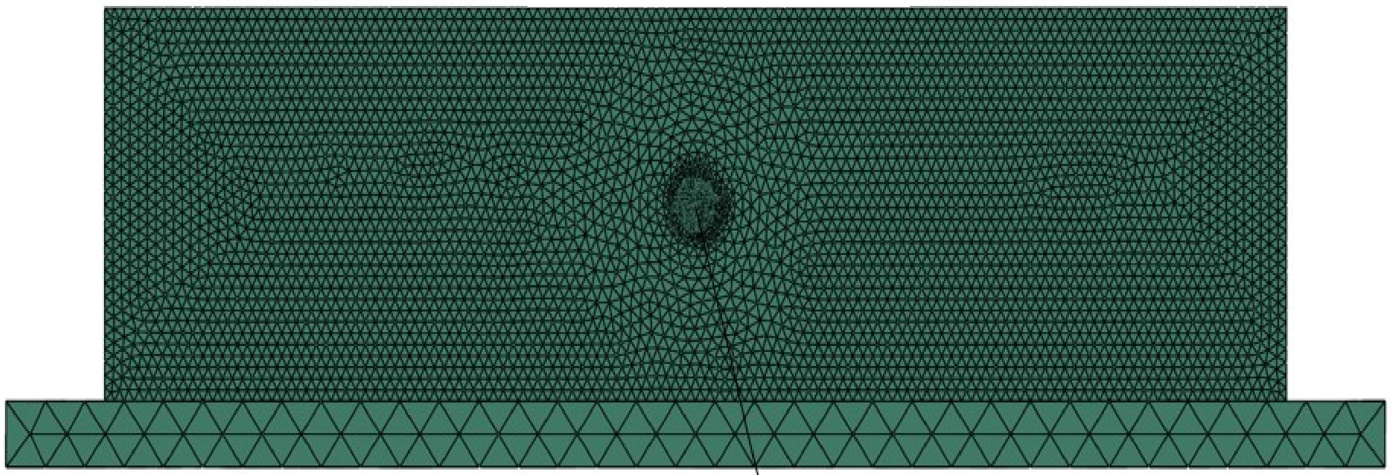
Process simulation

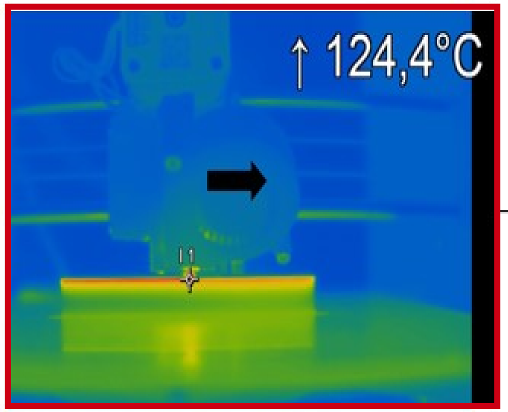
FFF

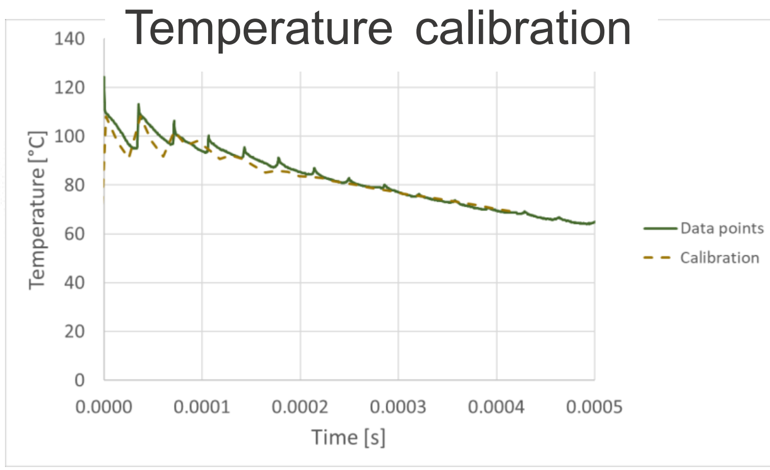


Deposition path
=
Fiber orientation

FE-model





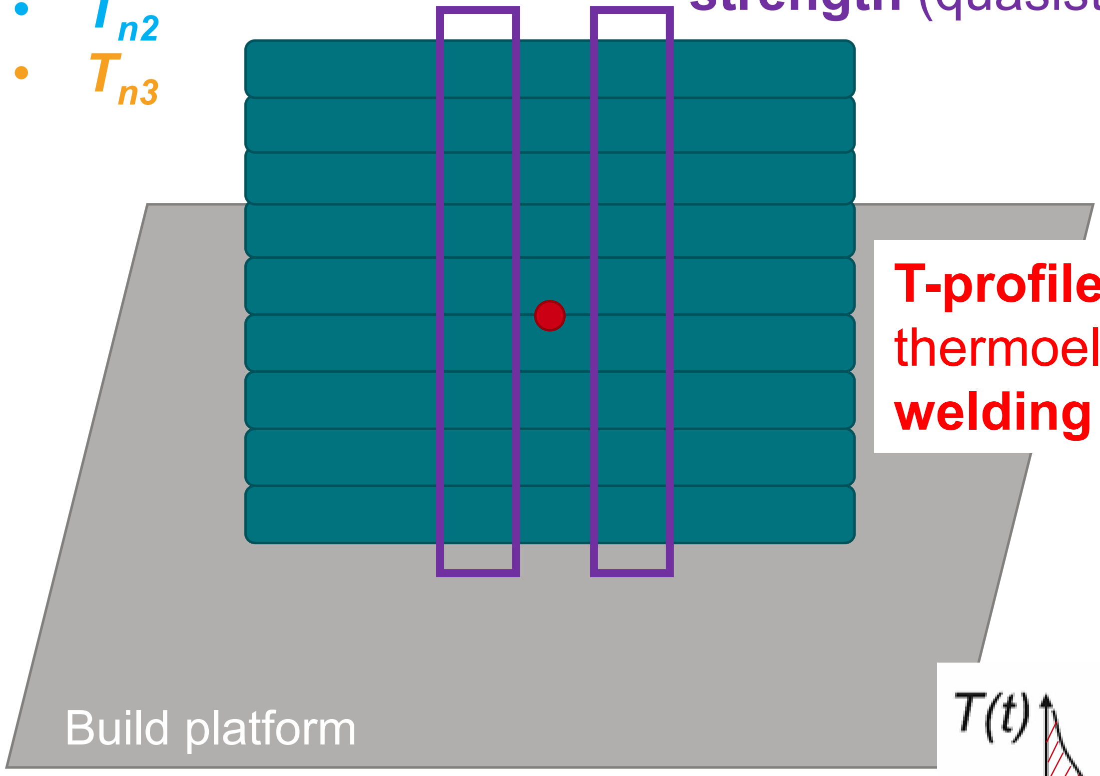


Thermo couple (0.08mm)

Temperature history – welding time – strength

Processing at different nozzle temperatures (T_n)

- T_{n1}
- T_{n2}
- T_{n3}

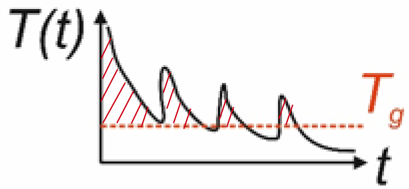


Mechanical test specimen → strength (quasistatic, fatigue)

- σ_1
- σ_2
- σ_3

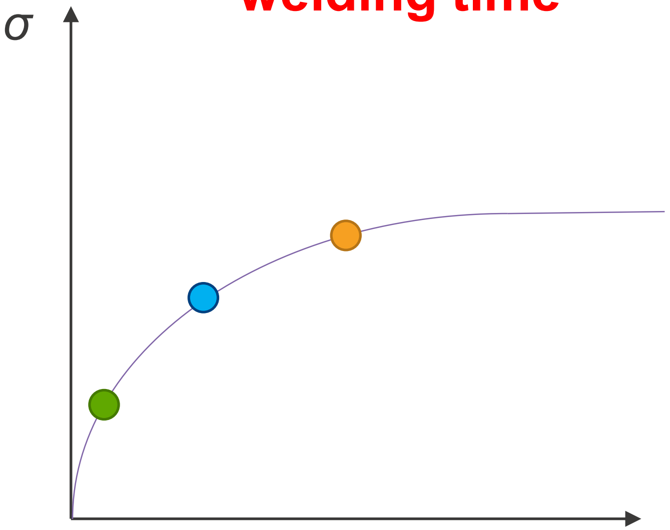
T-profile (IR cam, thermoelements) → **welding time**

- τ_1
- τ_2
- τ_3



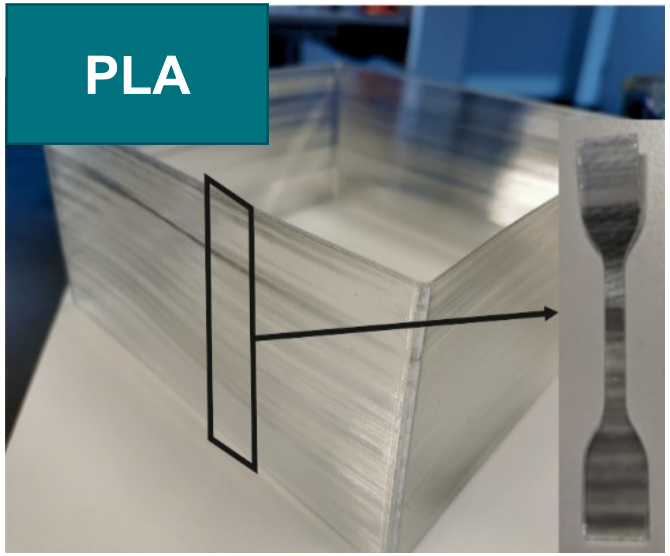
τ = areas above T_g weighted by $1/a_T$
(temperature shift factor - chain mobility)

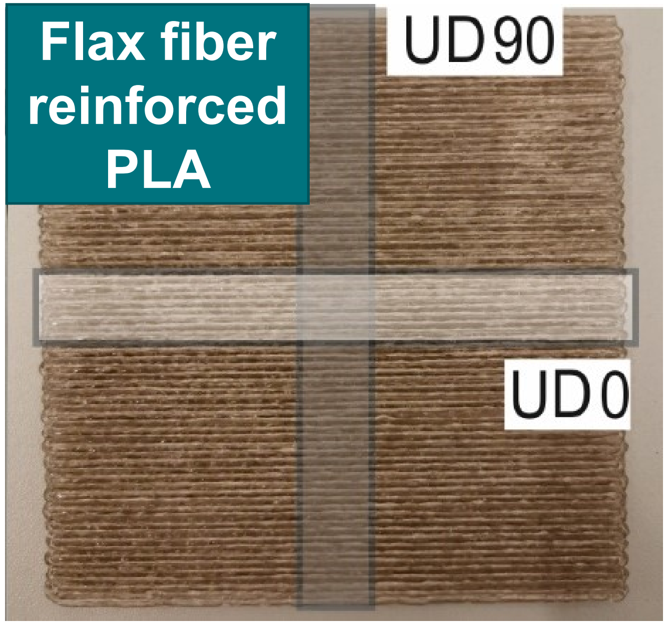
strength
vs.
welding time



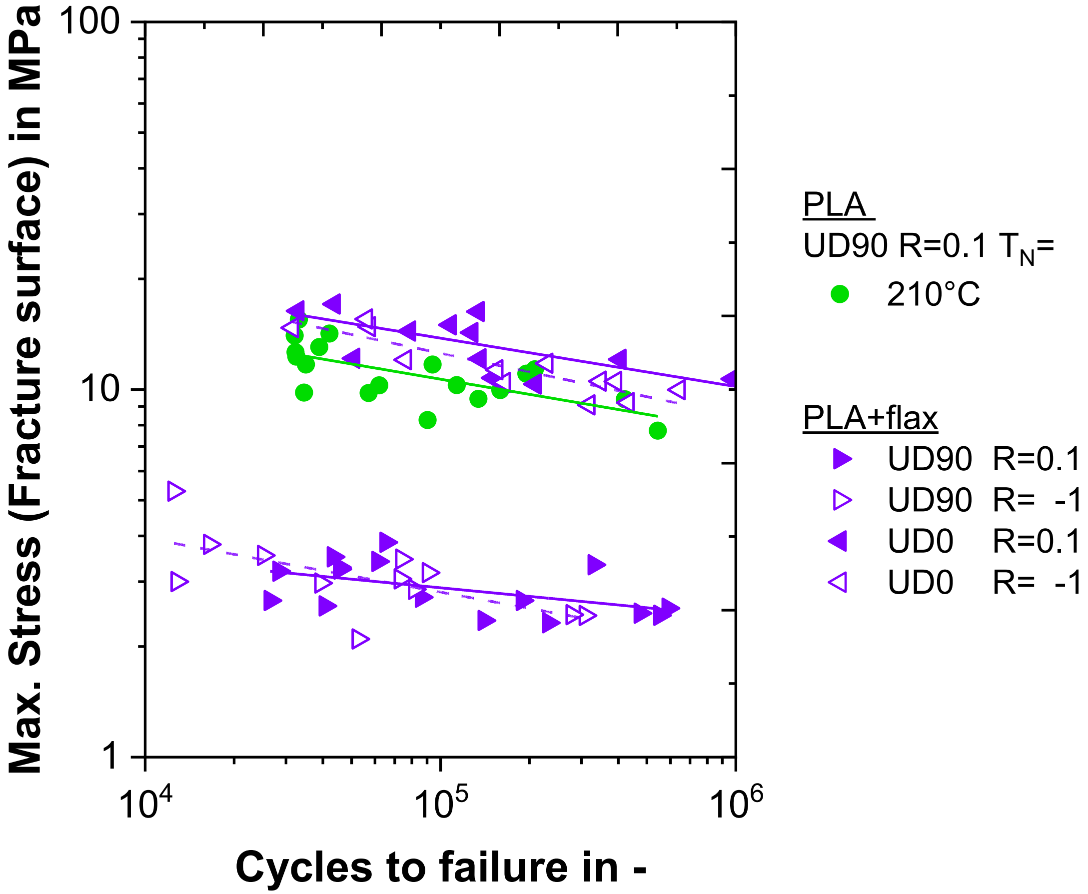
equivalent isothermal weld time
[J. Seppala, Soft Matter 2017]

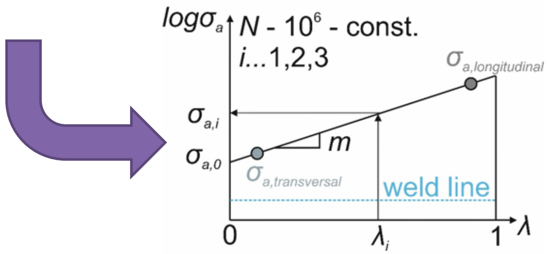
Temperature history – welding time – fatigue data





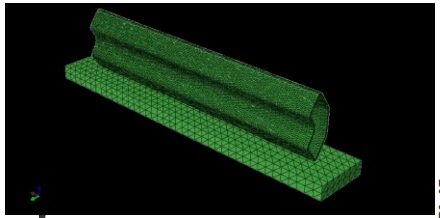
R = 0.1 / -1
f = 5 Hz



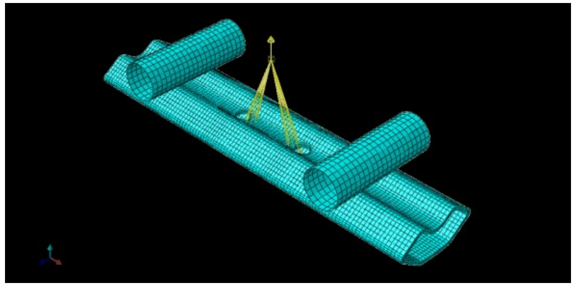


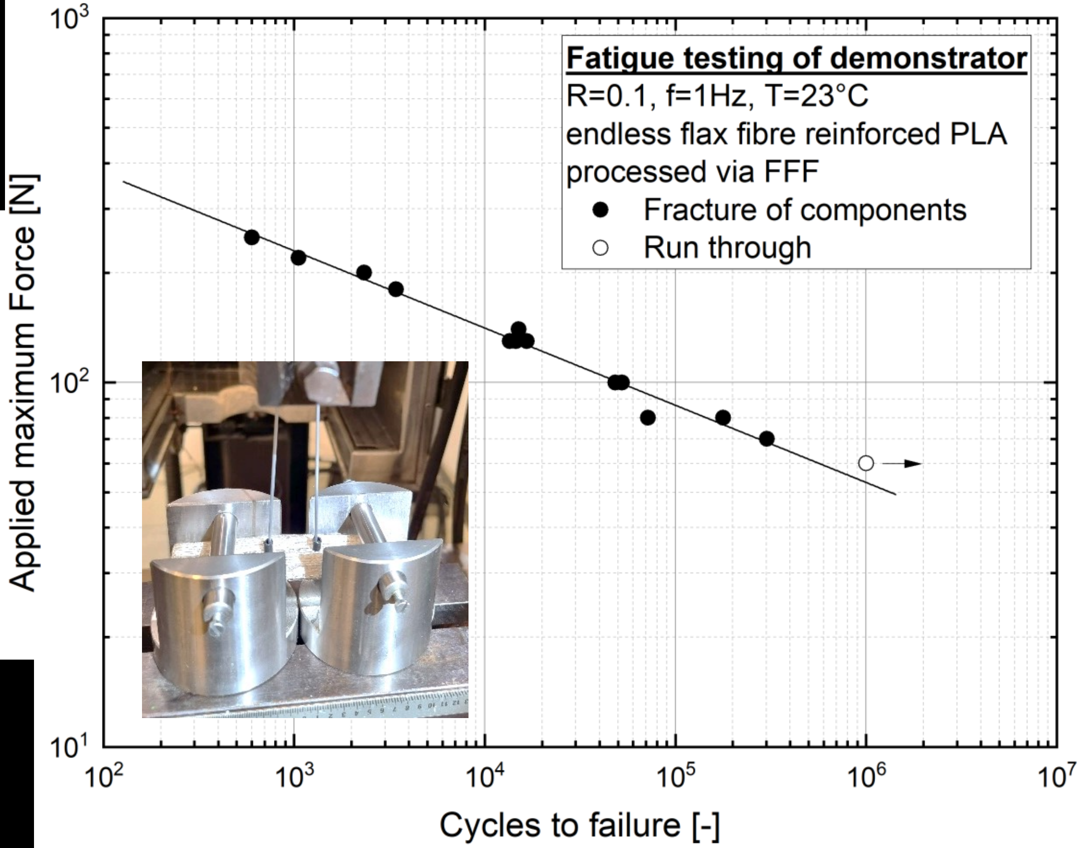
Validation via demonstrator

- Validation of specimen data on demonstrator level



- Temperature simulation of demonstrator
- Fatigue test on demonstrator with R=0.1, f=1Hz

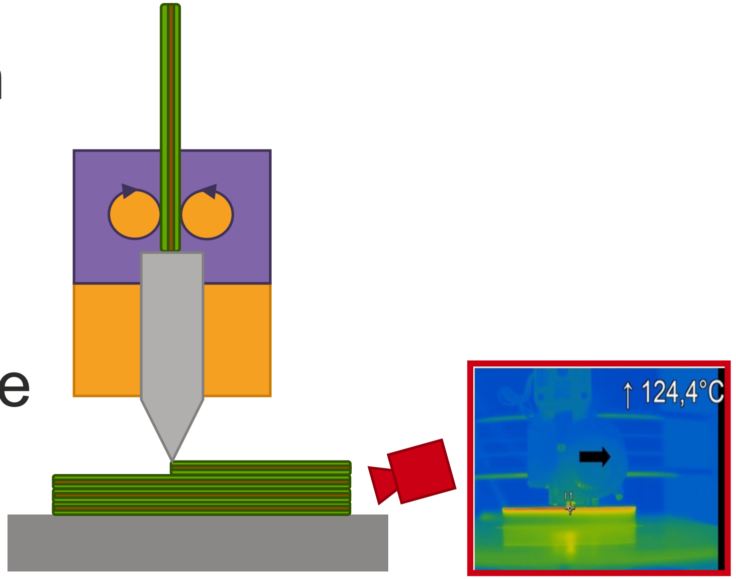




Conclusion and outlook

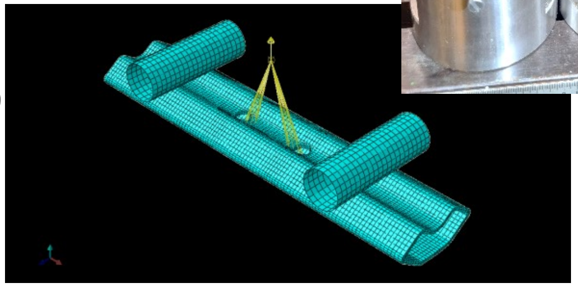
Conclusion and outlook

- Determine effect of **thermal history** and **fiber orientation** on **weld strength** → temperature and orientation dependent model



- Thermo-mechanical coupled process simulation to evaluate welding time → possibility to evaluate **mechanical behavior for each node** in a part volume

- **Validation via demonstrator**
  - Simulation of thermal history and fiber orientation
  - Femfat based lifetime estimation based on local properties
  - Comparison to actual lifetime of tested demonstrato

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WOOD KPLUS

PCCL

Polymer Competence Center Leoben

FFG

Forschung wirkt.