TECHNISCHE UNIVERSITÄT DRESDEN

DRESDEN concept

Faculty of Mechanical Science and Engineering
Chair of Computational and Experimental Solid Mechanics

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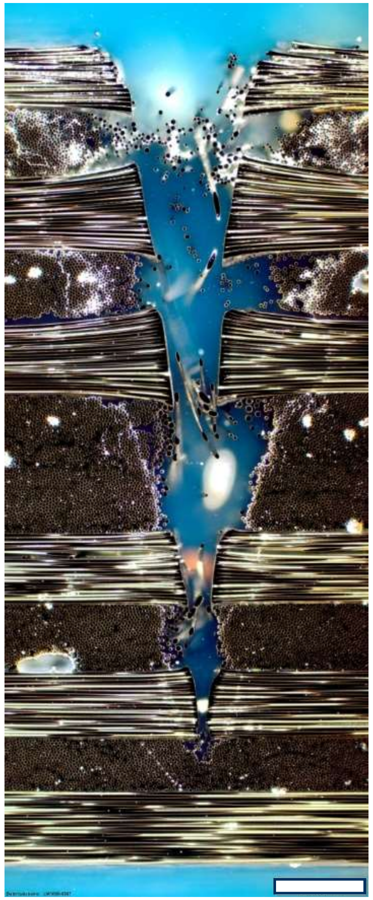
Analyse der Korrelation zwischen dem Ermüdungsverhalten Remote-Lasergeschnittener Faserkunststoffverbunde und der Prozessführung

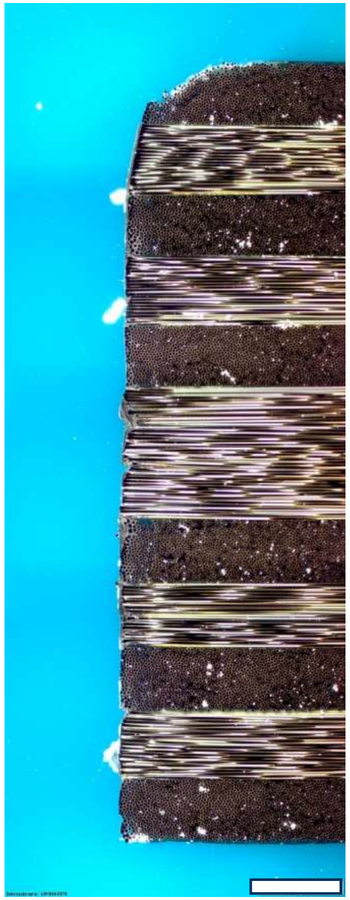
Analysis of the correlation between the fatigue behaviour of remote-laser cut fibre-reinforced polymers and process parameters

15th German LS-Dyna Forum Bamberg, 15-17 October 2018

FKM

Content





1) Fraunhofer IWS

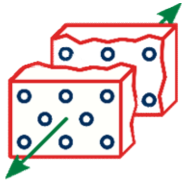
Static damage

Pinho[1)] damage model – MAT_261 *MAT_LAMINATED_FRACTURE_DAIMLER_PINHO

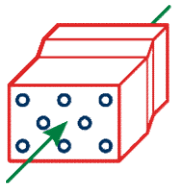
- Macroscopic scale, orthotropic, linear elastic model
- Linear degradation
- Physically based failure criteria

Failure modes and criteria

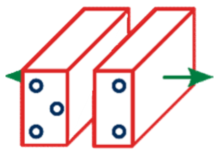
- Fibre tensile mode (a)
- Fibre compression mode (3D fibre kinking) (b)
- Matrix tensile mode (c)
- Matrix compression mode (d)

a) 

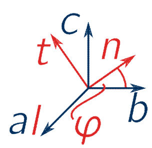
$$\frac{\sigma_a}{X_T} = 1$$

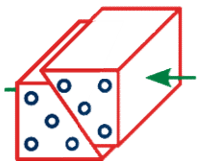
b) 

$$X_C(Y_T, Y_c, S_l, S_t, \phi_0)$$

c) 

$$\frac{\sigma_b}{Y_T} = 1$$



d) 

$$\left(\frac{\tau_t}{S_t - \mu_t \sigma_n}\right)^2 + \left(\frac{\tau_l}{S_l - \mu_l \sigma_n}\right)^2 = 1$$

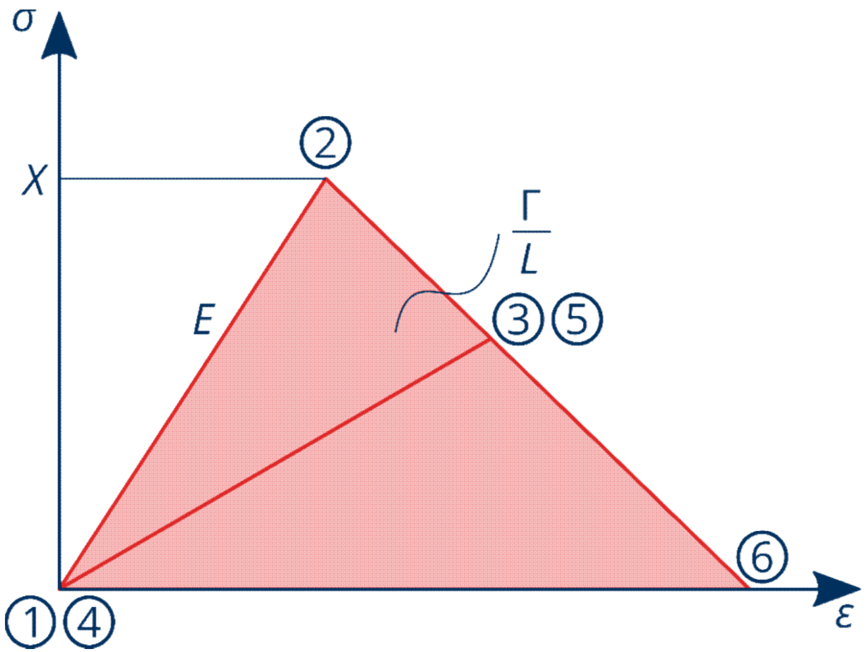
1) Pinho (2006)

Static damage

Modell

Degradation for mode *i*

$$\sigma_i(d_i) = (1 - d_i)\sigma_{0,i}$$



Parameter identification

Experiments

- Stiffnesses, strengths
  - Tensile test 0° (fibre) E_a, X_T
  - Tensile test 90° (matrix) E_b, Y_T
  - Tensile test 45° (shear) G_{ab}, S_l
- Fracture Toughness (pending)
  - Compact tension 90° (matrix) Γ_b
  - Compact tension 0°/90° (fibre) Γ_a

Literature, numerical values

- Compression strengths X_C, Y_C
- Fracture toughness Γ_{kink}

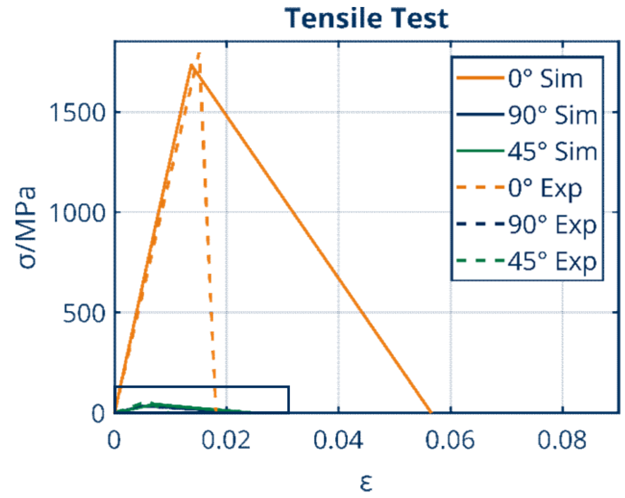
Static Damage

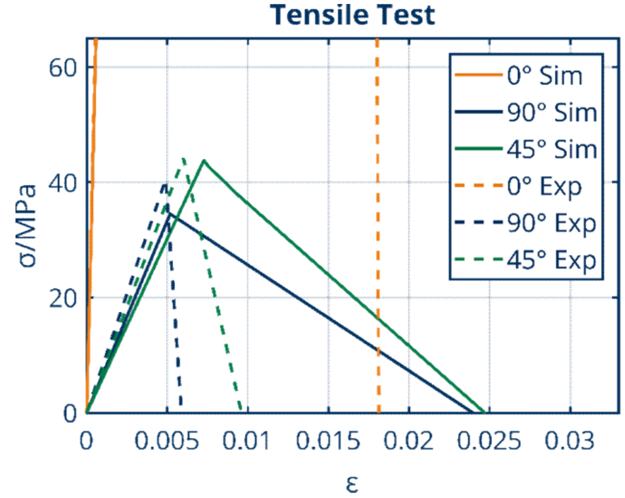
Validation

Simulation of UD specimen 0°, 45°, 90°

Fracture pattern of 0° UD specimen – experiment and simulation

0° tensile test





Thermal damage

Damage phenomena

Matrix

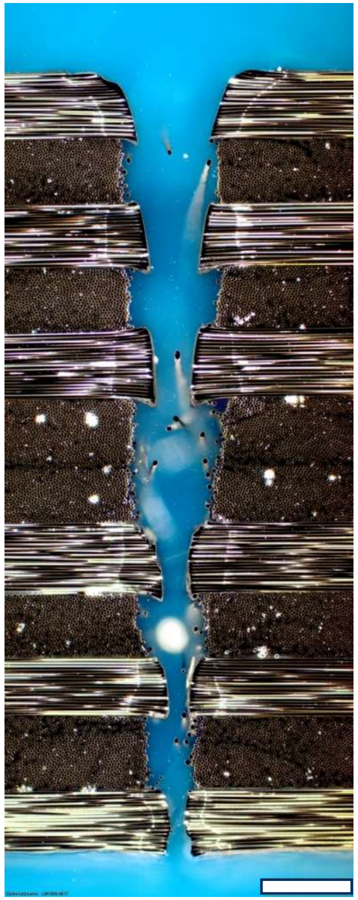
- Sublimated material
- Chemical decomposition
- Micro-cracks

Fibre

- Detached parallel fibres
- Disrupted contact
- Oxidised ends

Others

- Misaligned edge


1)

200 µm

Modelling

- Thermal damage as pre-existing damage
- Spatial distribution depending on distance to edge
- Separate distribution for matrix and fibre

Challenges

- Mapping damage phenomena to damage mode $d_{\text{therm}} \rightarrow d_i$
- Degradation of strength, stiffness and fracture toughness
- Invisible damage

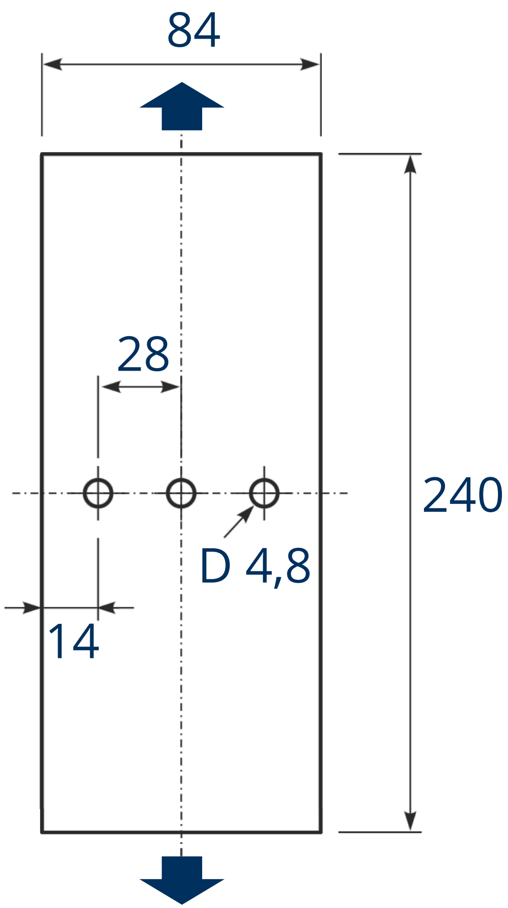
1) Fraunhofer IWS

Thermal damage

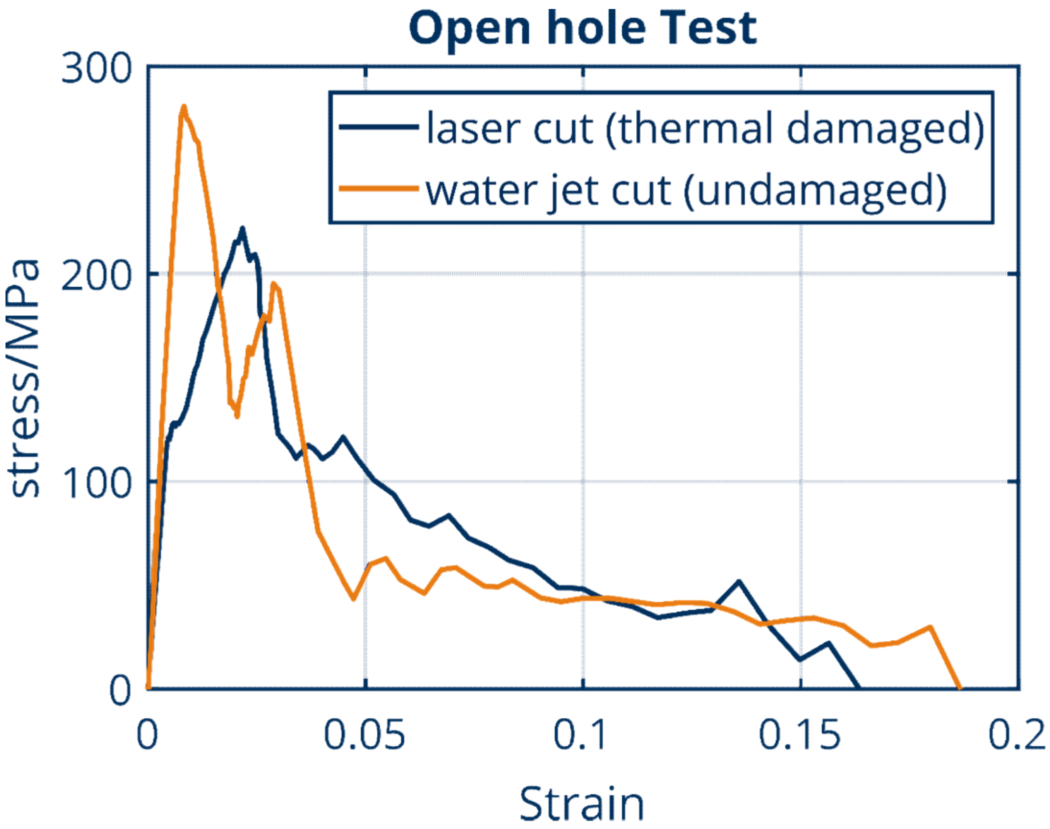
Modelling in LS-Dyna

- Keywords *INTERFACE_SPRINGBACK_LSDYNA and *INITIAL_STRESS_SOLID to read and write stress states, history variables, damage parameters
- Matlab routine reads nodes, elements and materials, calculates material damage as function of distance from cutting edge
- Dimensions for damage from micro-sections
  - Fibre $d = 0.1$ at surface and 0 at 0.06 mm
  - Matrix $d = 1$ at surface and 0 at 4 mm

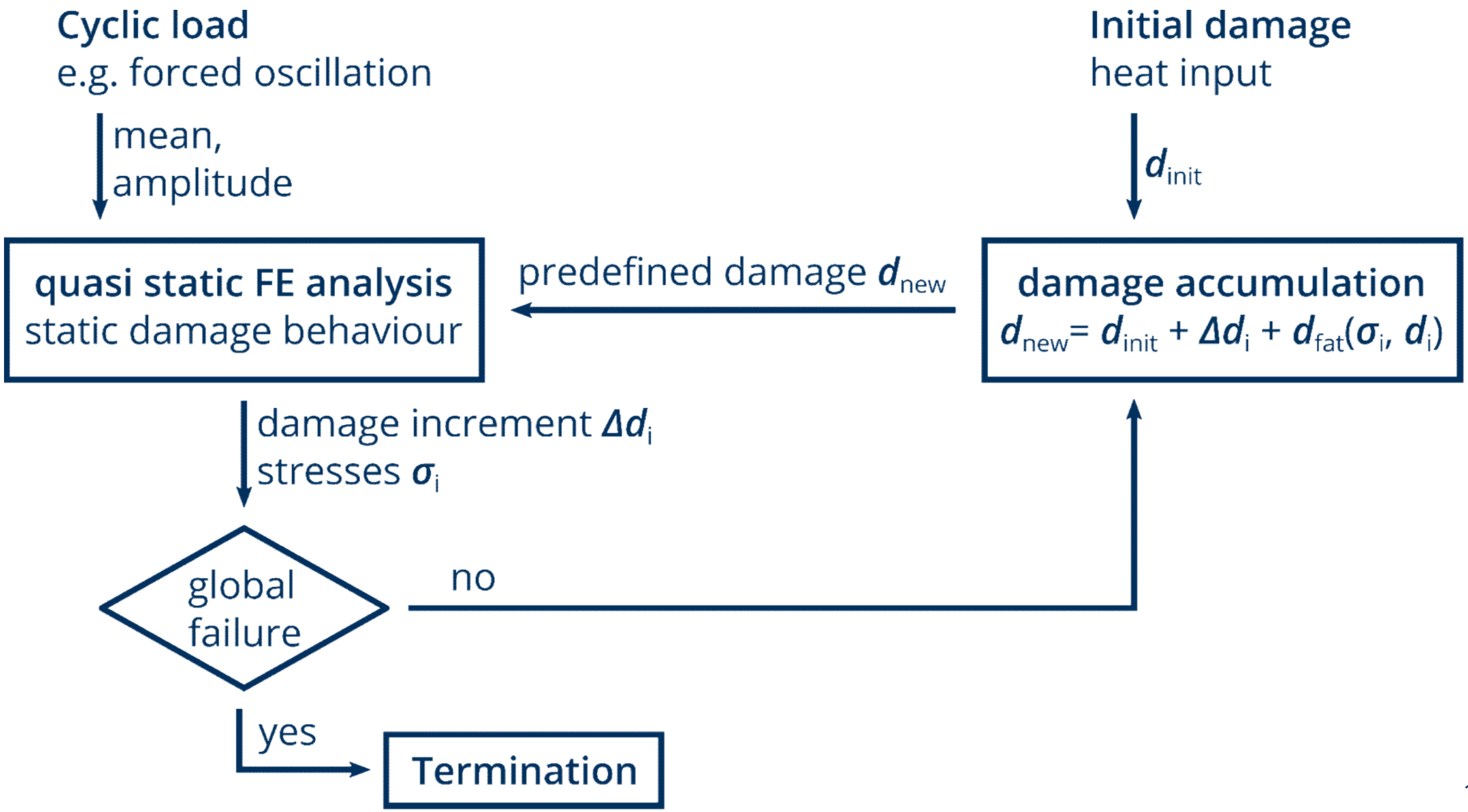
Thermal damage



- Comparative Simulation of water jet and laser cut notched specimen



Fatigue modelling approach



1)

1) Koch (2010)

Summary

Summary

- Fitted static material model (MAT_261 *MAT_LAMINATED_FRACTURE_DAIMLER_PINHO)
- Modelling of thermal damage caused by laser cutting
- Modelling approach for fatigue based on damage parameters

Outlook

- Temperature field for thermal damage
- Validation of simulation results
- Fatigue simulations

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