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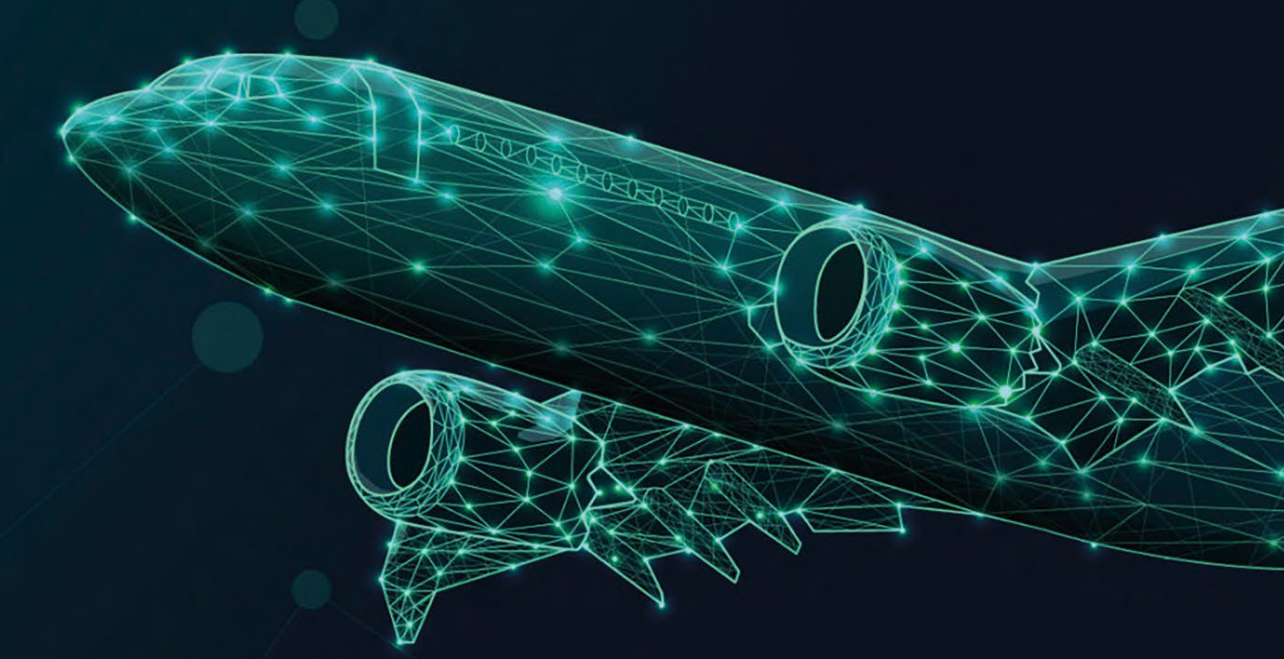
for Durability Modelling of Composites



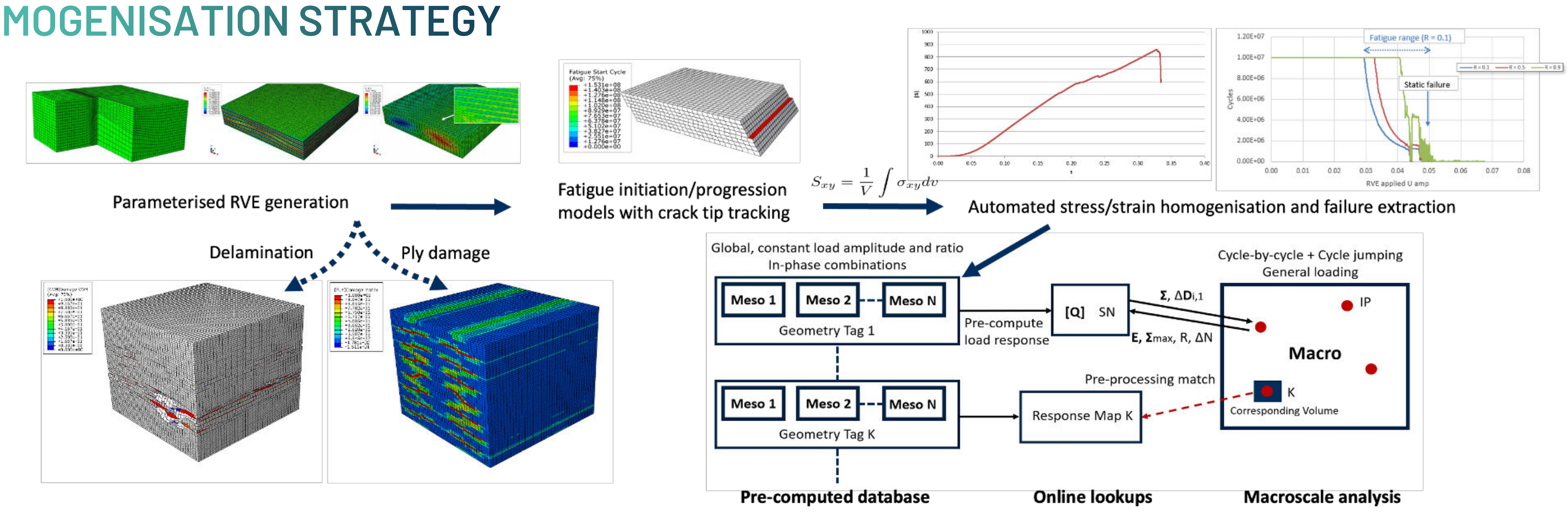
Towards Multiscale Modelling of Fatigue in Laminated Composites

G. Cucu, B. El Said, G. Allegri

OBJECTIVES

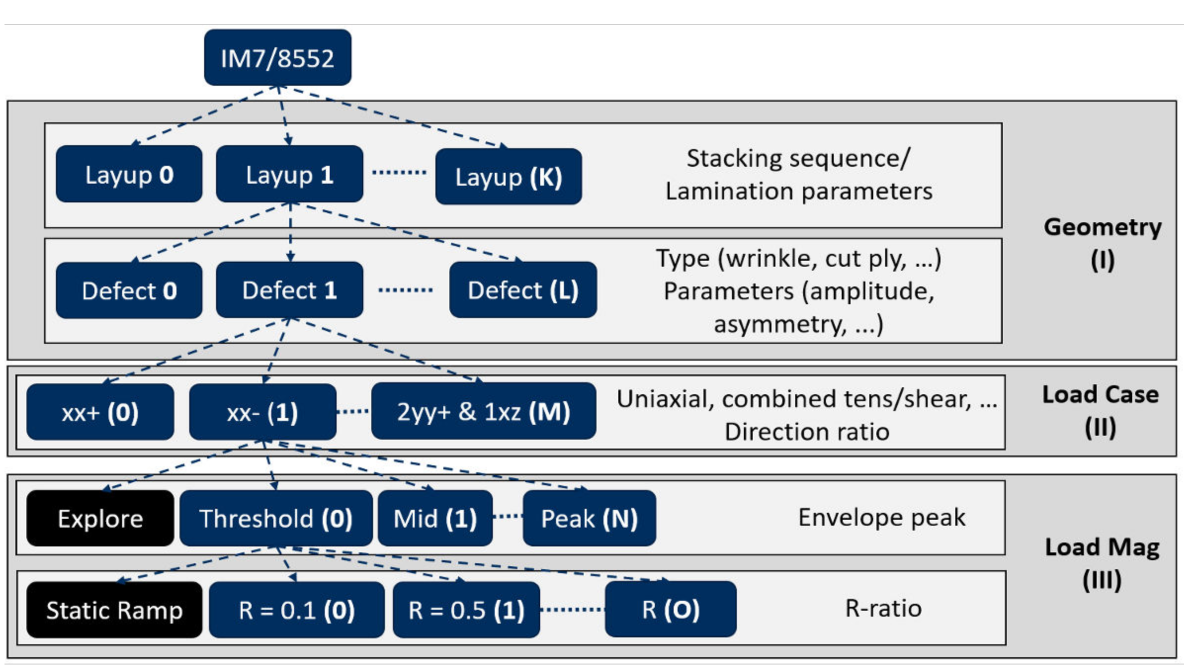
- Enable simulation of fatigue on macro-scale laminated composite structures
- Build a database of high-fidelity ply-by-ply RVEs with varying layups, defects, loading
- Pre-compute responses of meso-scale RVEs under periodic boundary conditions and simplified cyclic loading
- Homogenise RVEs and combine into continuous responses for a given material system, to be sampled at runtime

HOMOGENISATION STRATEGY

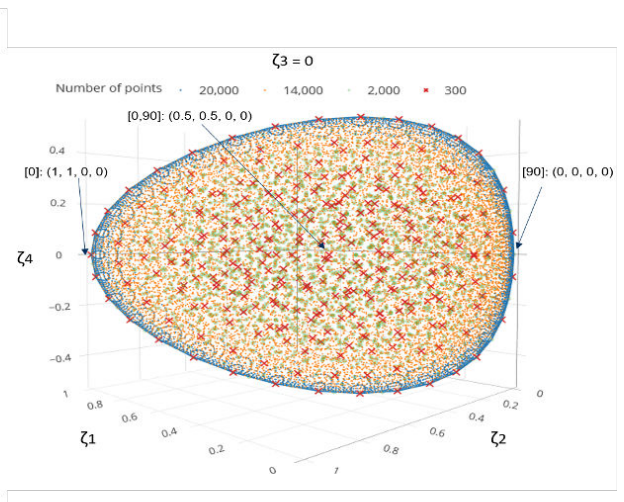


EXPLORATION OF MATERIAL RESPONSE

- Initial focus on meso progression --- macro initiation.
- Separate the multiscale framework from specific physical models. Allow swapping/combination of different models.
- Focus on interfaces, means of combining discrete responses, and means of generating the discrete inputs.



Model hierarchy



Feasible lamination parameters space (z1, z2, z3, z4). Projection with z3 = 0. Four levels of simplification (20,000 - blue to 300 points - red).

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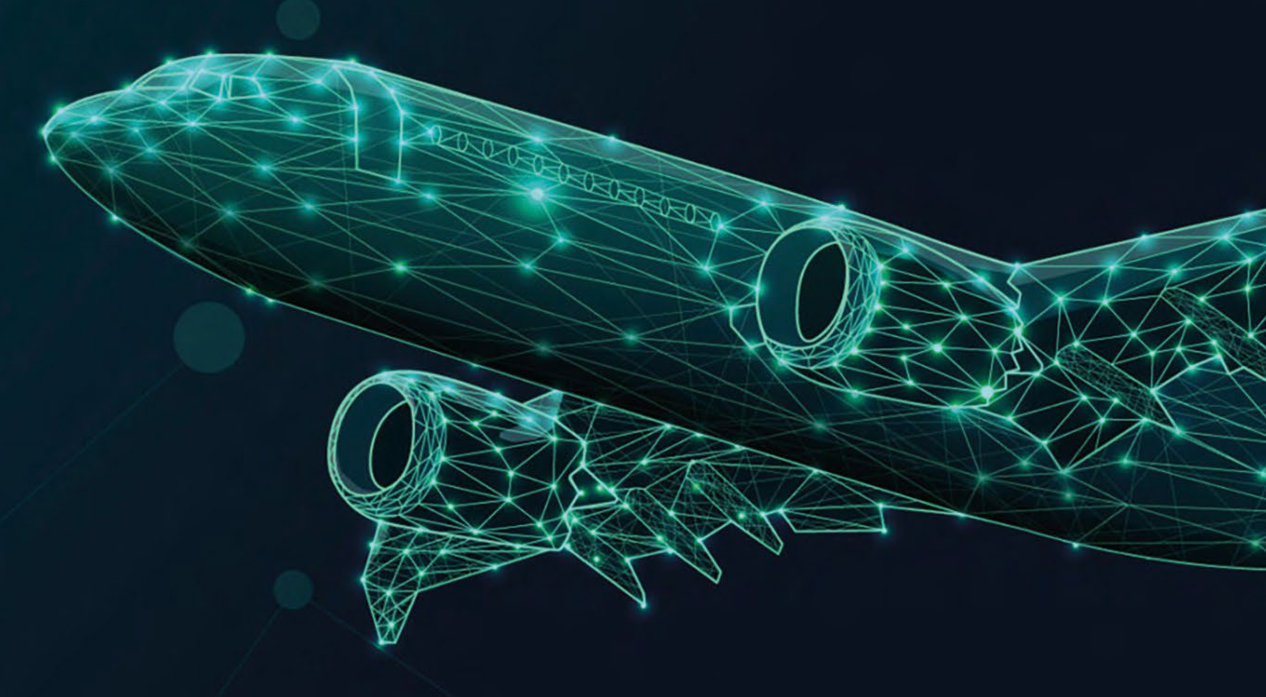

Meso-scale Modelling of Fatigue Delamination Growth in CFRP

B. Zhang, G. Allegri, S.R. Hallett

OVERVIEW

The University of Bristol have developed an advanced Cohesive Zone Model (CZM) for predicting fatigue delamination in composites. For industrial applications, the fatigue CZM has been compiled in a user-defined material subroutine in the commercial FEA software Abaqus/Explicit. The fatigue CZM development is motivated by two key considerations: 1) delamination (interlaminar failure) is the critical failure model in composite structures under cyclic loading; 2) it is generally accepted that fibre-reinforced composites perform better than metals, but the almost unavoidable manufacturing-induced defects, e.g. wrinkles and cut-plies, can knock down the fatigue strength of composite structures to a significant extent

LOAD-ENVELOPE APPROACH

- The numerical model is globally loaded under the peak or trough load envelope, so that a large numerical fatigue frequency can be used to speed up computational efficiency.

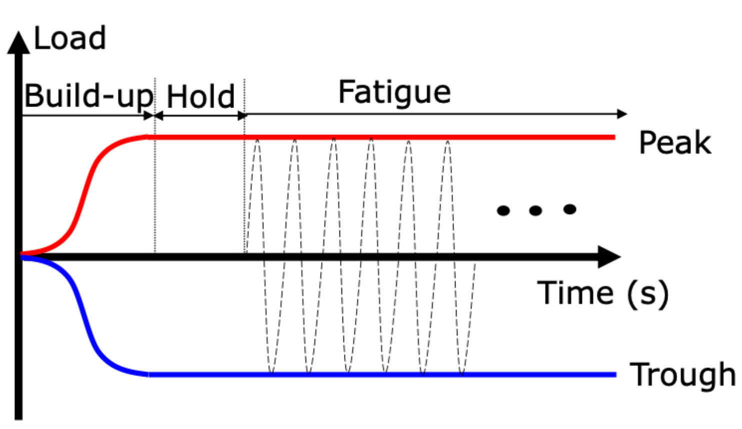

Fig. 1. Peak or trough load envelope applied to a composites model.

FATIGUE COHESIVE FORMULATION

- The inserted cohesive elements used to describe delamination follow a bilinear static and fatigue cohesive law.

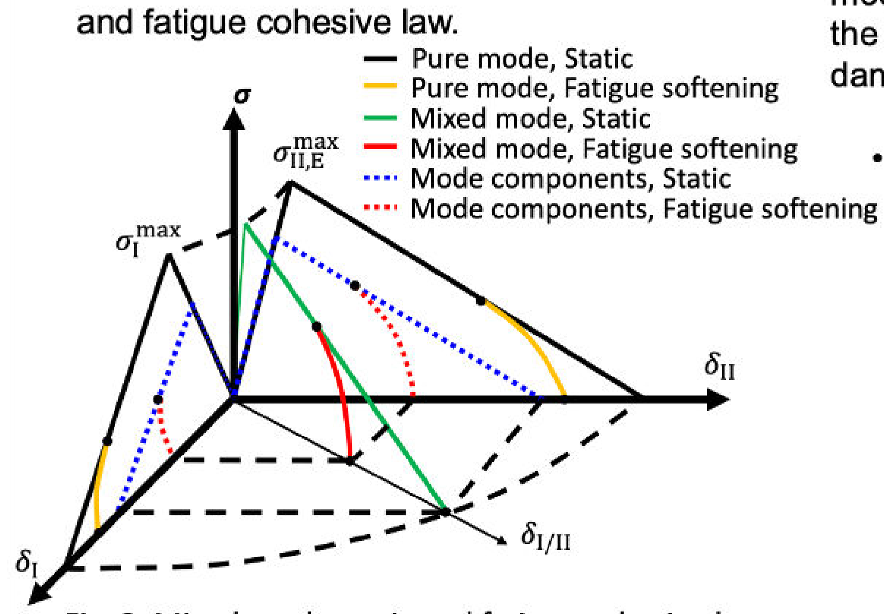

Fig. 2. Mixed-mode static and fatigue cohesive law.

- Fatigue damage initiation is controlled by a mixed-mode *S-N* formula and the Palmgren-Miner linear damage rule.

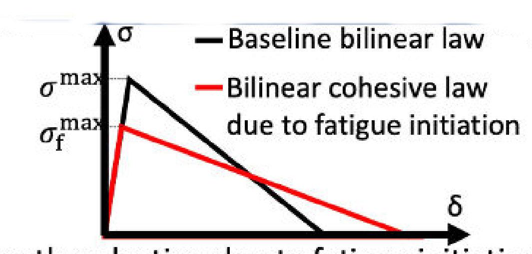

Fig. 3. Strength reduction due to fatigue initiation.

- A modified Paris law can be used to estimate crack growth rate da/dN. Alternatively, an Artificial Neural Network can be selected to estimate da/dN for negative and positive *R* ratios.

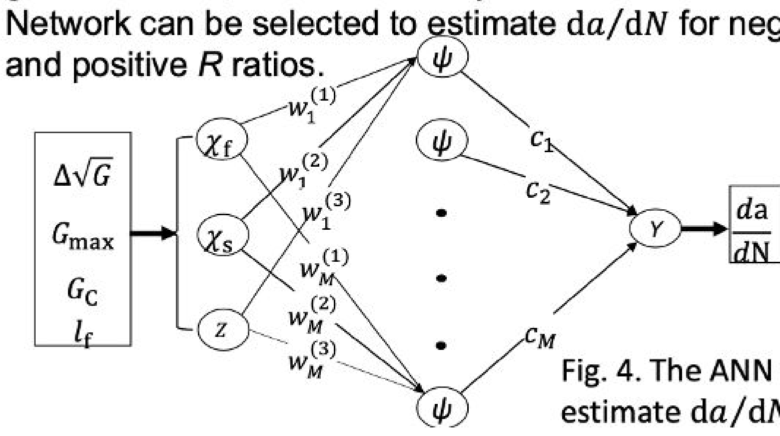

Fig. 4. The ANN used to estimate da/dN.

APPLICATIONS TO COUPONS WITH EMBEDDED WRINKLES AND PLY TERMINATIONS

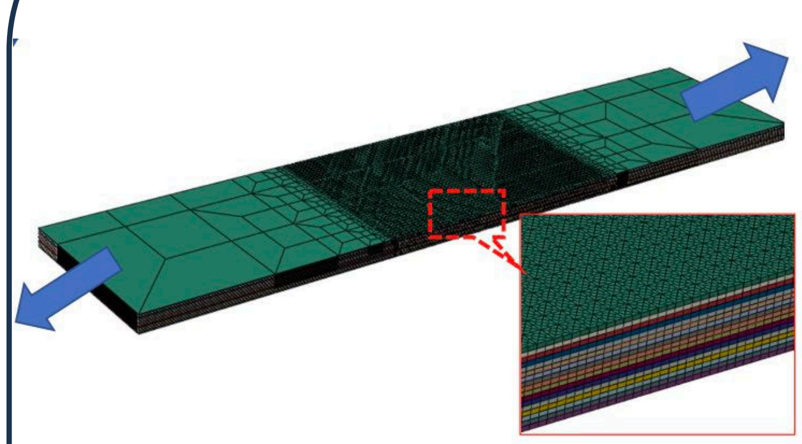

Fig. 5. Snapshot of pristine model.

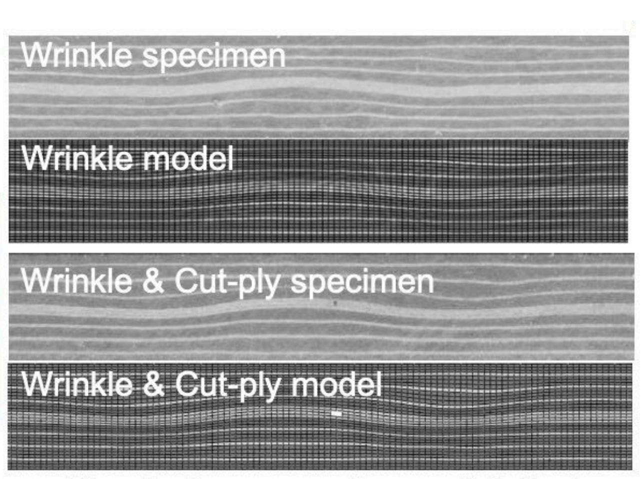

Fig. 6. Cross sections of defect specimens and models.

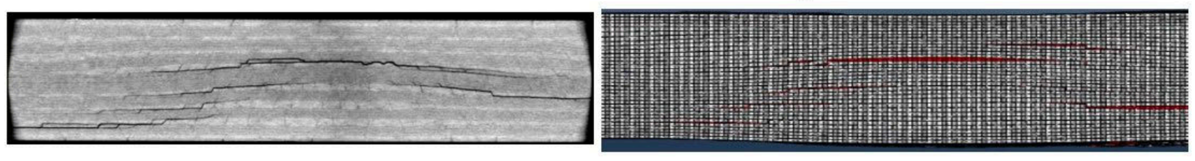

Fig. 7. CT observed and model predicted damage in the "wrinkle" case.

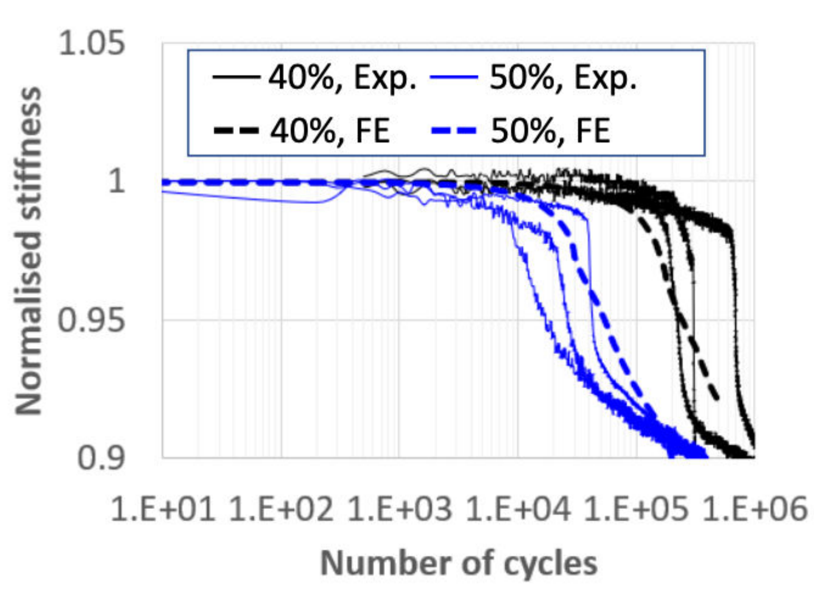

Fig. 8. Comparison between experiment and "wrinkle" model.

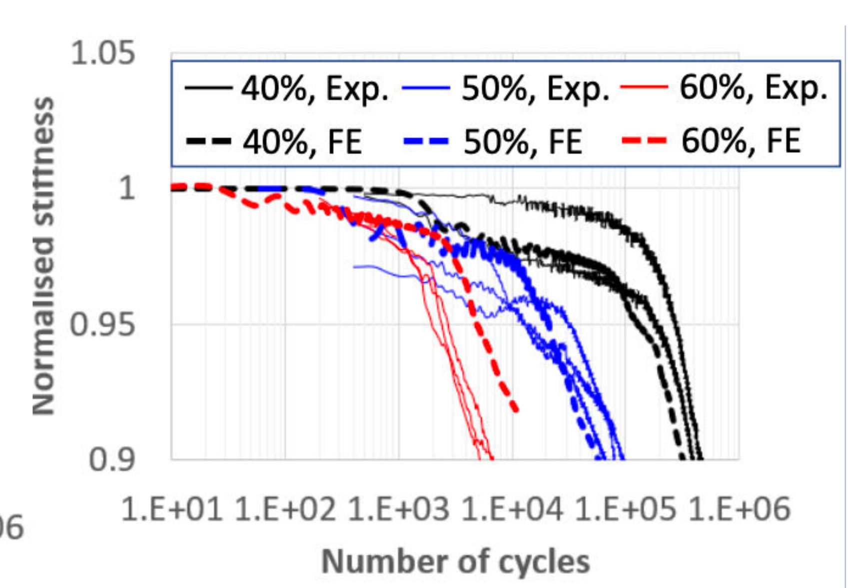

Fig. 9. Comparison between experiment and "wrinkle & cut-ply" model.

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