D-STANDART:

Upgrading materials characterization for composite structures

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Advancements in Modelling and Characterization: Driving Innovation and Sustainability in Advanced Materials | EMMC – 8 April 2025

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d-standart.eu

01

D-STANDART project background

motivation and context

section 01

D-STANDART background

project motivation

Situation

- Composite materials crucial for sustainable future
  - Aircraft 50% or more out of fibre-reinforced plastics
  - Wind energy sector with larger turbines
- Extreme loads and stress cycles during product lifetime
- Damage tolerance needed to extend lifespan

Challenge

- Lack of fundamental knowledge regarding damage growth process under cyclic loading
- Complex interaction of fibres, fibre orientation, and matrix materials
- Every new design requires multiple new tests at different scales
- Imperfect solutions: high-safety factors, 'no growth' criterion

Consequence

Composites products are

- Expensive
- Laborious
- Inefficient to manufacture

NEED ▷ **A better understanding of fatigue characterization at the meso-scale, so that we can scale up the gained insights to larger composite structures**

Section 02

Project context

problem statement

For composites: each combination of lay-up/fibre/resin + mfg. process is in essence a new 'material'

Practical consequence: design freedom is limited to qualified layups

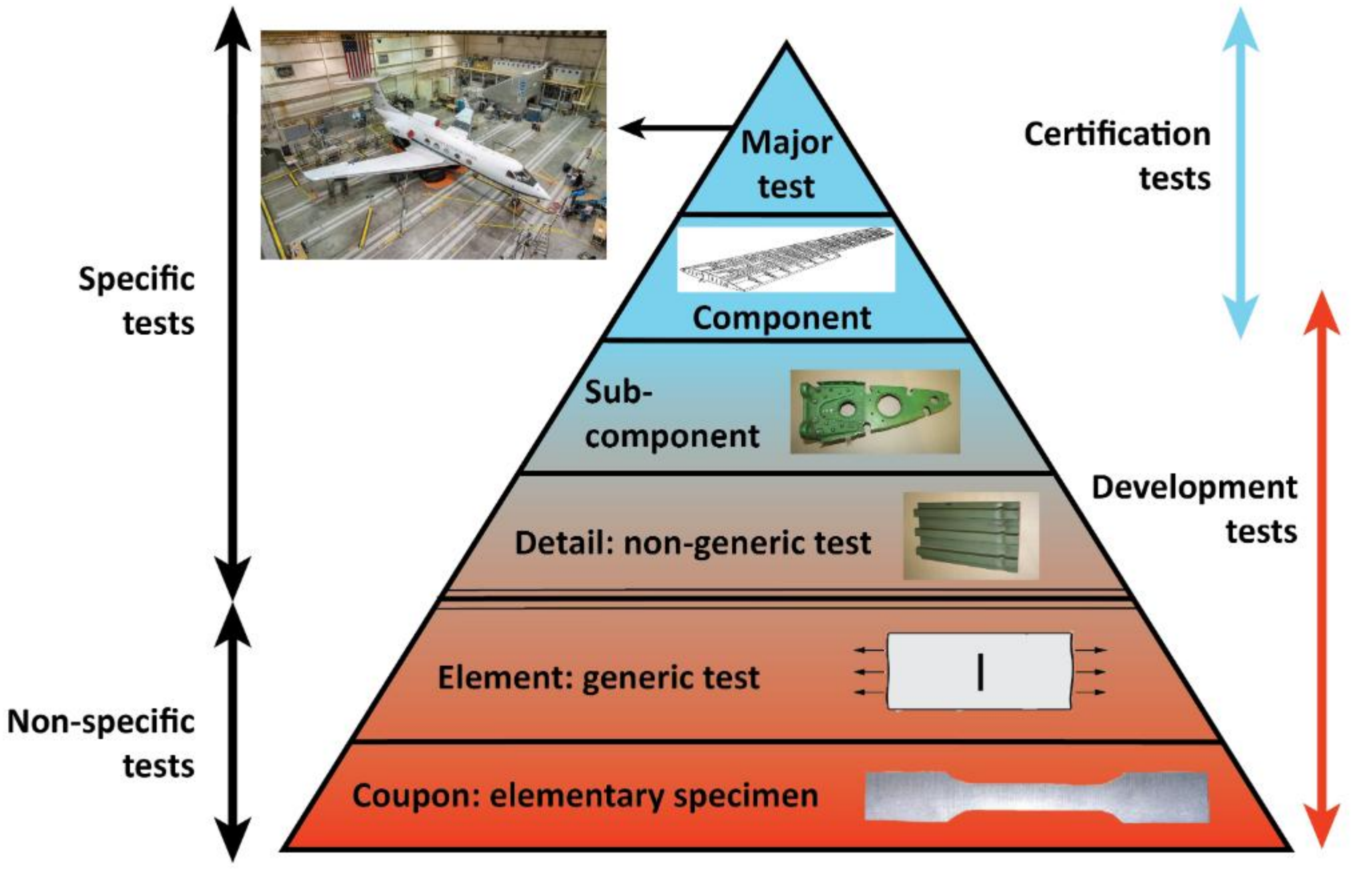


Image: Alderliesten (2018), Introduction to Aerospace Structures and Materials, TU Delft Open, CC-BY-NC-SA 4.0
https://doi.org/10.5074/t.2018.003

02

D-STANDART project overview

objective / approach / impact

section 02

D-STANDART objective

project intent

What?

Develop **rapid** methods to **characterize fatigue damage** in composites and **sustainability of composite** supply chains; and thereby **model the durability** and sustainability of large-scale composite structures with arbitrary layups **under realistic conditions** (operating loads, application environment, and impact of manufacturing features)

How?

- **Through minimal and accelerated testing** of generic specimens
- Transferring the results of the experiments to large-scale structures using **artificial intelligence and machine learning**

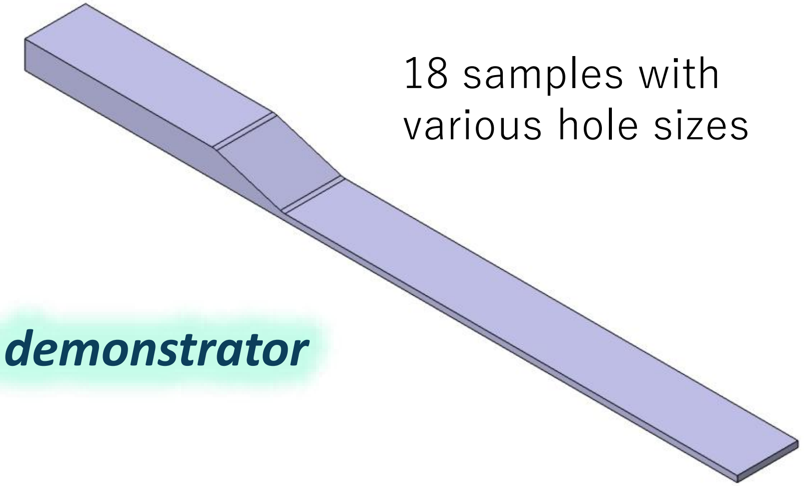
Impact?

Enabling **reduced time-to-market, material waste, and increased lifespan** of composite products in the **aerospace and wind energy** industries

section 02

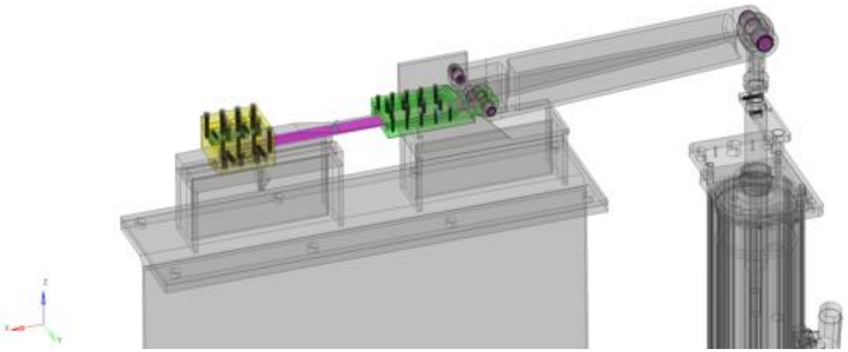
Validation cases

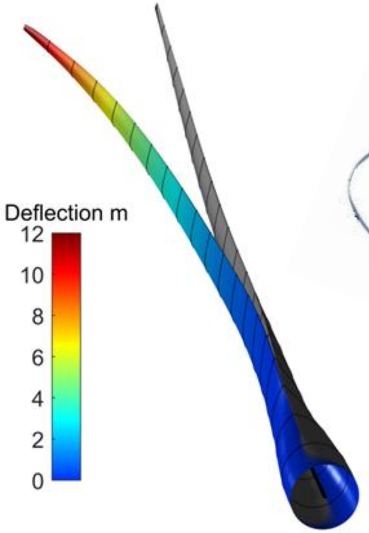
two demonstrators

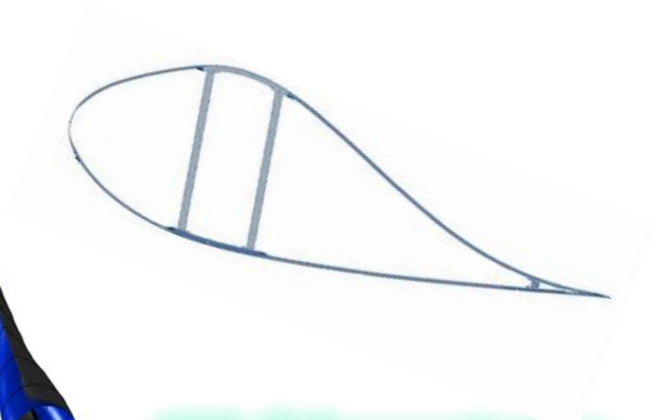


18 samples with
various hole sizes

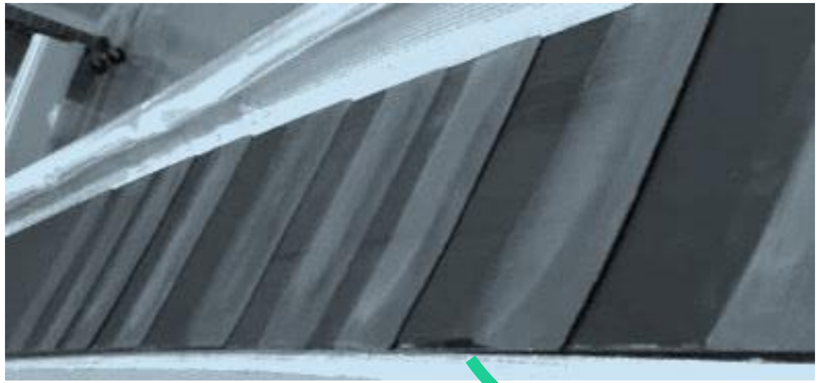
Aero demonstrator

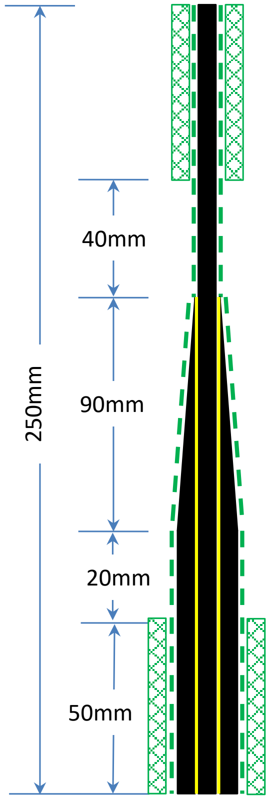






Wind demonstrator



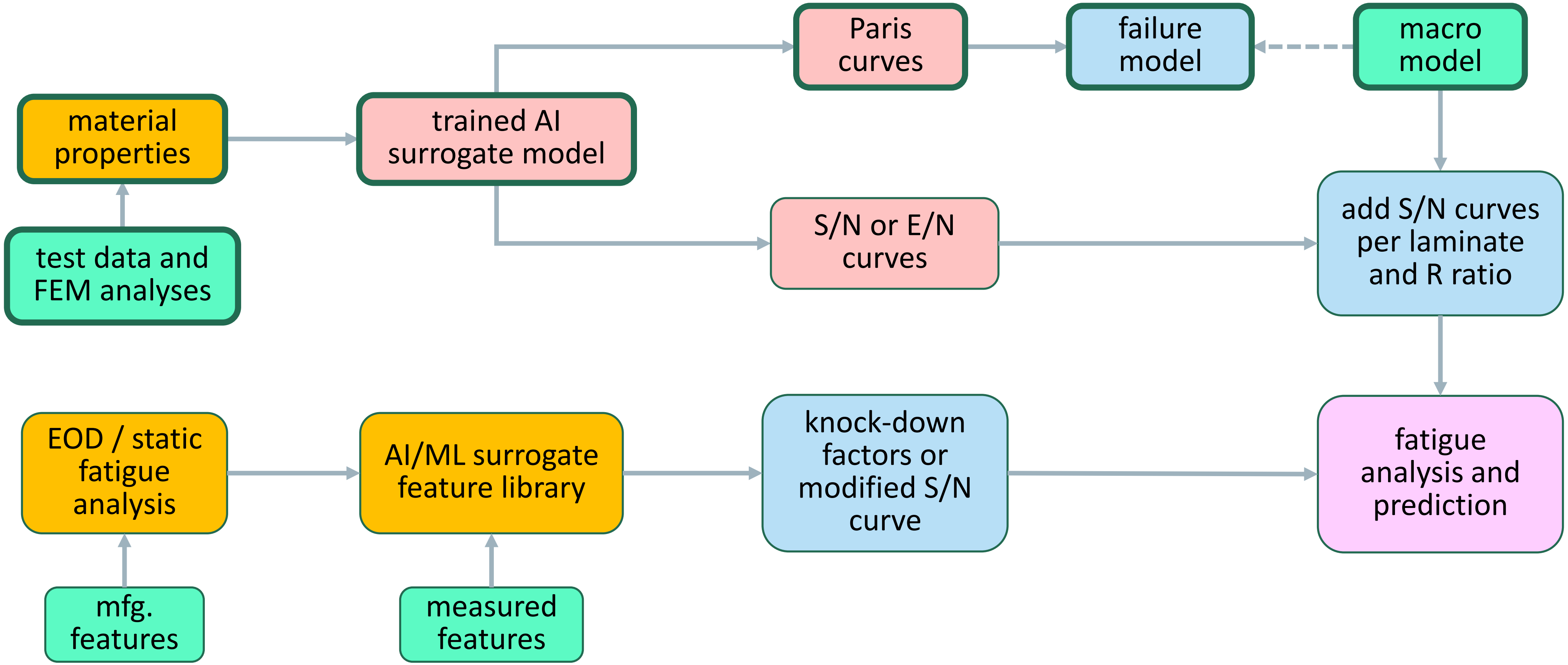


03 D-STANDART characterization and modelling approach

methods & results

D-STANDART approach

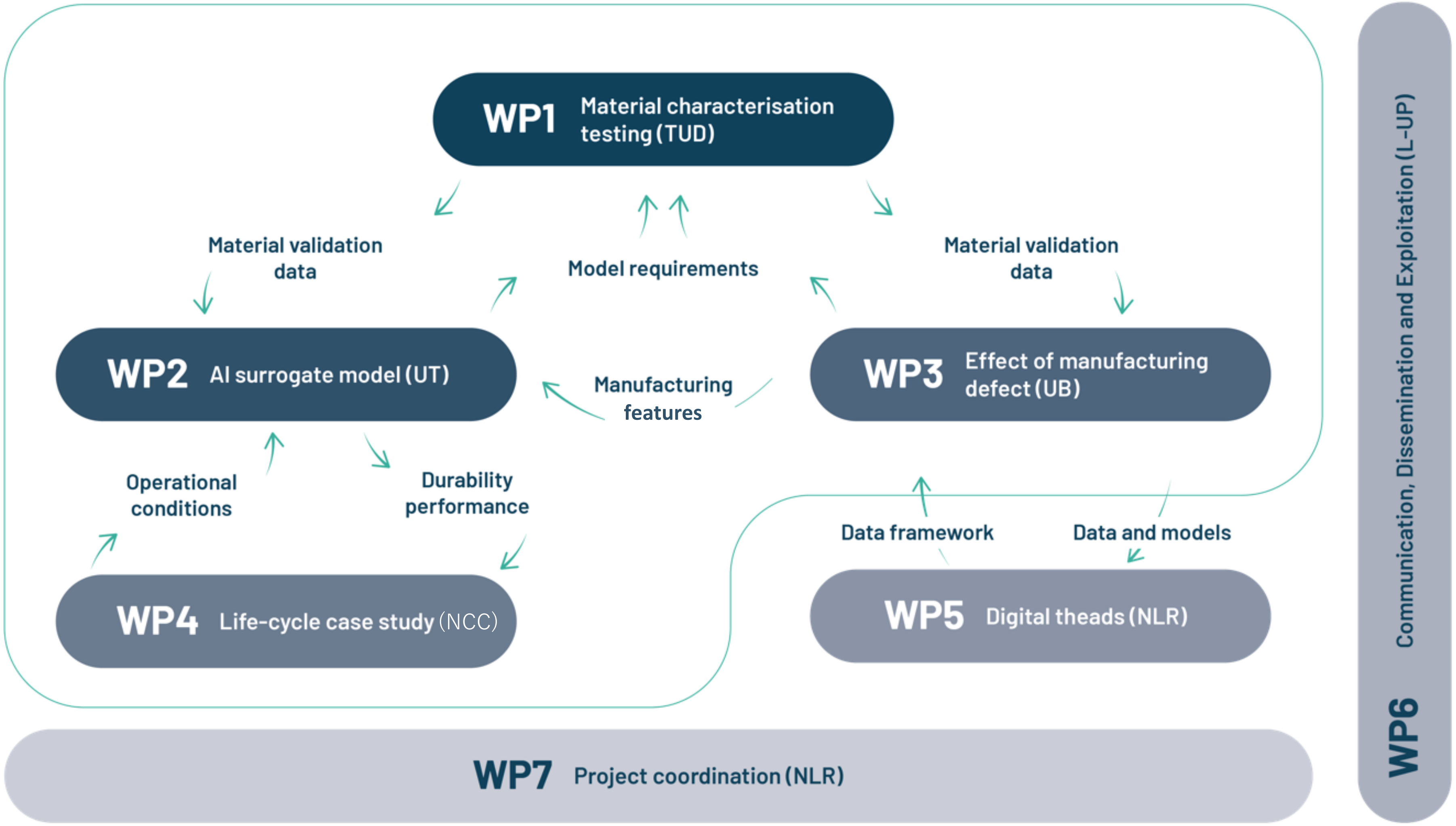
leveraging AI to quickly infer composite material properties based on hundreds of tests and analyses



section 03

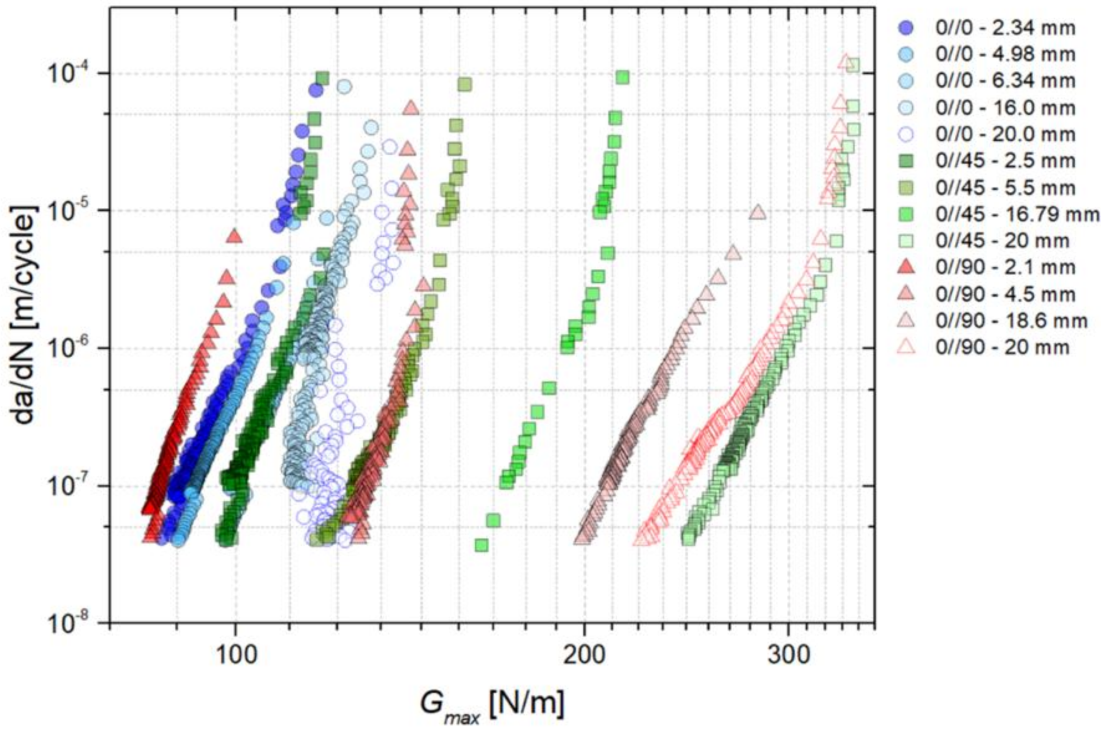
D-STANDART partners

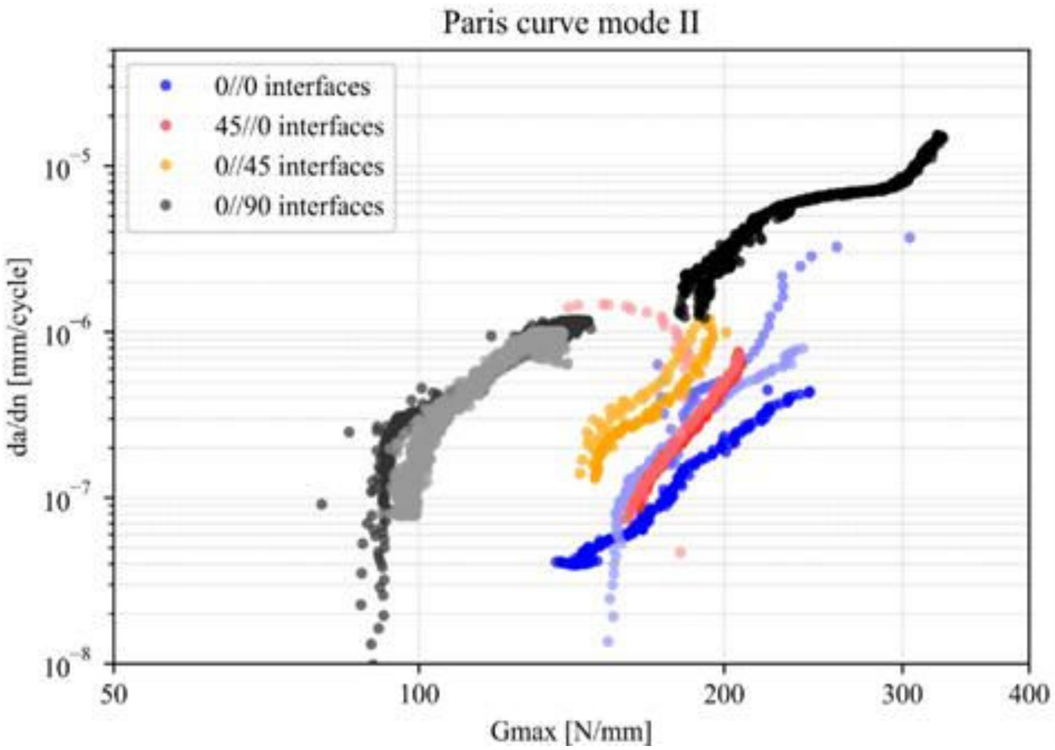
and collaboration



WP1: Fibre orientation effect

based on existing ASTM / ISO standards





Mode I: Main effect at longer pre-cracks -> more fibre bridging

Mode II: Strong effect, also for short pre-cracks

WP1: ANN to capture fibre orientation effect

ongoing trials

ECCM21
02-05 July 2024
Nantes - France

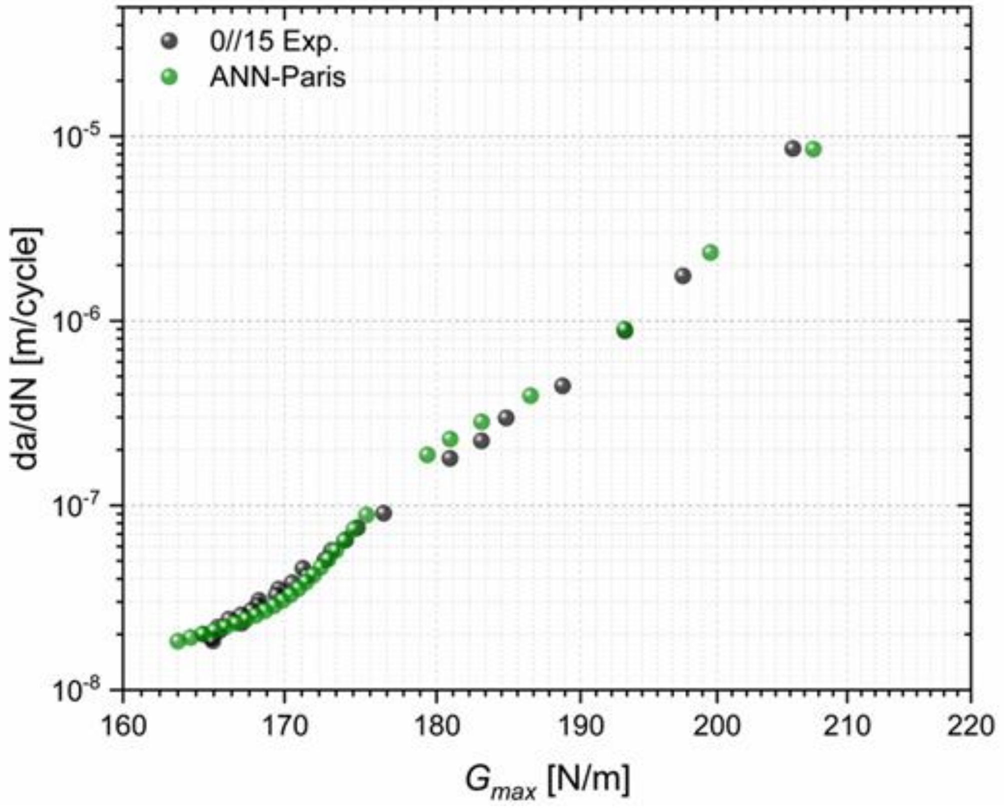
Proceedings of the 21st European Conference on Composite Materials
Volume 8 - Special Sessions

571
1420

Identifying the Most Effective Data Processing for Fatigue Delamination Growth in FRPs: Insights on Artificial Data Simulation

Francisco Maciel Monticeli[1*], Yasmine Mosleh[2], John-Alan Pascoe[1]

NTENTS



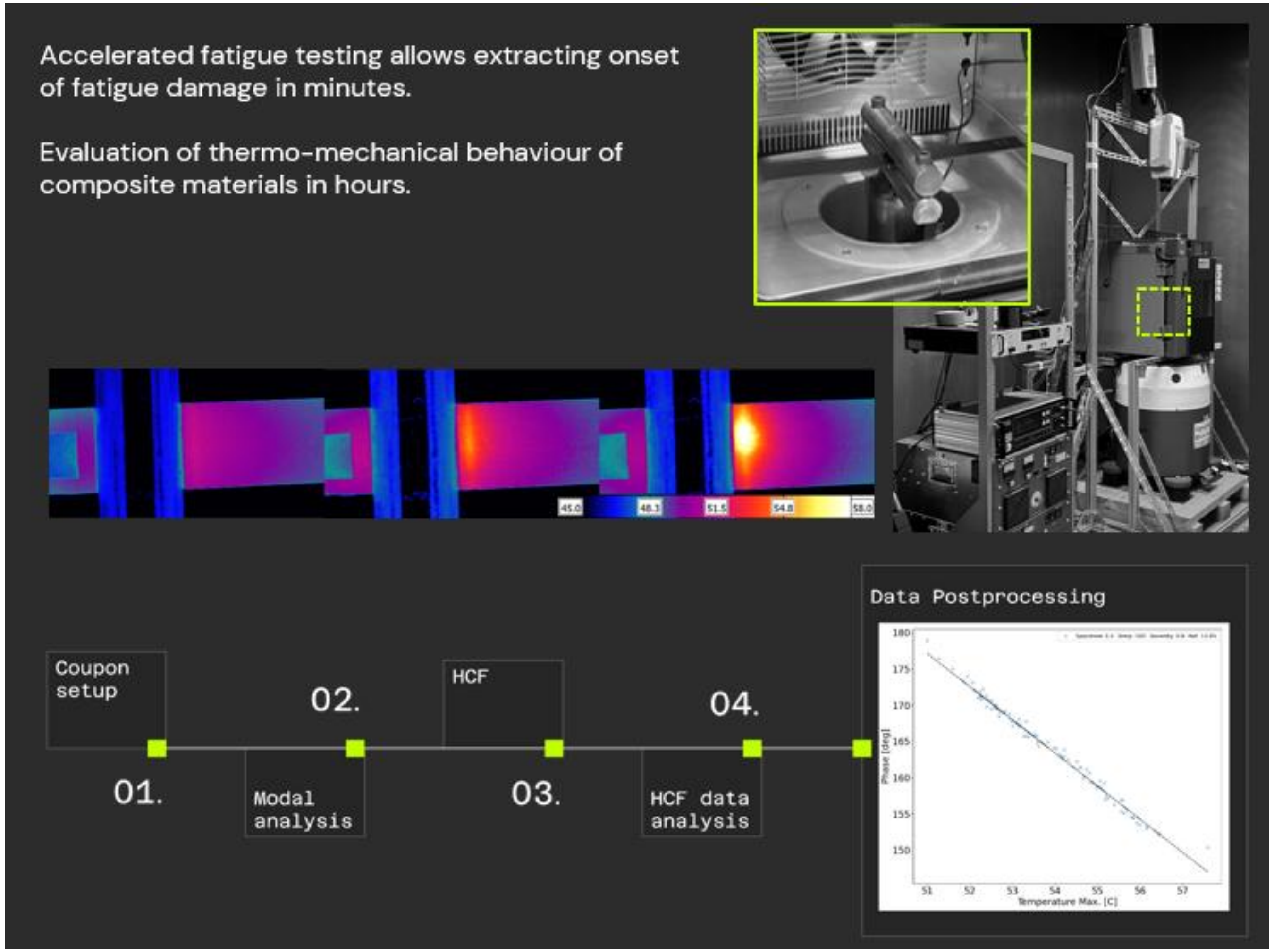
Model trained on 0//0, 0//45, 0//90 data; validated against 0//15 data

“Scalable surrogate modelling with uncertainty quantification – adaptive sparse Gaussian process regression” (WebEx seminar this coming June)

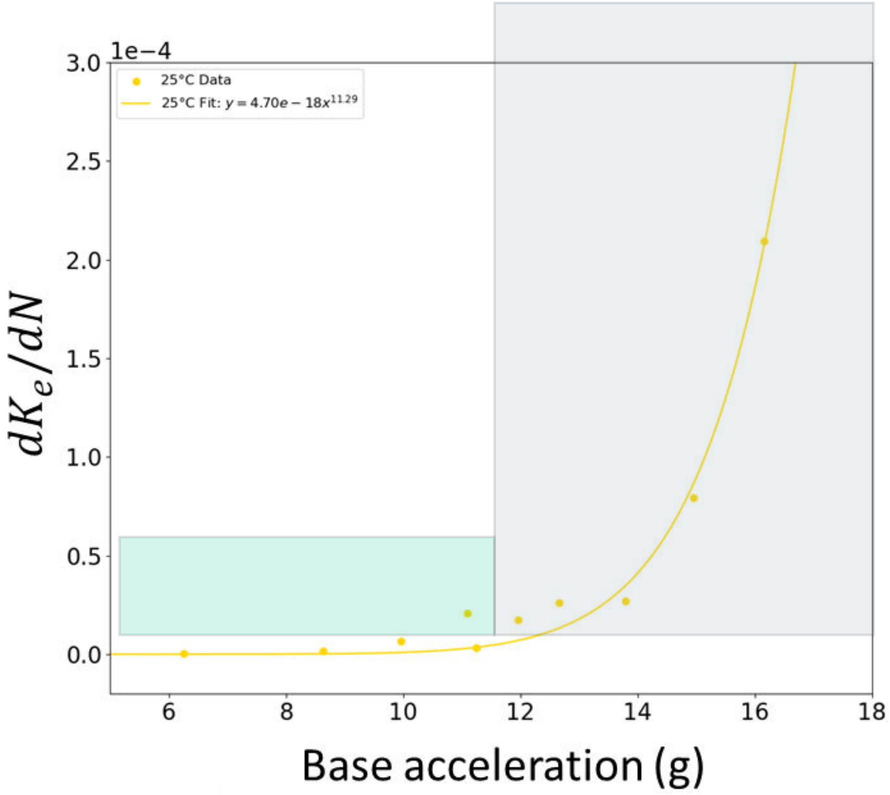
>> see **d-standart.eu/d-standart-academy**

WP1 & WP2: High-frequency testing

accelerated failure testing



The onset fatigue master curve indicates the transition from onset to propagation of fatigue damage.



WP3: Modelling of mfg. features

high-fidelity FEA

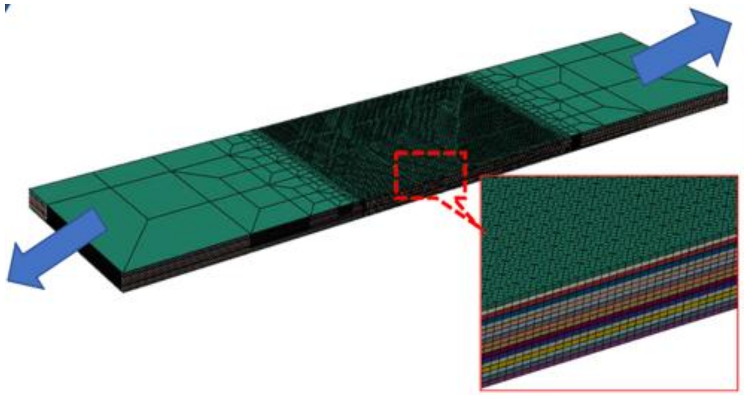


Fig. 5. Snapshot of pristine model.

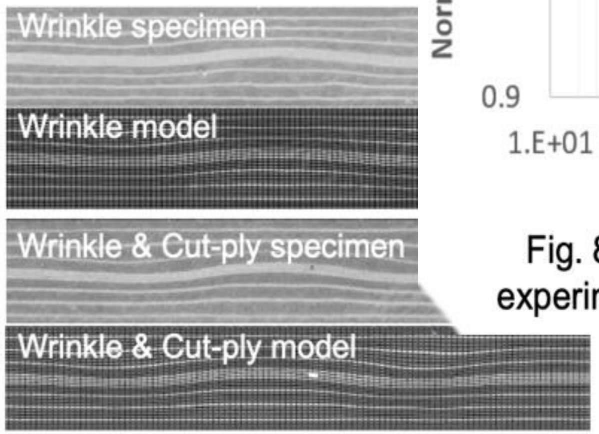


Fig. 6. Cross sections of defect specimens and models.

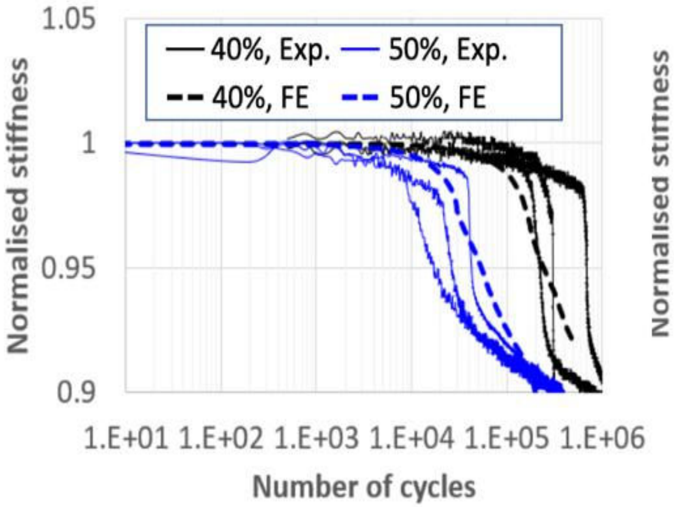


Fig. 8. Comparison between experiment and “wrinkle” model.

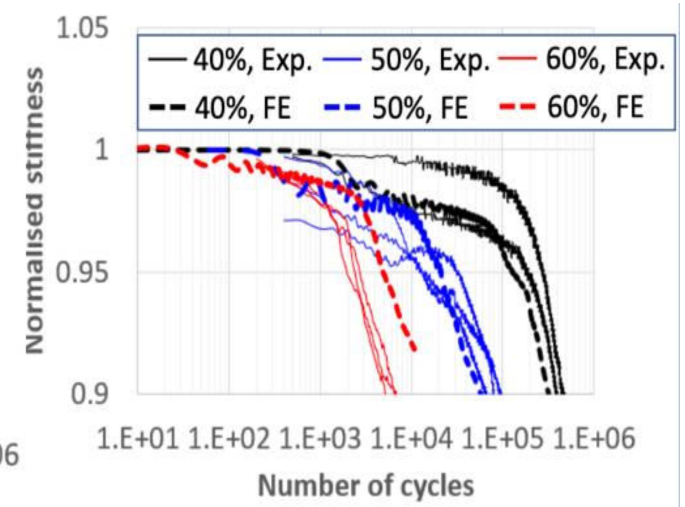


Fig. 9. Comparison between experiment and “wrinkle & cut-ply” model.

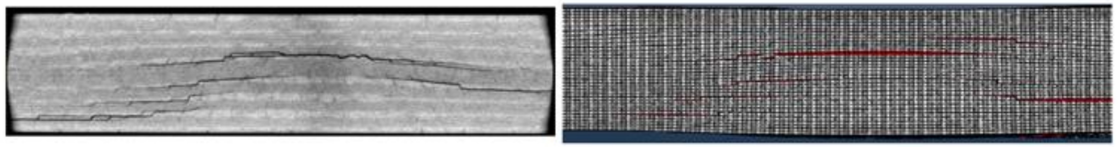
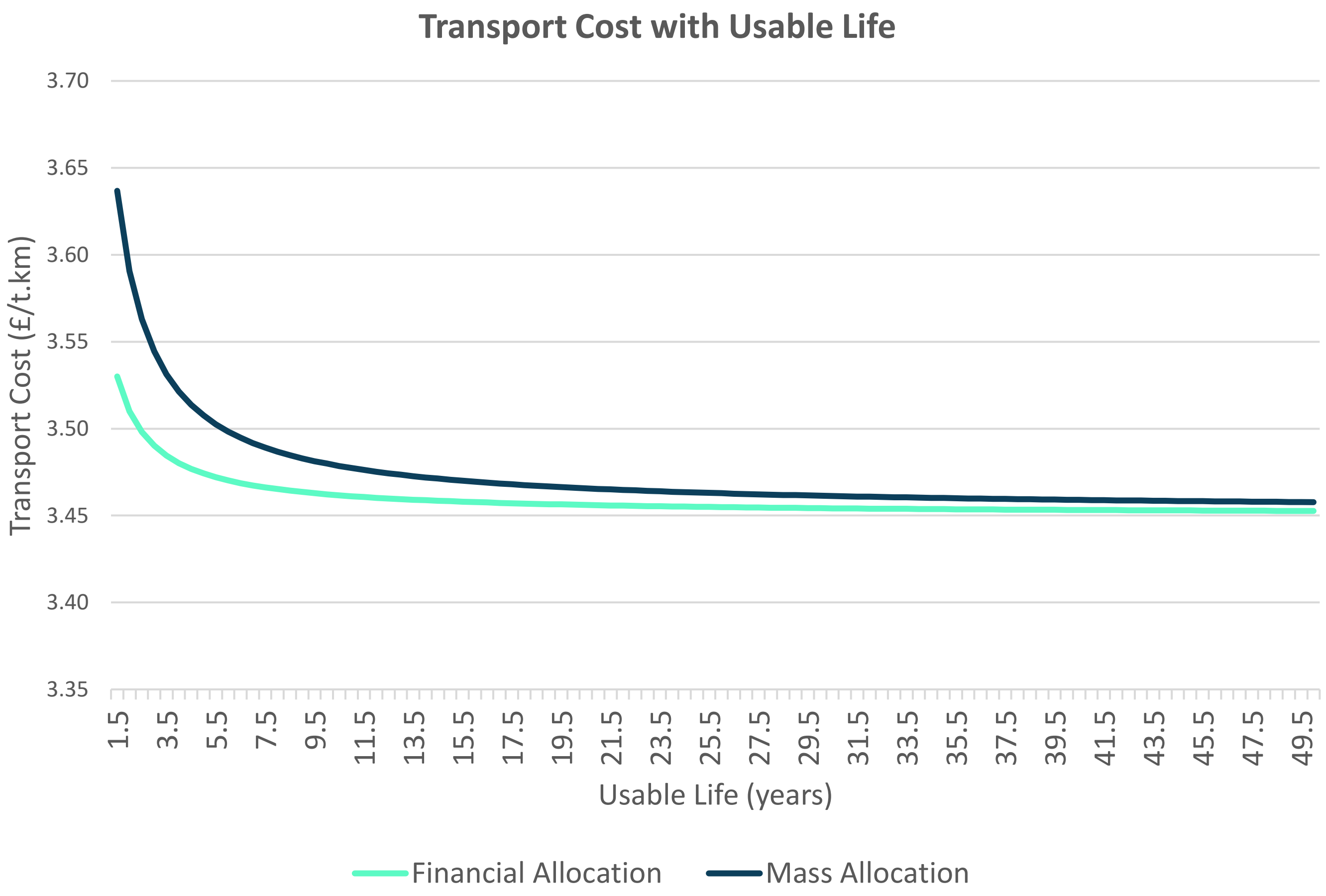


Fig. 7. CT observed and model predicted damage in the “wrinkle” case.

WP4: Relationship of LCA/C to Durability

use case: aerospace turbine blades

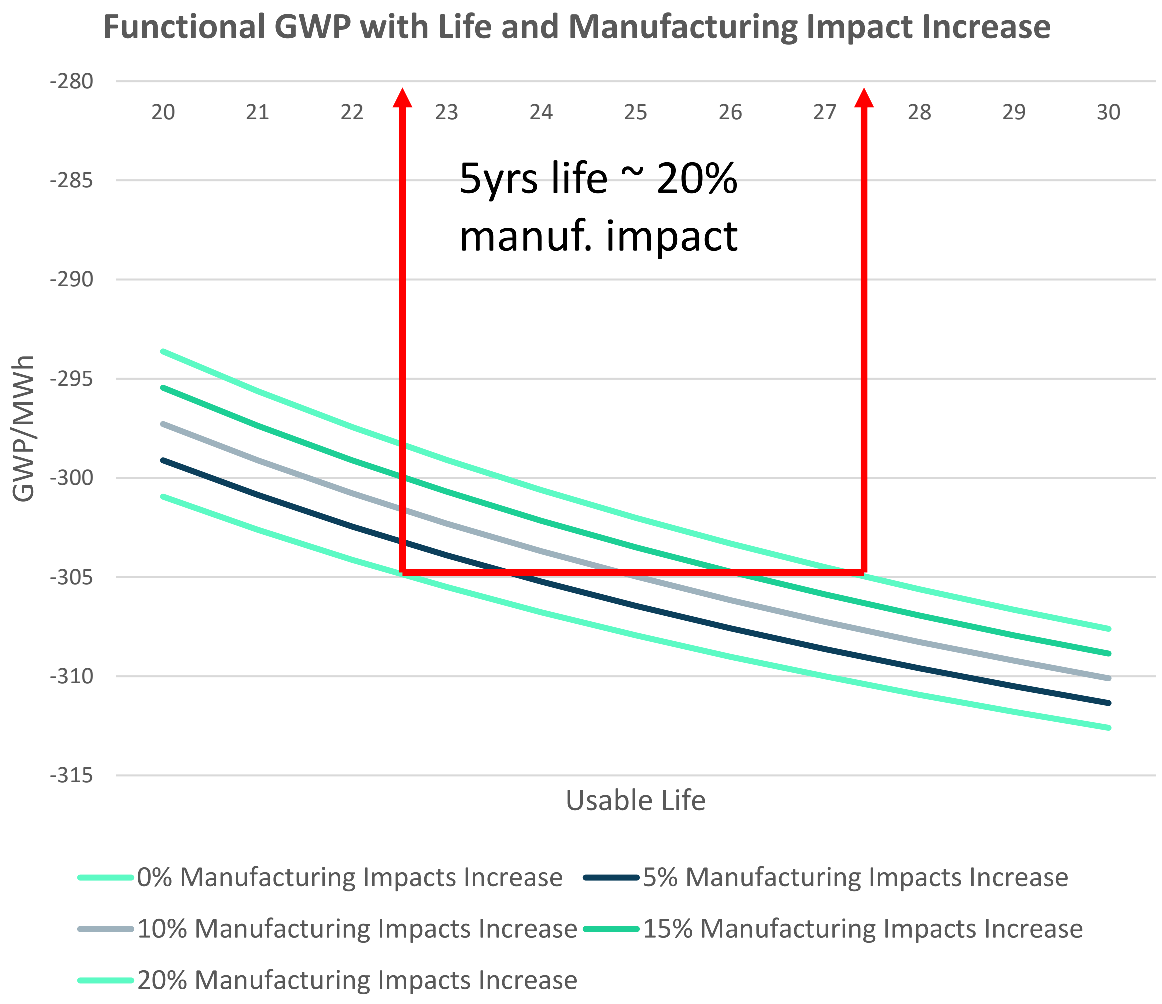


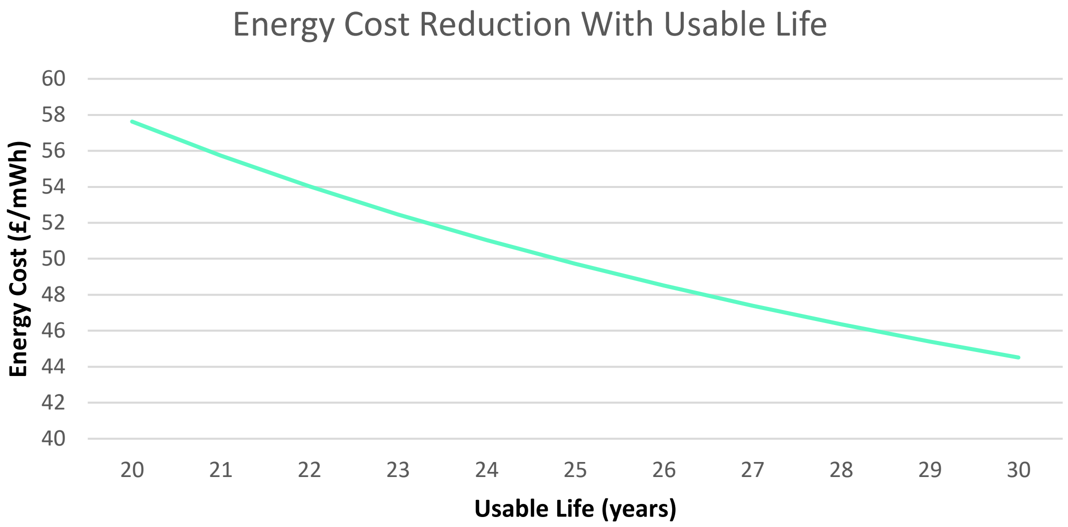
- Transport costs are quickly eclipsed by use phase, plateauing after 20 years
- Extension of life has minimal cost reductions, with a 10-year life extension only reding lifecycle cost by 0.07%

section 03

WP4: Relationship of LCA/C to Durability

use case: wind farm turbine blades





Life Extension (years)	LCOE ($/MWH)	Cost Savings (% from standard life)
(20+) 1	55.7	3.1
(20+) 5	49.7	13.9
(20+) 10	44.5	24.3

WP5: Bridging the scales with data

digital thread to support AI-based surrogate modelling as well as future exploratory research

Experimental data
- Capturing fibre orientation effect
- Capturing manufacturing features

High fidelity mesoscale models
- Validated with experimental data
- Including manufacturing features

Synthetic data
- Database of material fatigue responses at mesoscale

AI model
- Gaussian processes to interpolate material behaviour

Surrogate model
- Material constitutive behaviour

Macroscale FE analysis
- Large structure, coarse mesh
- Surrogate model provides material response

Digital thread

- Facilitate data exchange
- Maintain traceability from macroscale FE results all the way back to the raw materials used

04

D-STANDART, EMMC & EMCC

alignment

EMMC & EMCC alignment

D-STANDART

Priority to align with EMMC and EMCC objectives since proposal stage

Five complimentary activities:

- Test methodology
- Lifecycle assessment
- **Materials characterization**
- AI-enabled material modelling
- Digital thread

Yielding five distinct and tangible outcomes:

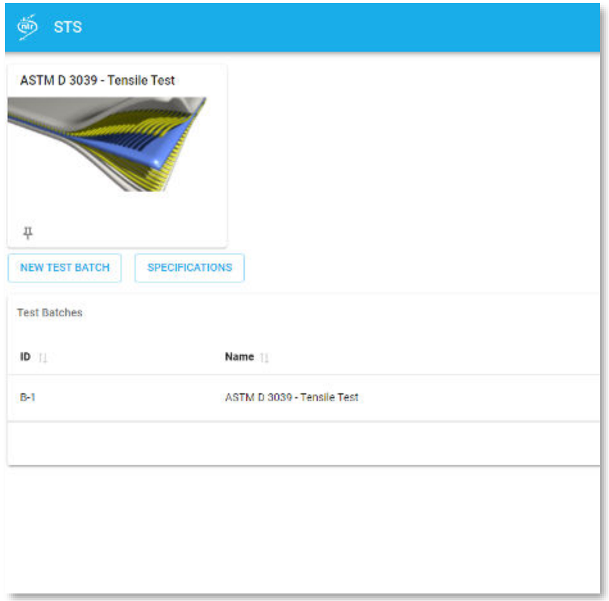
- A novel approach for accelerated fatigue testing
- A repository of materials data under fatigue loading
- A repository of multi-scale models capable of modelling “feature-free” layups and specimens with manufacturing defects
- Demonstrating the impact of our approach through TEA and LCA
- A roadmap aligned with EMCC/EMMC to include proposed ongoing research and development prospects

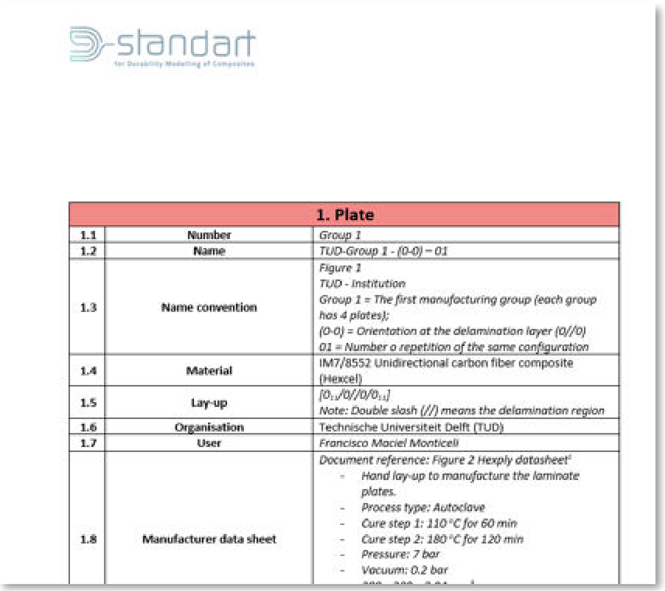
section 04

EMMC & EMCC contributions

application and extension of standards

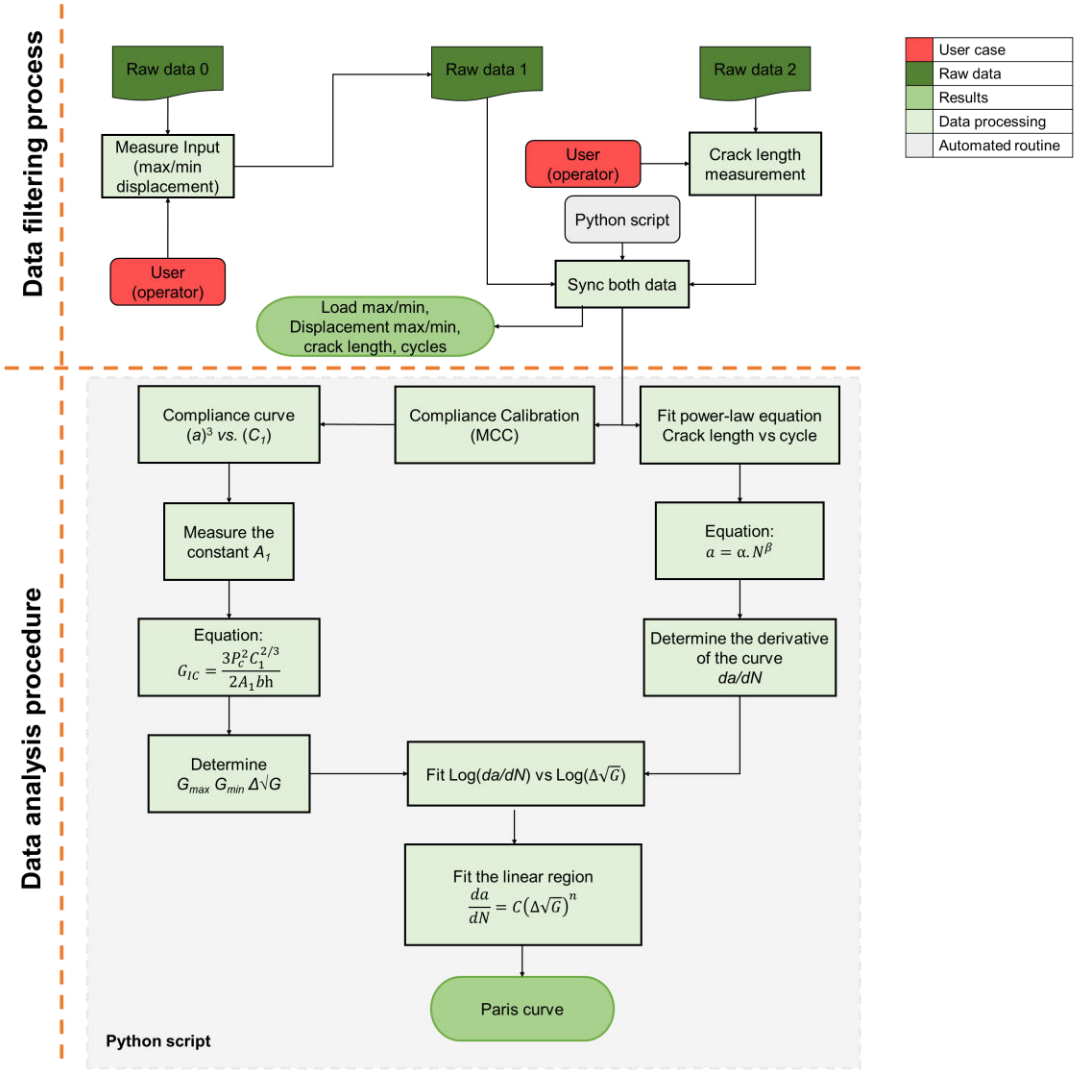
- CHADA and MODA templates in use for meta-data capture within D-STANDART
- CHAMEO tags integrated into digital thread infrastructure
- CENELEC CWA updated to support composite materials





d-standart

1. Plate		
1.1	Number	*Group 1*
1.2	Name	*TUD-Group 1 - (0-0) – 01*
1.3	Name convention	*Figure 1* *TUD - Institution* *Group 1 = The first manufacturing group (each group has 4 plates);* *(0-0) = Orientation at the delamination layer (0//0)* *01 = Number o repetition of the same configuration*
1.4	Material	IM7/8552 Unidirectional carbon fiber composite (Hexcel)
1.5	Lay-up	*$[0_{11}/0//0/0_{11}]$* *Note: Double slash (//) means the delamination region*
1.6	Organisation	Technische Universiteit Delft (TUD)
1.7	User	*Francisco Maciel Monticeli*
1.8	Manufacturer data sheet	*Document reference: Figure 2 Hexply datasheet*[1] - *Hand lay-up to manufacture the laminate plates.* - *Process type: Autoclave* - *Cure step 1: 110 °C for 60 min* - *Cure step 2: 180 °C for 120 min* - *Pressure: 7 bar* - *Vacuum: 0.2 bar*



...thank you!

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standart
for Durability Modelling of Composites

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UK Research
and Innovation

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D-STANDART project consortium

members and beneficiaries

section 05

partners

consortium

GA: 101091409
Timeline: 1 Jan 2023 – 31 Dec 2025
Duration: 36 months

6 Beneficiaries, **4** Affiliates
3 Associated Partners
7 European countries

5 RTOs
1 IND
2 SMEs

section 05

advisory board

aerospace and wind energy representatives

Rolls Royce	Fokker Aerostructures	Siemens Gamesa	Embraer	Coexpair (SME)

section 05

cross-fertilisation

EC sister projects

Project No.	Project Name	Project Focus
101091409	D-STANDART	Durability Modelling of Composite Structures with Arbitrary Lay-up using Standardized Testing and Artificial Intelligence
101091621	AddMorePower	Advanced modelling and characterization for power semiconductor materials and technologies
101091534	KNOWSKITE-X	Knowledge-driven fine-tuning of perovskite-based electrode materials for reversible Chemicals-to-Power devices
101091687	MatCHMaker	Open data and industry driven environment for multiphase and multiscale Materials Characterization and Modelling combining physics and data-based approaches
101092211	CoBRAIN	Integrated Computational-Experimental material Engineering of Thermal Spray coatings
101091912	AID4GREENEST	AI powereD characterization and modelling for GREEN STeel technology