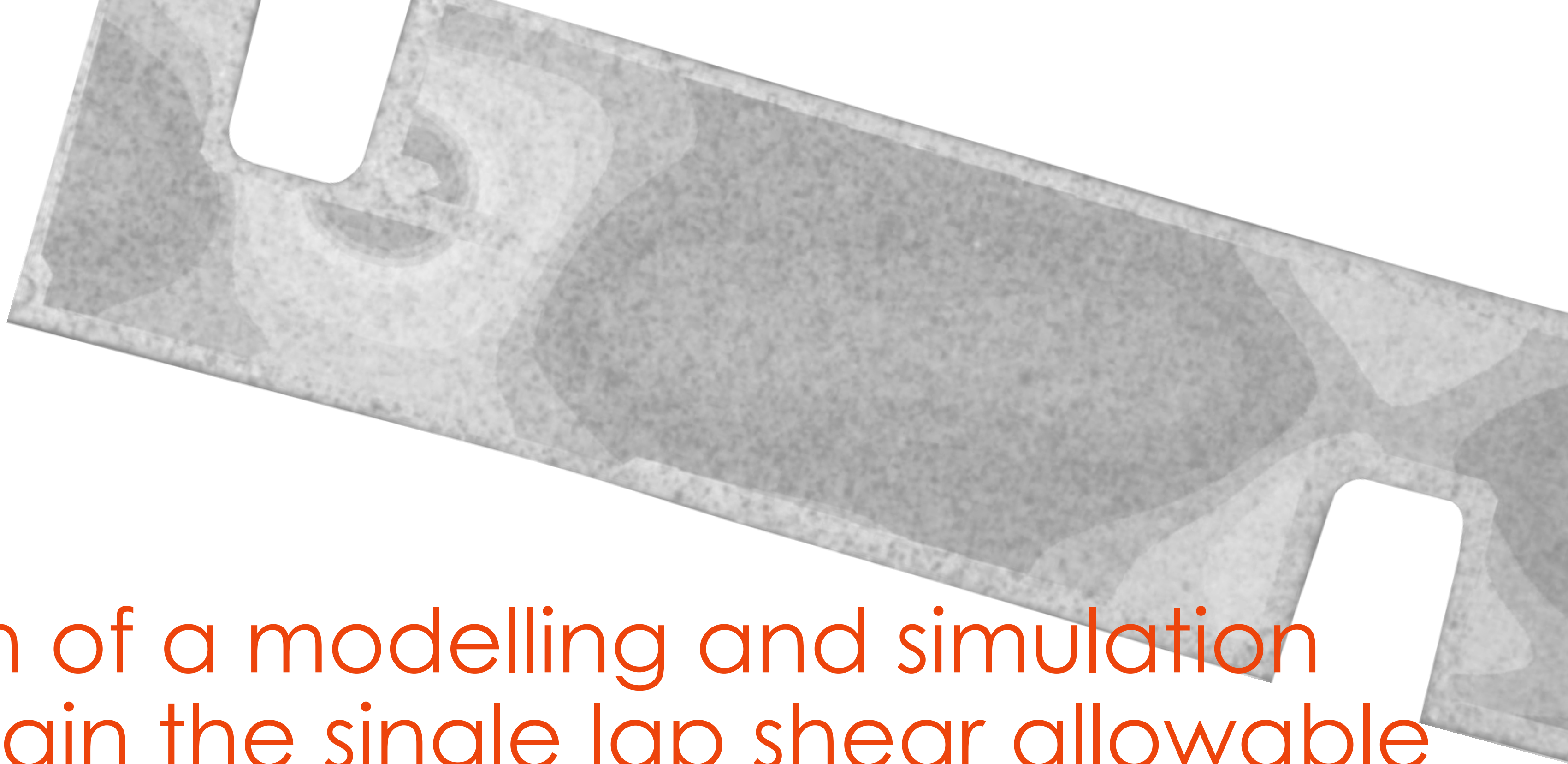

On the validation of a modelling and simulation approach to obtain the single lap shear allowable strength

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ANALYSIS AND ADVANCED MATERIALS FOR STRUCTURAL DESIGN

Universitat de Girona

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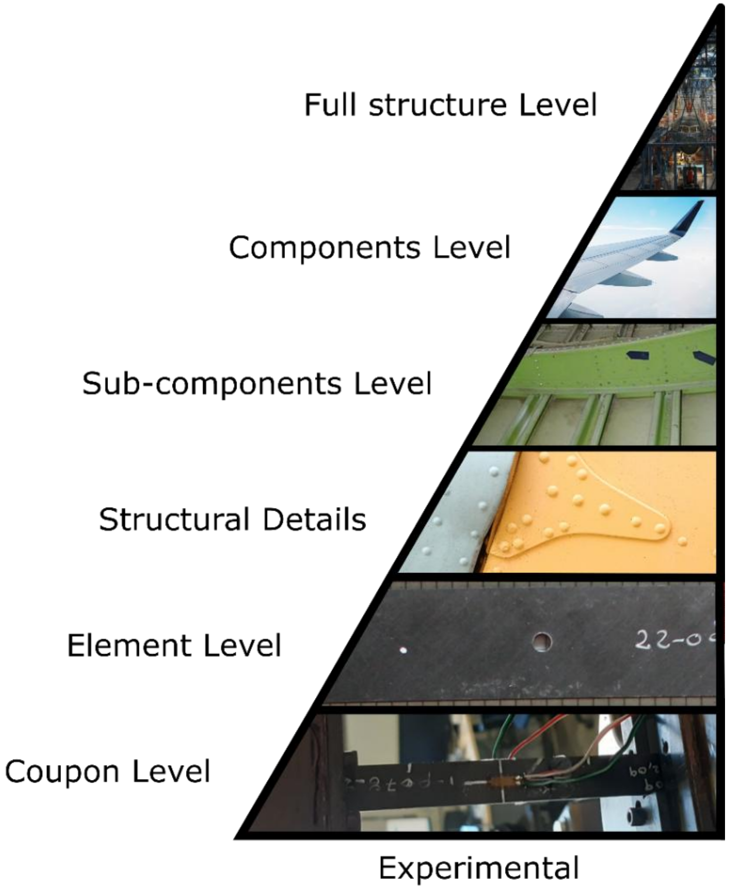
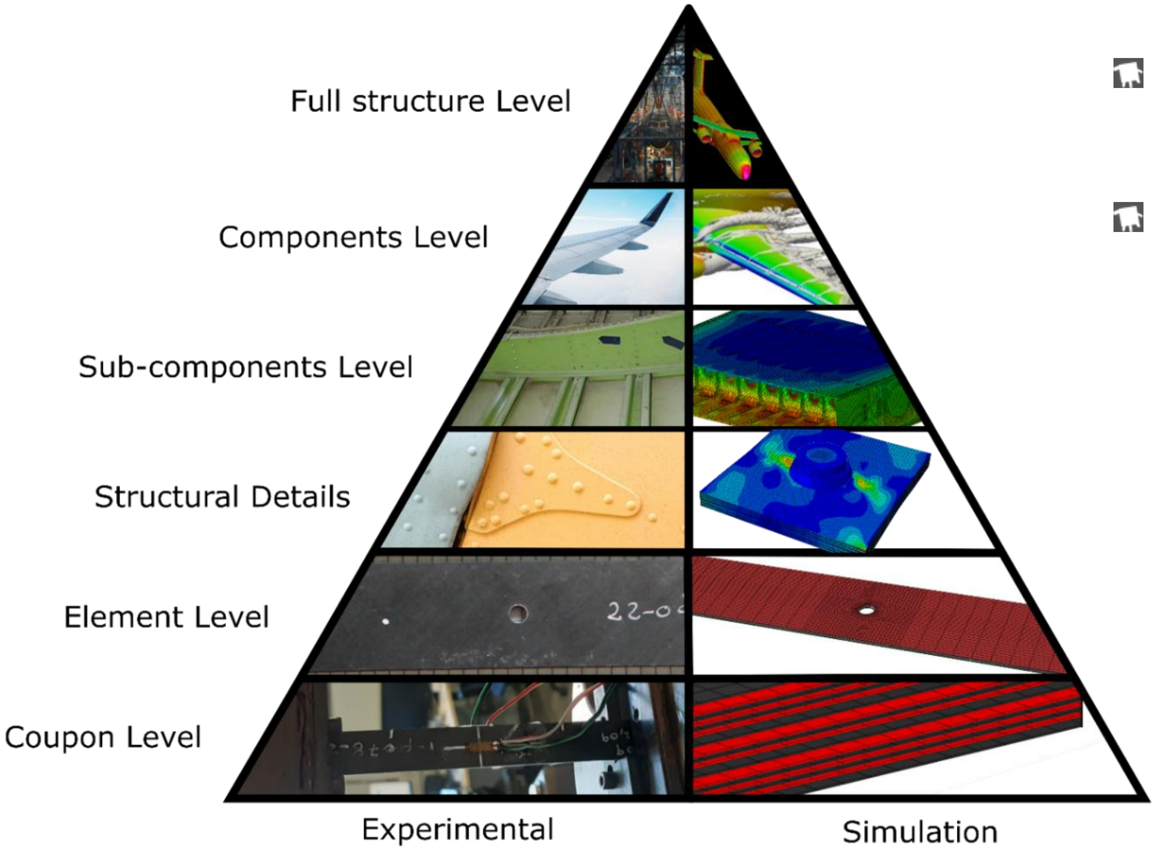
Introduction



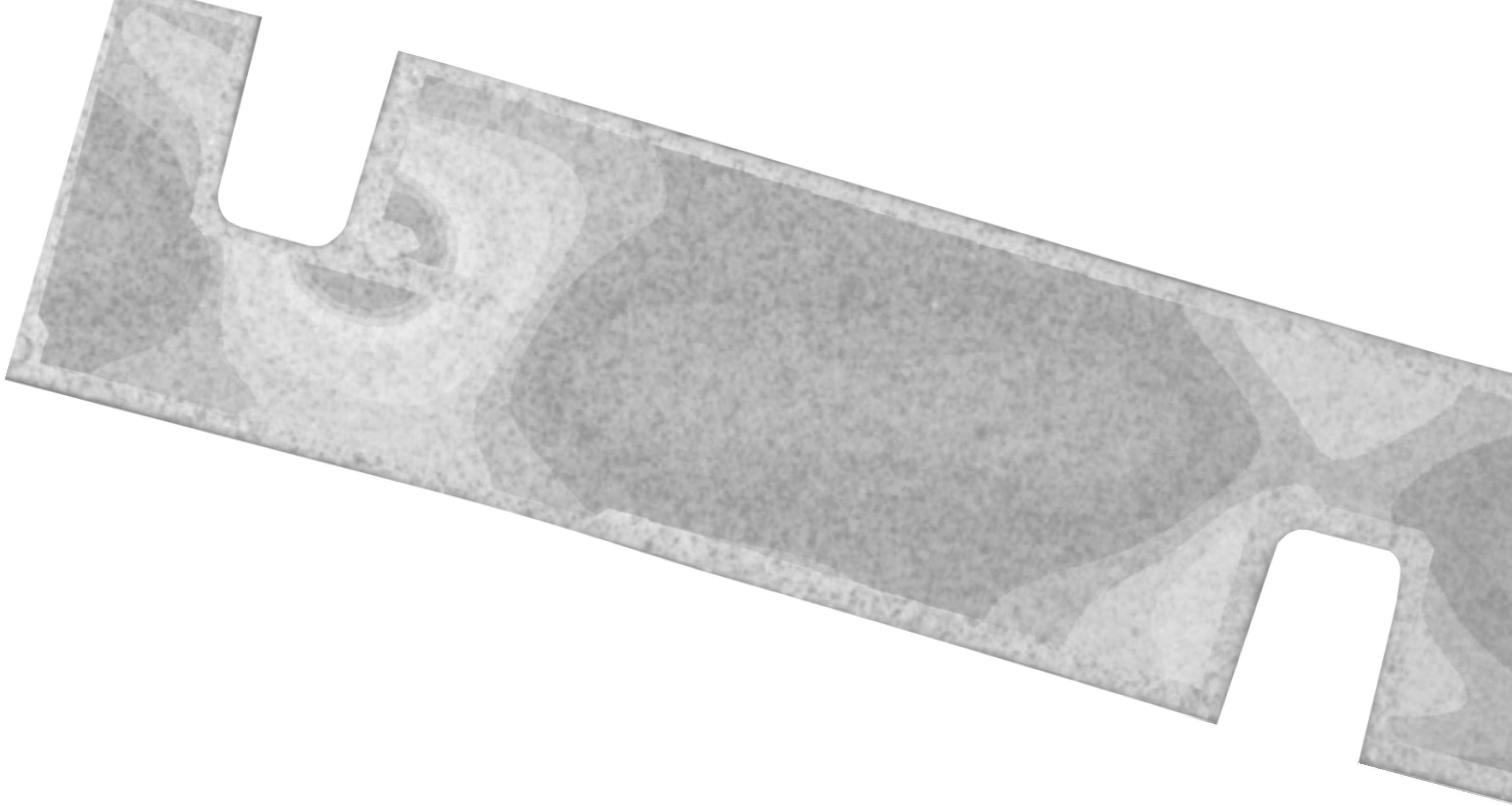
- Manufacturing processes for CFRP components are complex and may lead to defects, flaws…
- The certification method is nowadays based on experimental testing.
- At lower levels, conducting tests to statistically quantify the uncertainty, obtaining design allowables (DA).
- The requirement of high number of samples limits the weight-saving potential offered by the CFRPs.

Aim of the research

The generation of a **model and simulation approach** for the quantification of DA based on High fidelity models (HFM), with the same uncertainty.



- HFM: Deterministic result
- Design of experiments for the input material properties experimentally obtained.



Methodology

Model and simulation approach

Deterministic Validation

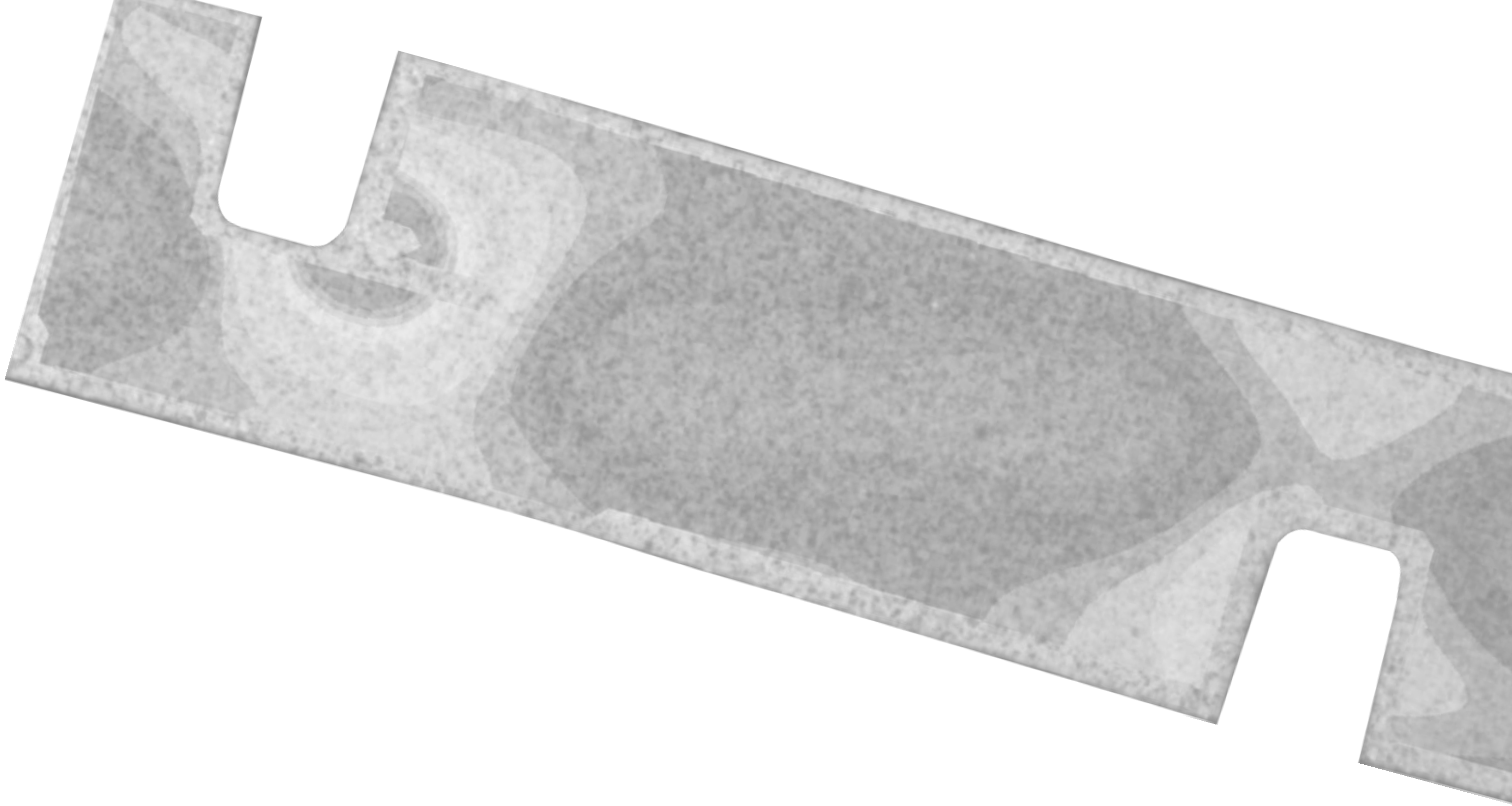
Validate the HFM accurately predicts the average behavior of the test specimens.

- Mean value of the input parameters.
  - Compare simulated load-displacement curves to experimental averages.

Non-deterministic Validation

Validate the model's ability to account for variability and uncertainty in input parameters.

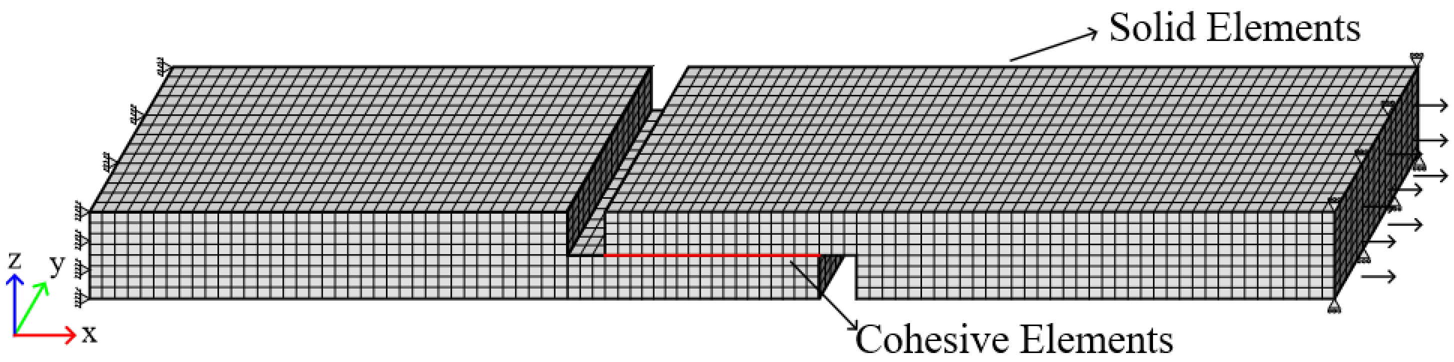
- Conduct Monte Carlo sampling using statistical distributions of input parameters.
  - Compare simulation results to experimental data distributions.
  - Area method
  - Hypothesis Tests



Case studied

Single Lap Shear

Material Properties	Test	Data Reduction Method	Num. Samples	Distribution	Scale	Shape
E_{11} (GPa)	Longitudinal Tensile (0º)	ASTM D3039 [43]	18	Weibull	1.0063	86.87
E_{22} (GPa)	Transverse Tensile (90º)	ASTM D3039 [43]	6	Weibull	1.0031	194.47
ν_{12}	Longitudinal Tensile (0º)	ASTM D3039 [43]	18	Weibull	1.0312	15.32
G_{12} (GPa)	In Plane Shear test	ASTM D3518M [44]	12	Weibull	1.0039	114.95
$\mathcal{G}_{c1}$ (J/m^2)	Double Cantilever Beam	ISO 15024 [46]	12	Weibull	1.0122	44.27
$\mathcal{G}_{c2}$ (J/m^2)	End Loaded Slip	ISO 15114 [47]	12	Weibull	1.0518	20.67
η	Mix-mode test	ASTM D6671 [45]	6	Weibull	1.0556	9.64
τ_I (MPa)	Double Cantilever Beam	Said et al. [48]	12	Weibull	1.0501	9.82
τ_{II} (MPa)	End Loaded Slip	Said et al. [49]	12	Weibull	1.0242	21.79



Non-stochastic parameters

- $\nu_{23} = 0.45$ (assumed)
- K = 1.000.000

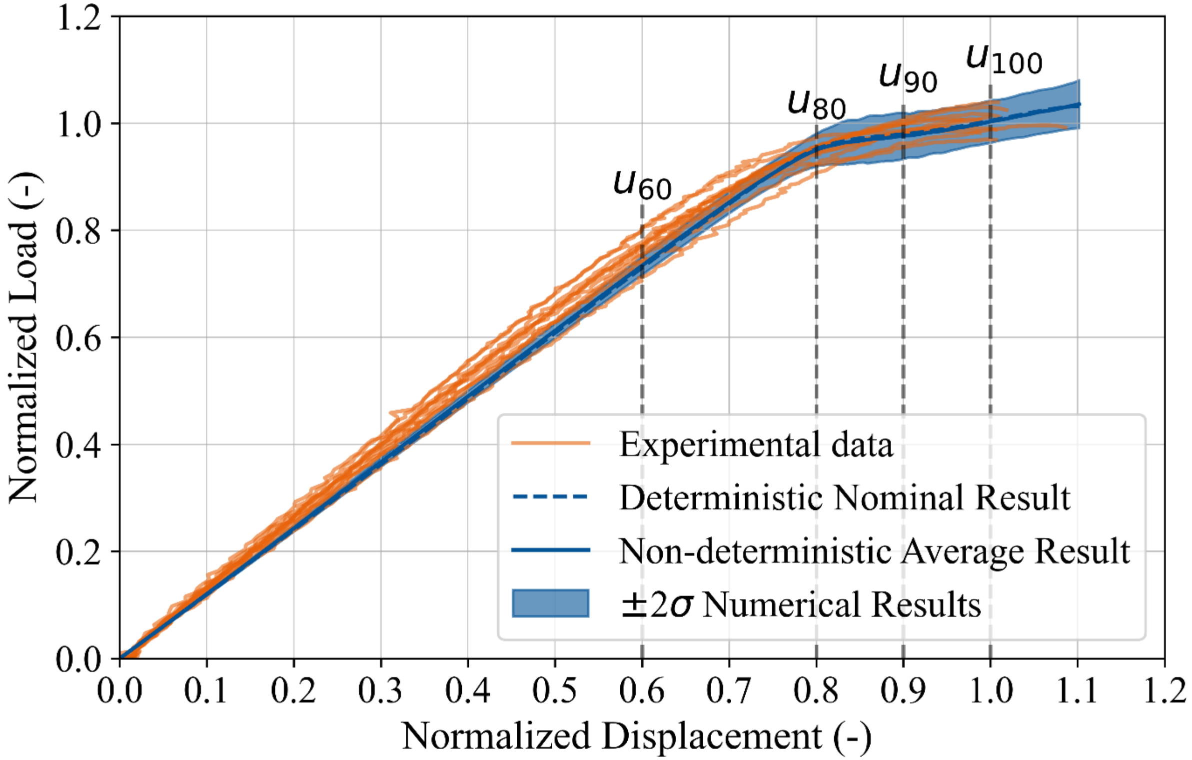
Deterministic validation

- 1 simulation with mean values

Non-deterministic validation

- Desing of experiments 100 sim.

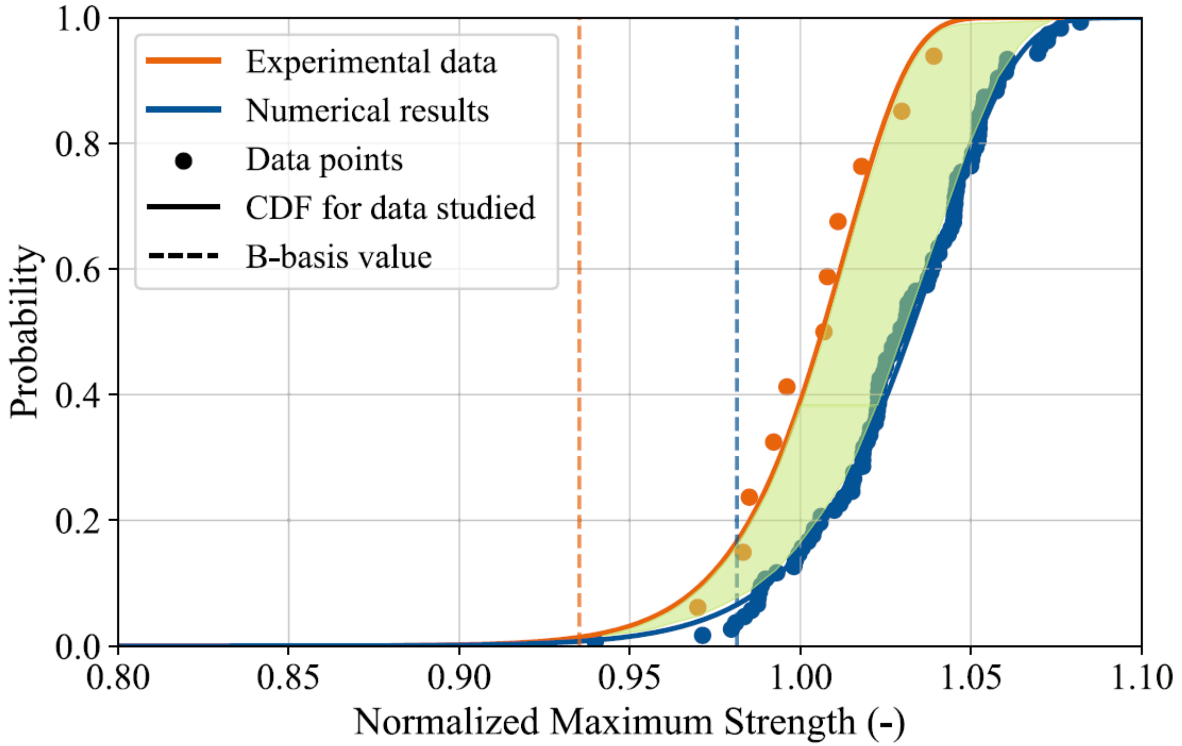
Load curves



Criterion: Error < 5%

	Slope of elastic region	u_{60}	u_{80}	u_{90}	u_{100}
Experimental	1.25 (-)	0.77 (-)	0.95 (-)	0.99 (-)	1.00 (-)
Deterministic nominal result	1.22 (-)	0.73 (-)	0.95 (-)	0.98 (-)	1.03 (-)
Non-deterministic average result	1.22 (-)	0.73 (-)	0.95 (-)	0.99 (-)	1.03 (-)
Err. Deterministic	2.38%	4.46%	0.99%	0.52%	2.80%
Err. Non-deterministic	2.14%	4.26%	0.56%	0.91%	2.48%

Distribution



Case	Size	Average	B-value	Distribution	Scale	Shape
Experimental data	11	1.00 (-)	0.932 (-)	Weibull	1.010 (-)	53.18
M&S results	100	1.03 (-)	0.981 (-)	Weibull	1.040 (-)	45.92

Wasserstein distance

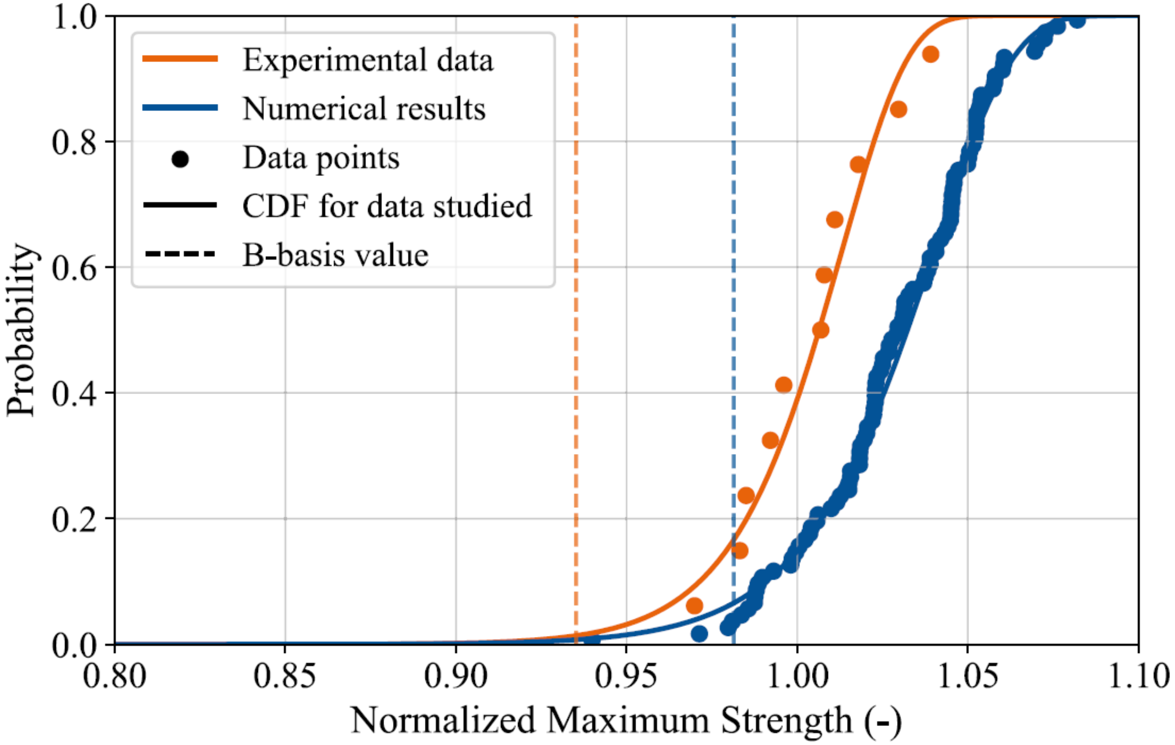
$$W_p(\mu_1, \mu_2) = \left(\int_0^1 \left| F_1^{-1}(q) - F_2^{-1}(q) \right|^p dq \right)^{1/p}$$

$$W_1(\mu_s, \mu_e) = \int_{-\infty}^{+\infty} \left| F(\tau^s) - F(\tau^e) \right| d\tau$$

$$\%d_{Area} = \frac{100}{\overline{\tau^e}} \int_{-\infty}^{+\infty} \left| F(\tau^s) - F(\tau^e) \right| d\tau$$

$$\%d_{Area} = 2{,}45\% < 5\%$$

Distribution



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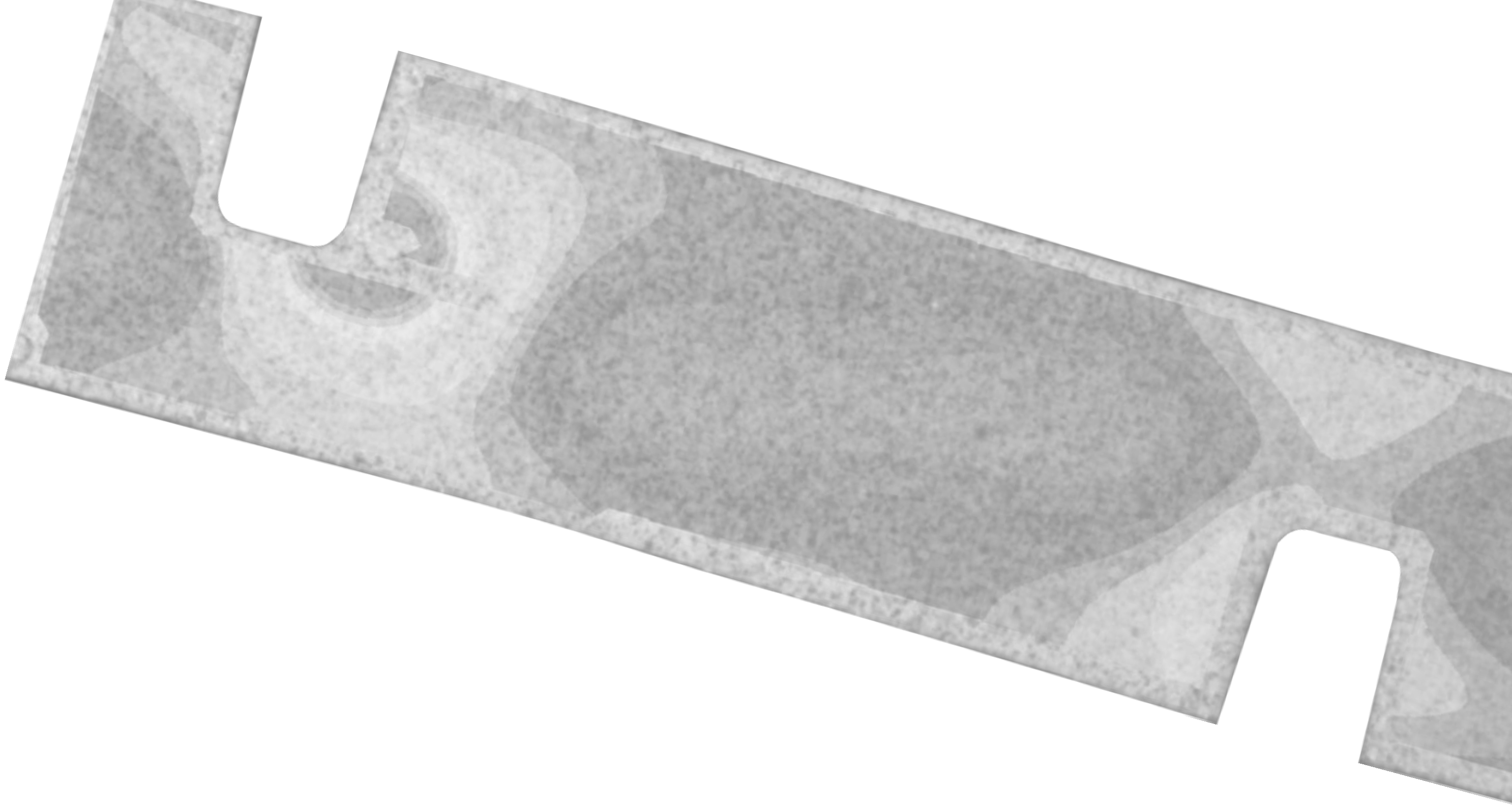
Hypothesis test

- Kolmogorov-Smirnov
- Anderson-Darling
- Cramer-Von Mises

Interval confidence 95%;
p-value > 0.05

Case	KV	AD	CV
p-value	0.962	0.895	0.855



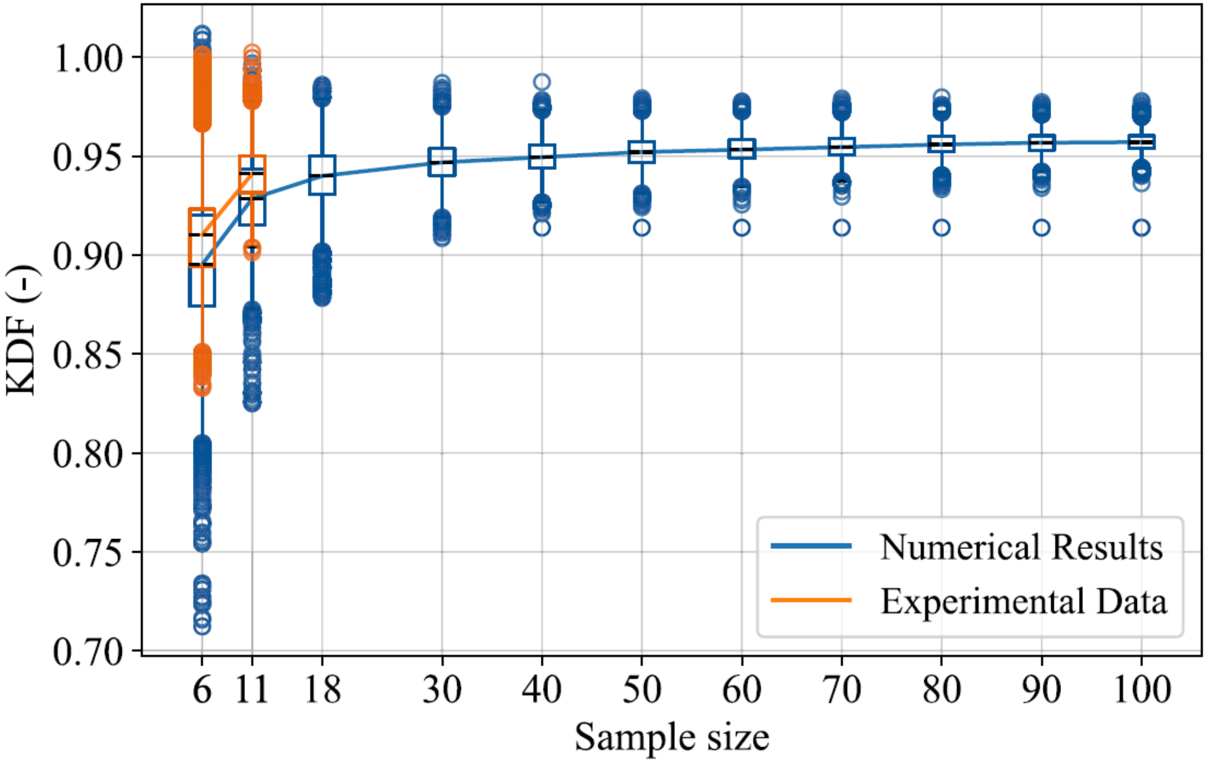
Extra considerations

Reduce computational cost: Size batch effect

By bootsraping sampling generate 10000 batch of each side.

Test	Number of specimens			
	18	30	50	70
KS	99.63	99.86	100	100
AD	99.69	99.93	100	100
CV	99.69	99.89	100	100

$$KDF = \frac{B\ value}{\bar{\tau}}$$



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A validated simulation methodology for determining single lap shear allowable strength in thermoplastic polymer composites

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