



Prediction of the low velocity impact response of plyscaled CFRP laminates

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- Context
- Methodology
- Material model
- Material calibration
- LVI predictions
- CAI predictions
- Conclusions

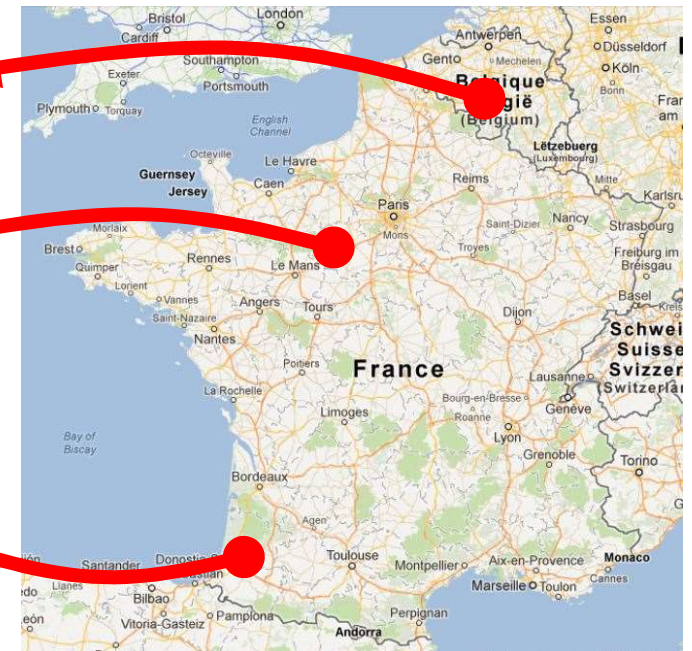
- ↪ Engineering Services and research
- ↪ Founded in 1991
- ↪ >200 employees
- ↪ 1000 cores on 4 clusters



GDTech (HQ)
Belgium.

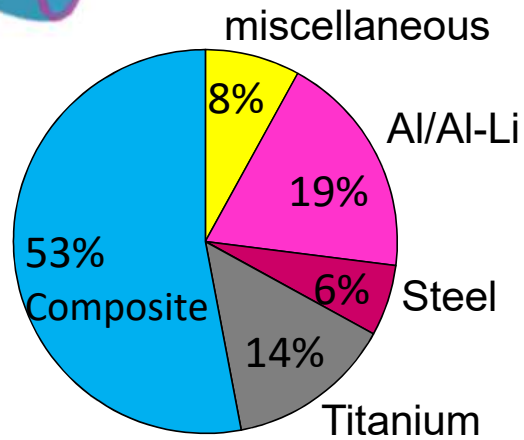
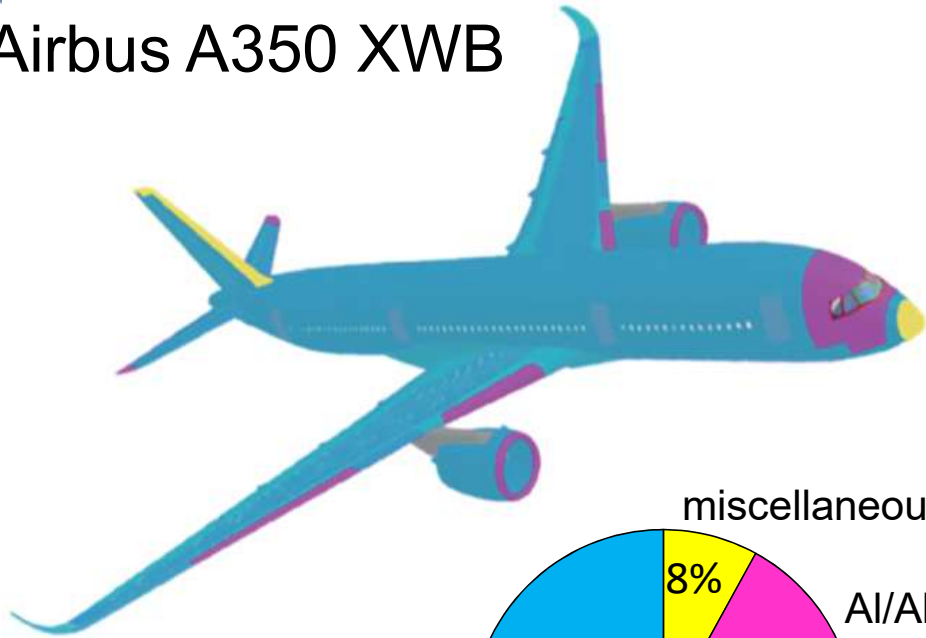
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Pau,
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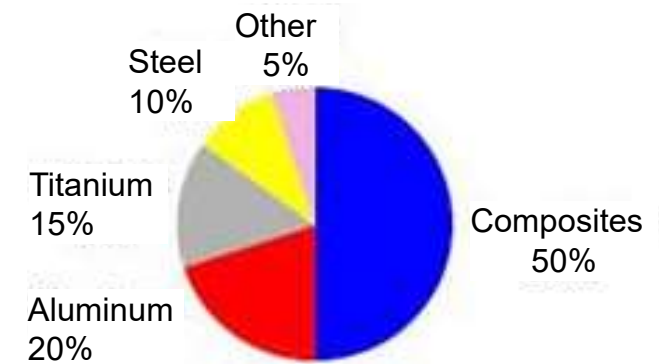


Composites in Aerospace

Airbus A350 XWB



Boeing 787



- Runway debris
- Tool drops in MRO
- Ground vehicles



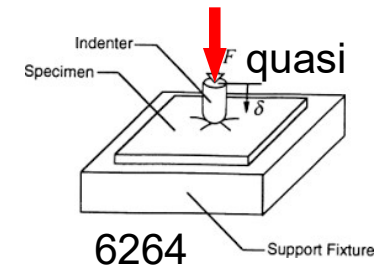
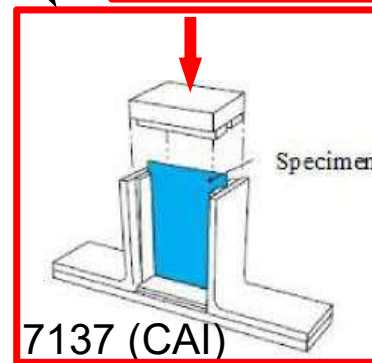
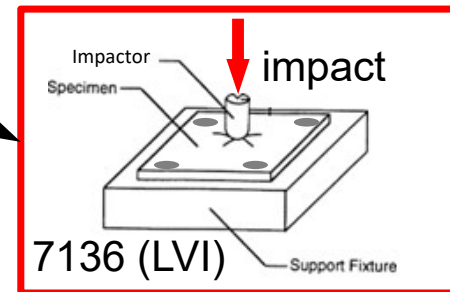
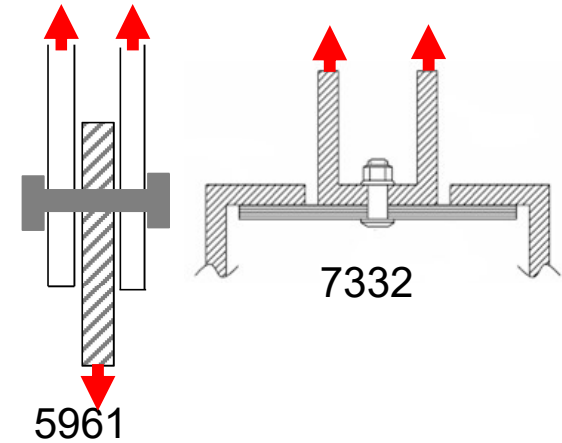
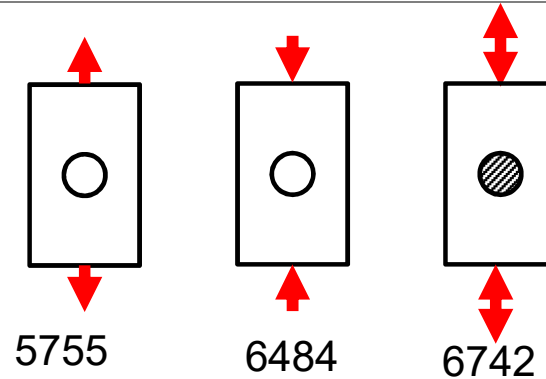
Damage from ground vehicle



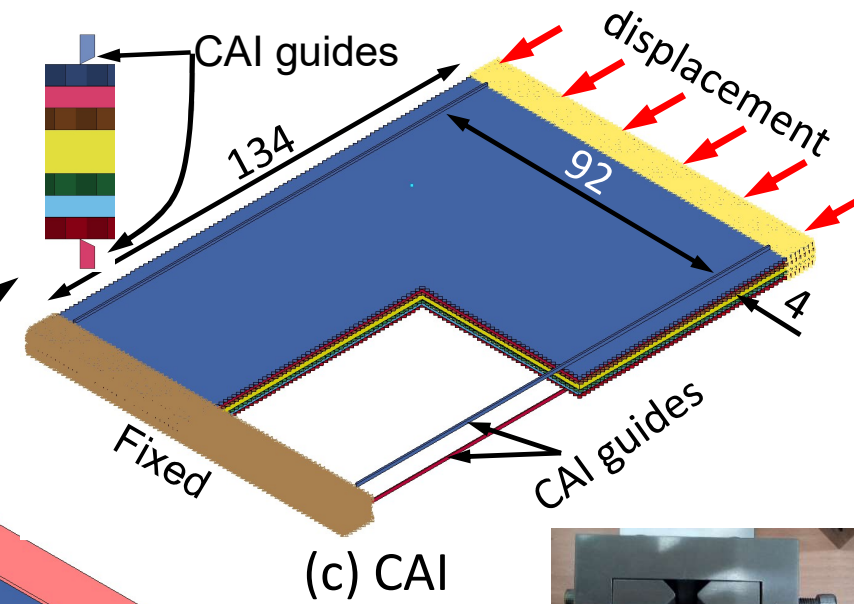
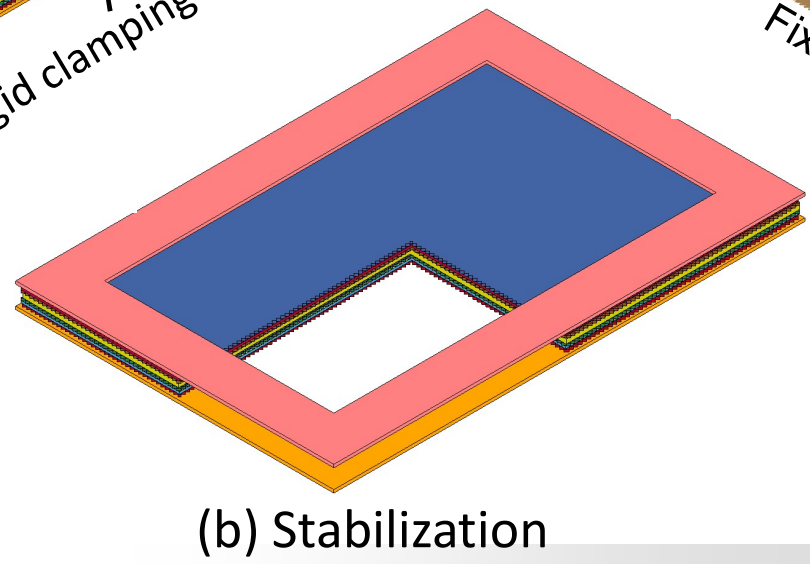
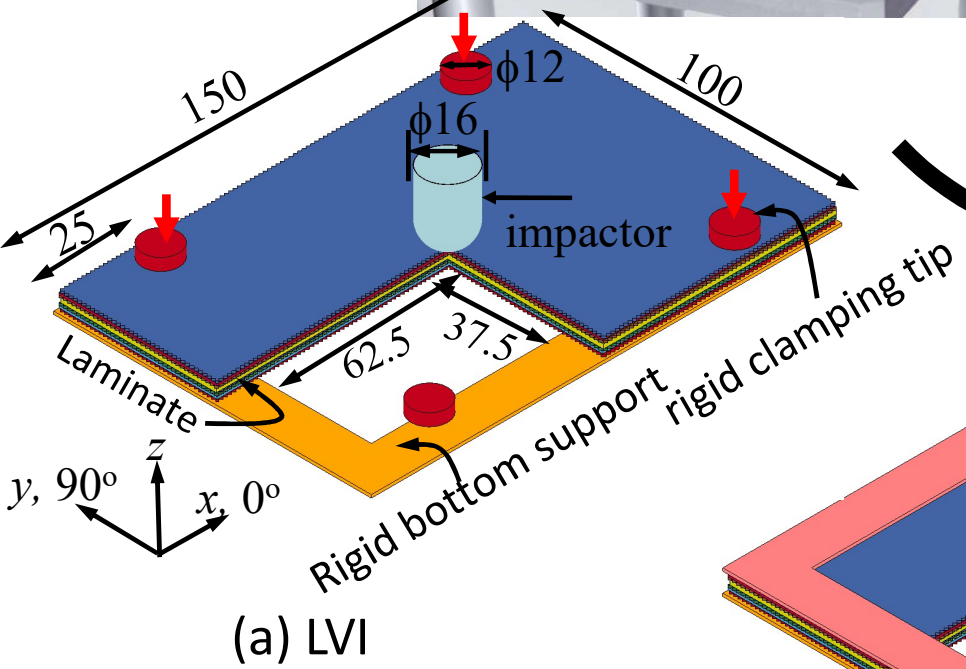
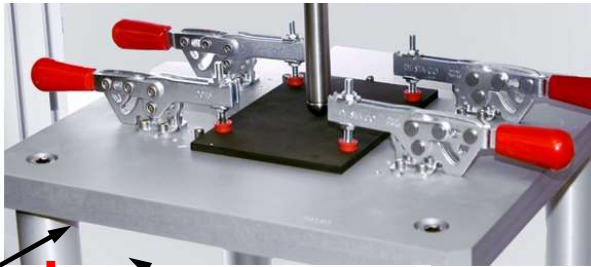
[FAA, SNL]

Composites certification – expensive and time consuming

Designation	Title
D5766 / D5766M - 11(2018)	Standard Test Method for Open-Hole Tensile Strength of Polymer Matrix Composite Laminates
D5961 / D5961M - 17	Standard Test Method for Bearing Response of Polymer Matrix Composite Laminates
D6264 / D6264M - 17	Standard Test Method for Measuring the Damage Resistance of a Fiber-Reinforced Polymer-Matrix Composite to a Concentrated Quasi-Static Indentation Force
D6484 / D6484M - 20	Standard Test Method for Open-Hole Compressive Strength of Polymer Matrix Composite Laminates
D6742 / D6742M - 17	Standard Practice for Filled-Hole Tension and Compression Testing of Polymer Matrix Composite Laminates
D6873 / D6873M - 19	Standard Practice for Bearing Fatigue Response of Polymer Matrix Composite Laminates
D7136 / D7136M - 20	Standard Test Method for Measuring the Damage Resistance of a Fiber-Reinforced Polymer Matrix Composite to a Drop-Weight Impact Event
D7137 / D7137M - 17	Standard Test Method for Compressive Residual Strength Properties of Damaged Polymer Matrix Composite Plates
D7248 / D7248M - 21	Standard Test Method for High Bearing - Low Bypass Interaction Response of Polymer Matrix Composite Laminates Using 2-Fastener Specimens
D7332 / D7332M - 16	Standard Test Method for Measuring the Fastener Pull-Through Resistance of a Fiber-Reinforced Polymer Matrix Composite
D7615 / D7615M - 19	Standard Practice for Open-Hole Fatigue Response of Polymer Matrix Composite Laminates
D8066 / D8066M - 17	Standard Practice Unnotched Compression Testing of Polymer Matrix Composite Laminates
D8101 / D8101M - 18	Standard Test Method for Measuring the Penetration Resistance of Composite Materials to Impact by a Blunt Projectile
D8131 / D8131M - 17e1	Standard Practice for Tensile Properties of Tapered and Stepped Joints of Polymer Matrix Composite Laminates
D8387 / D8387M - 21	Standard Test Method for High Bypass – Low Bearing Interaction Response of Polymer Matrix Composite Laminates

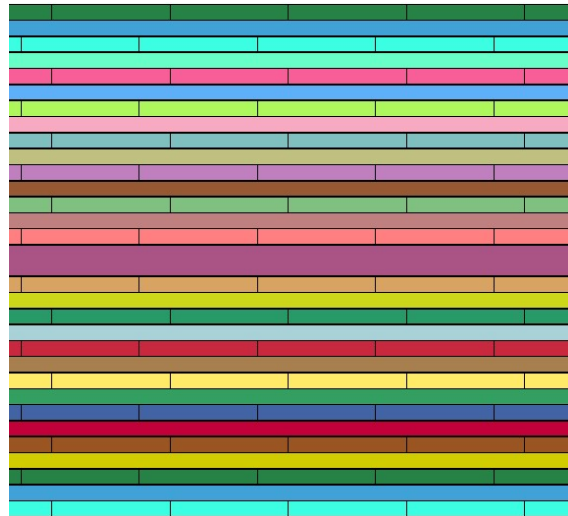


- Context
- **Methodology**
- Material model
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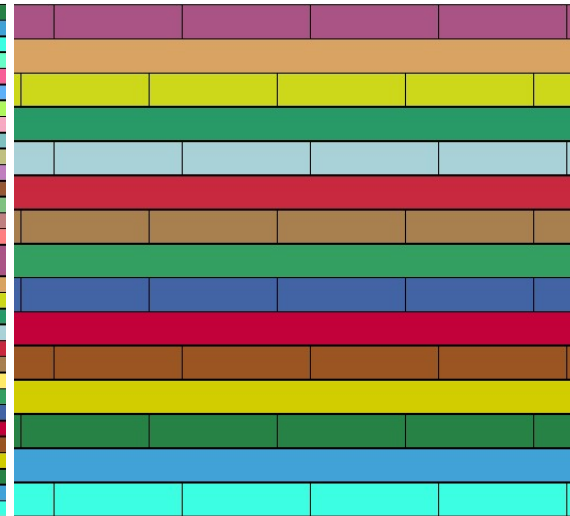


Ply modelling

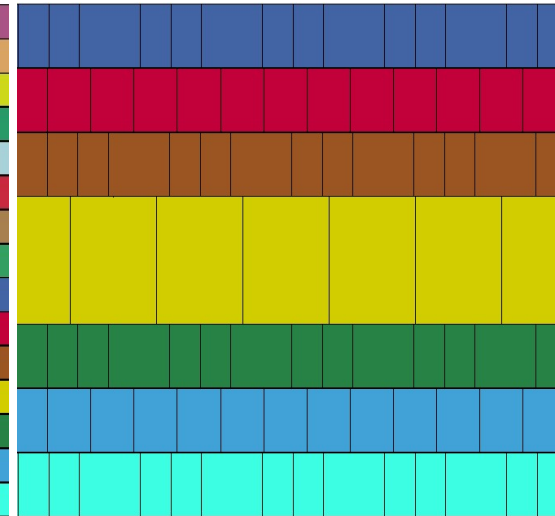
5.88 mm



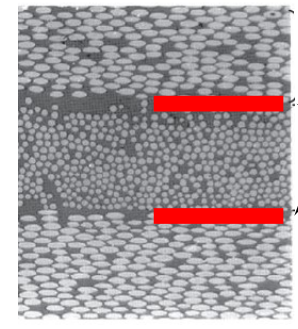
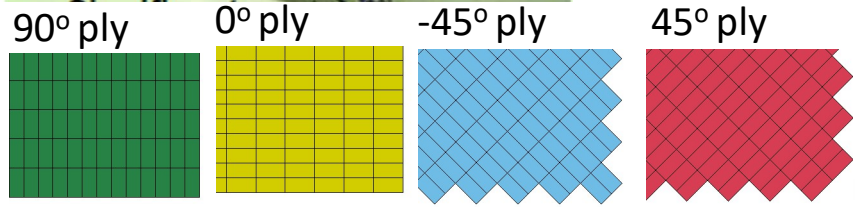
L1: $[(45/0/-45/90)_4]_s$



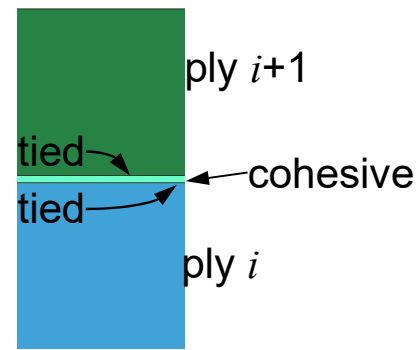
L2: $[(45_2/0_2/-45_2/90_2)_2]_s$



L4: $[45_4/0_4/-45_4/90_4]_s$

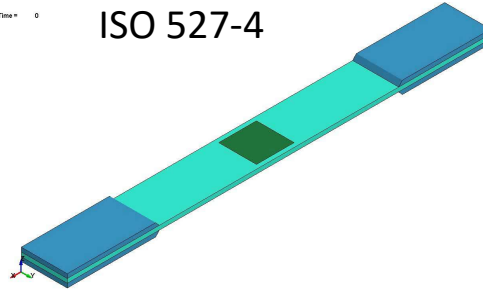


Interface failure

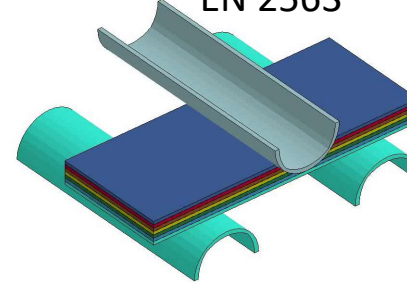


Pyramid approach

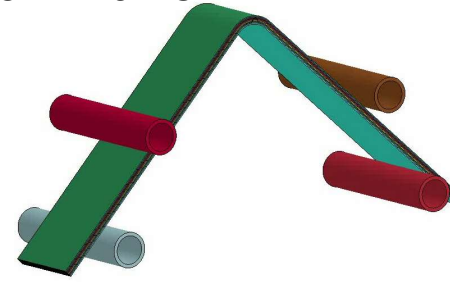
ISO 527-4



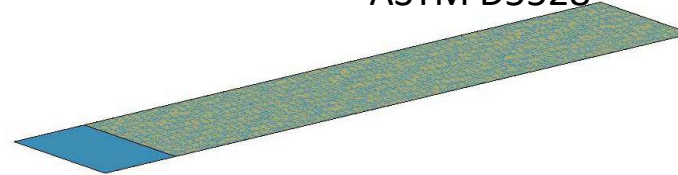
EN 2563



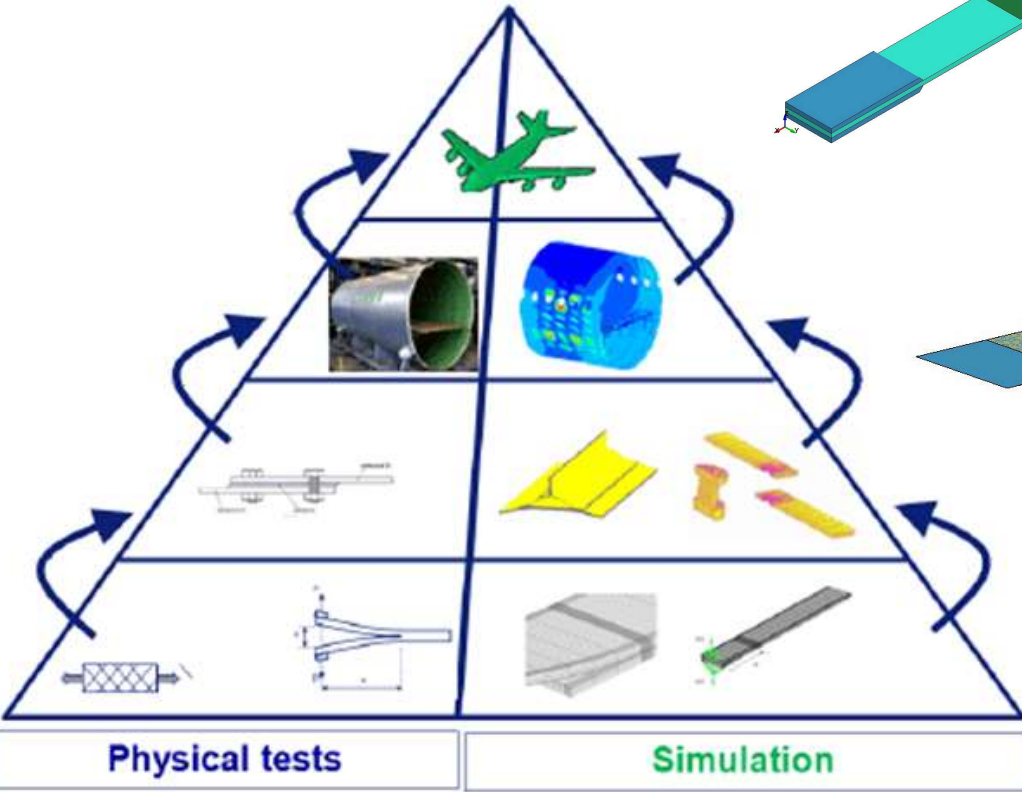
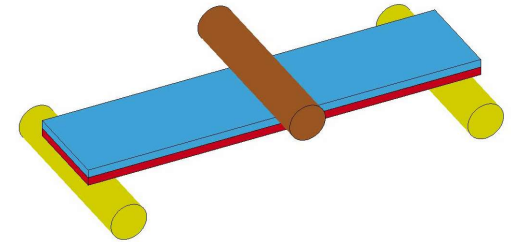
ASTM D6415



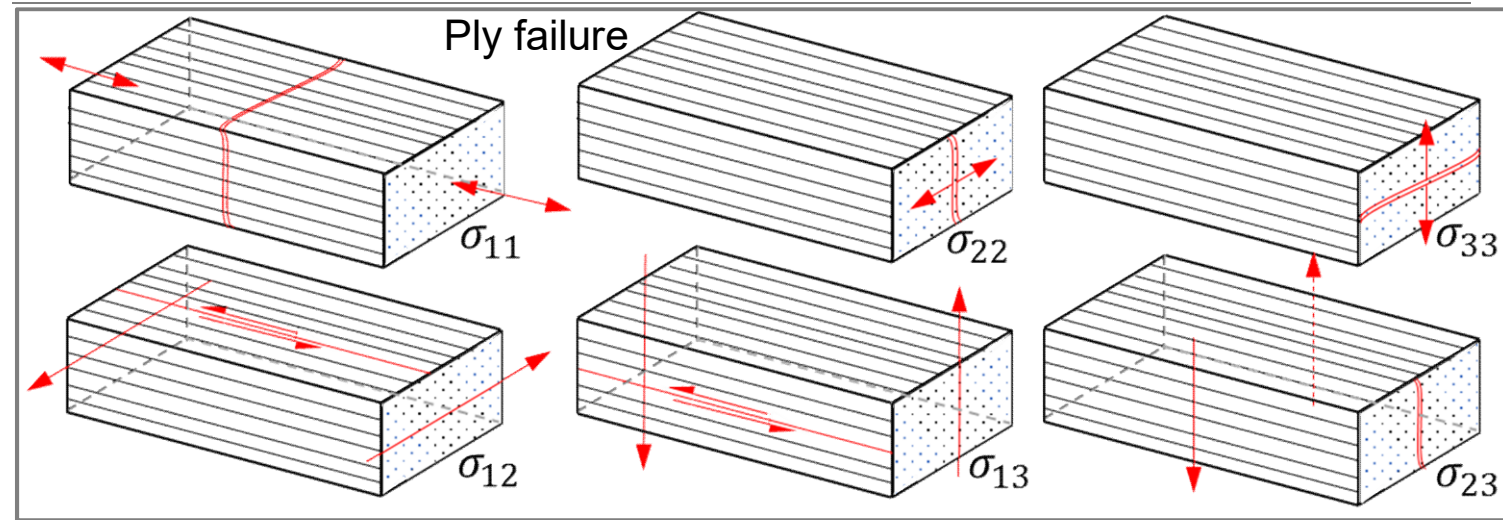
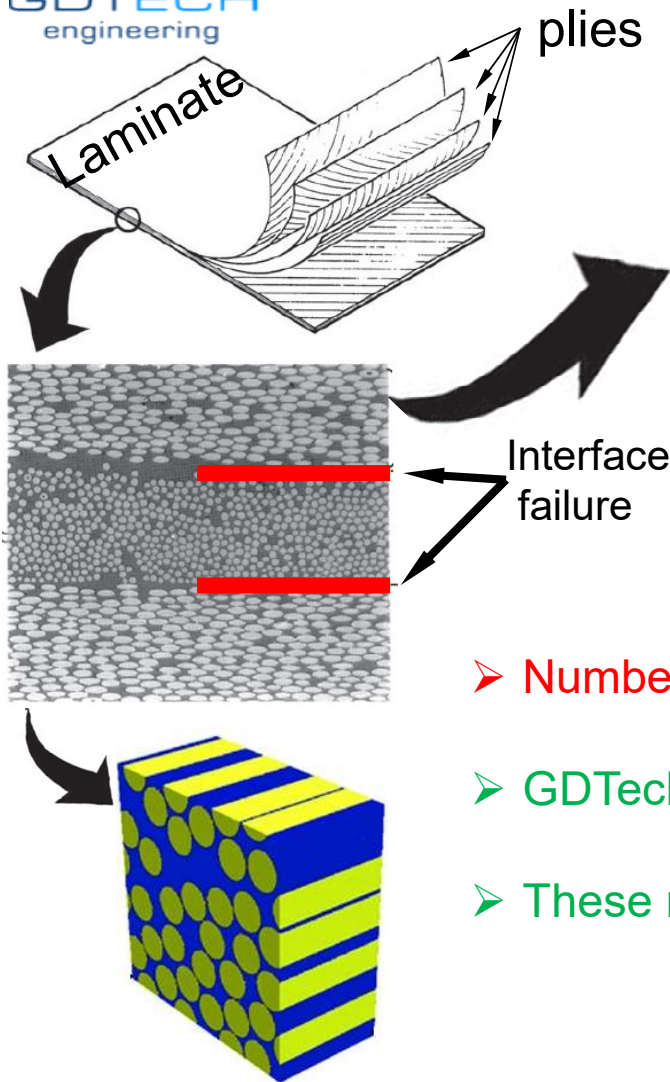
ASTM D5528



ASTM D7905



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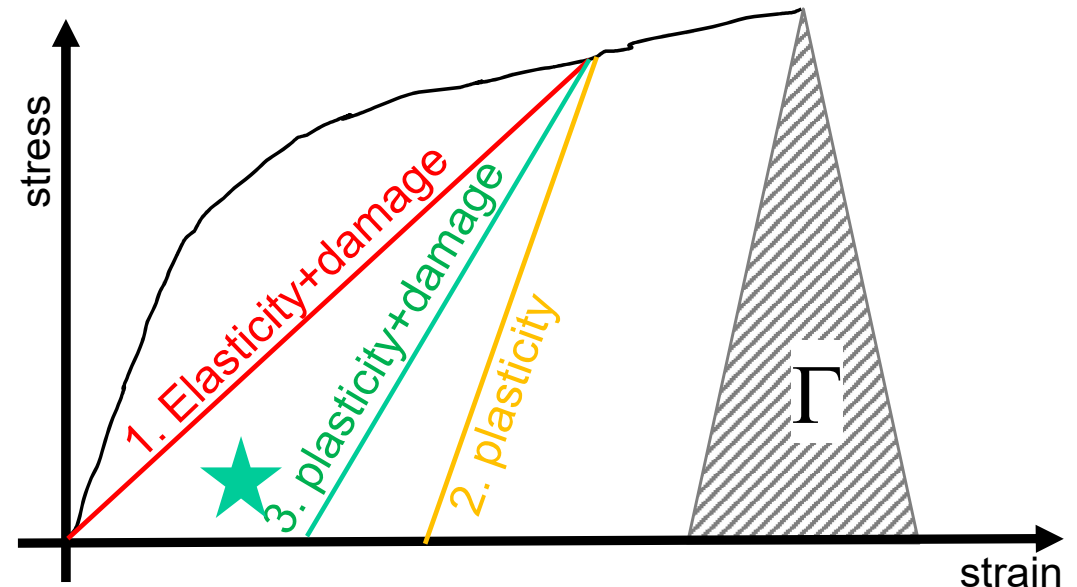


- Number of failure modes.
- GDTech : novel and robust material models for **virtual certification**.
- These models are physically based i.e. capable of blind-predictions.

Novel GDTEch material model for UD composites

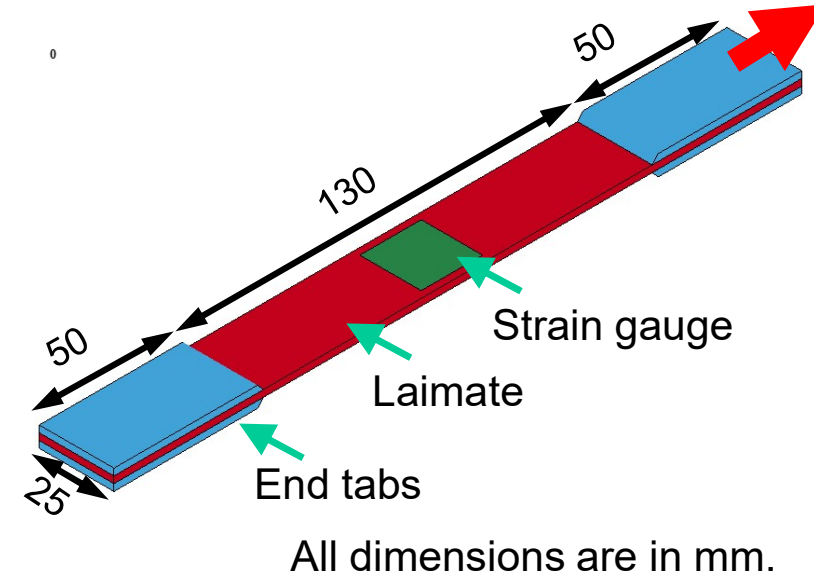
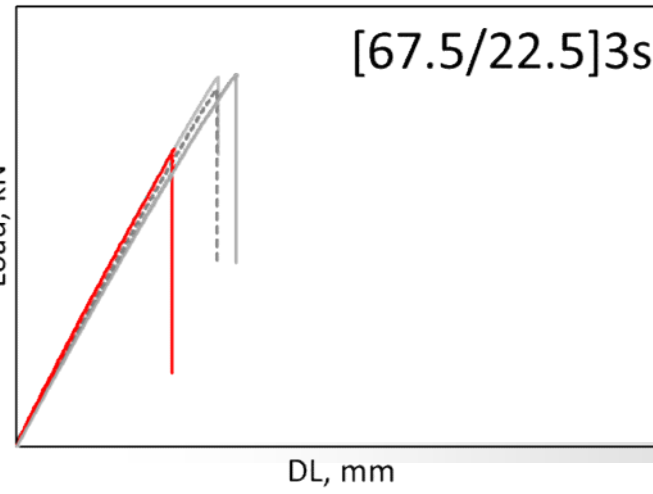
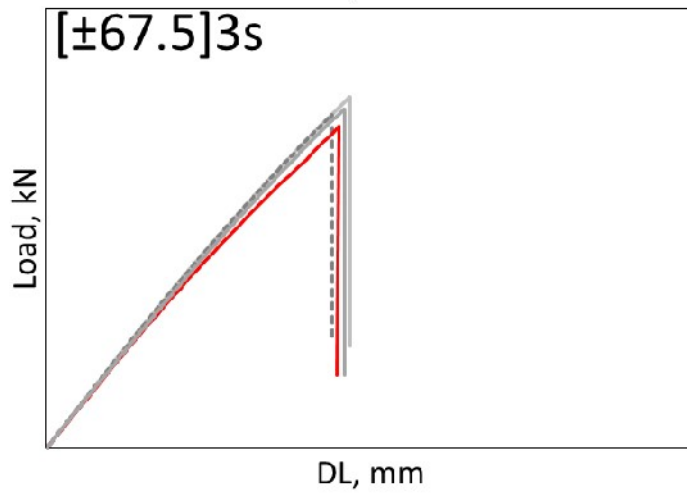
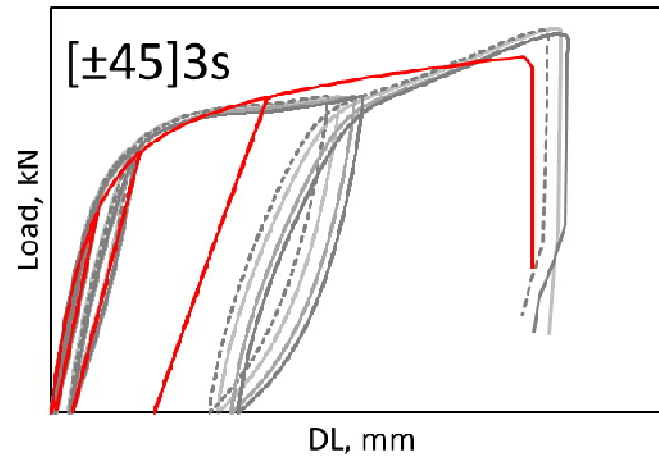
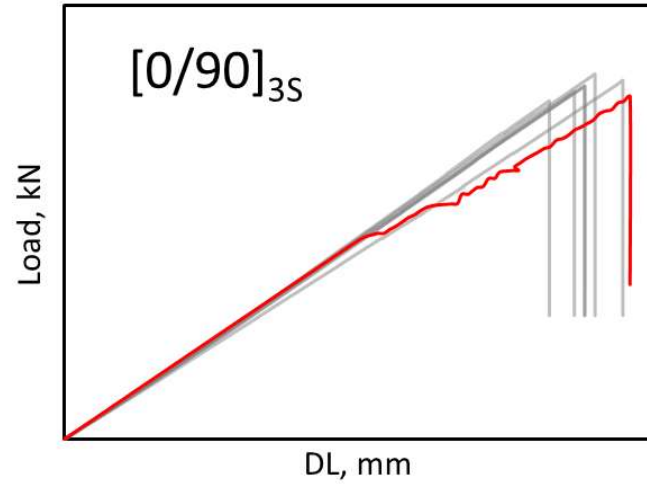
GDTEch model:

- Nonlinear damage
- Plasticity
- FE mesh size
- Accounts different damage modes
- Properties are measurable from physical tests.
- Insitu effects

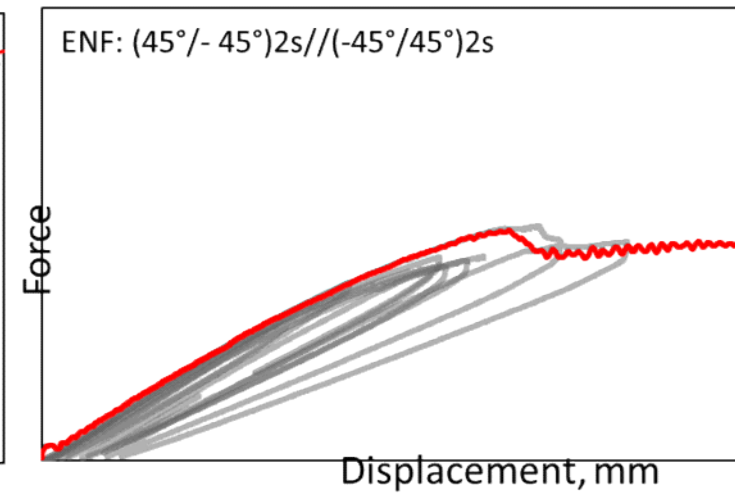
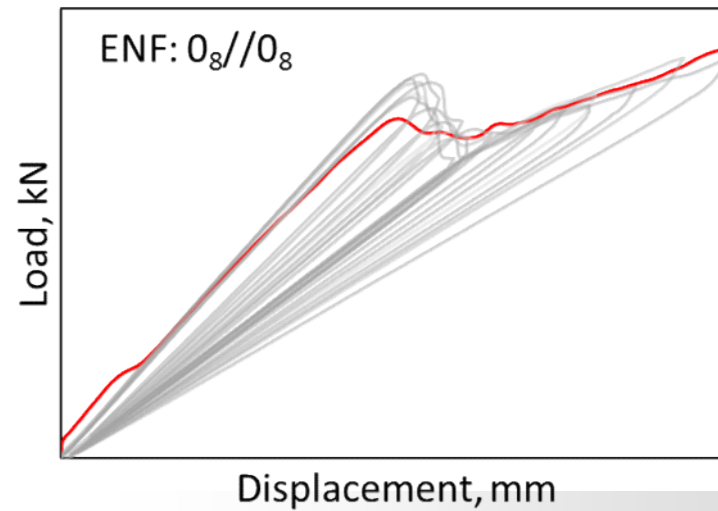
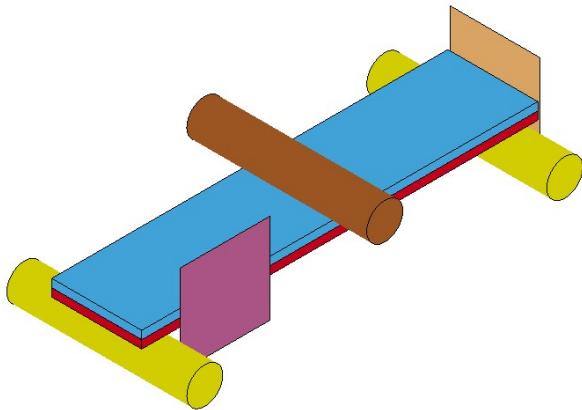
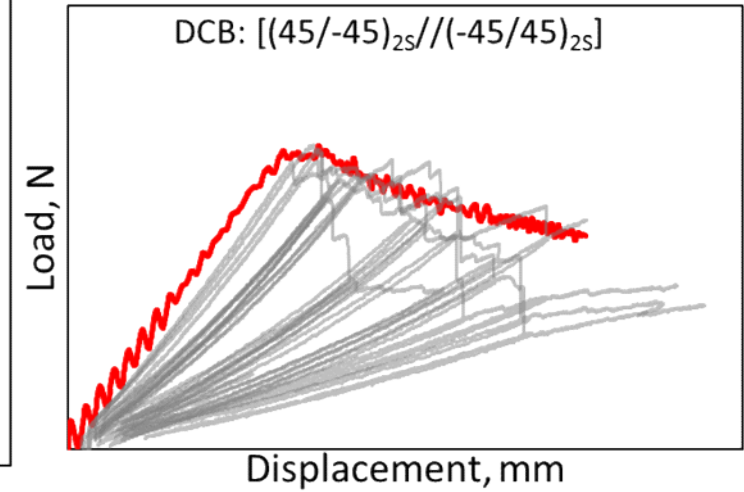
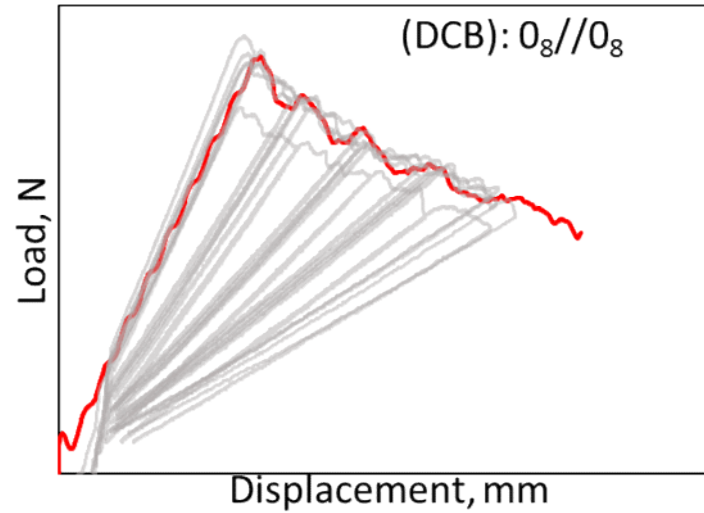
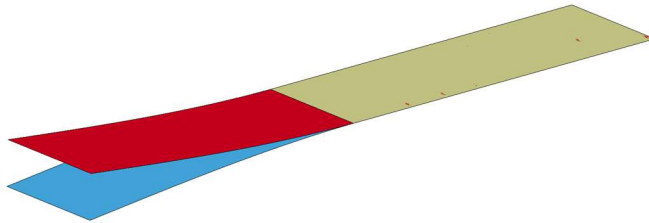


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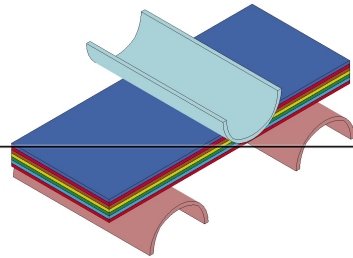
FE Tests



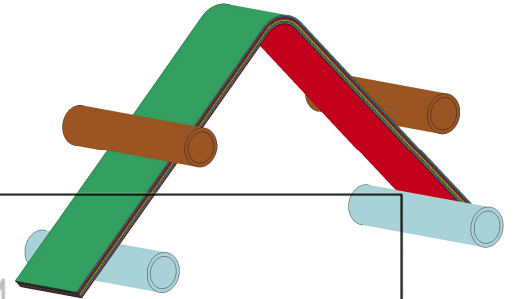
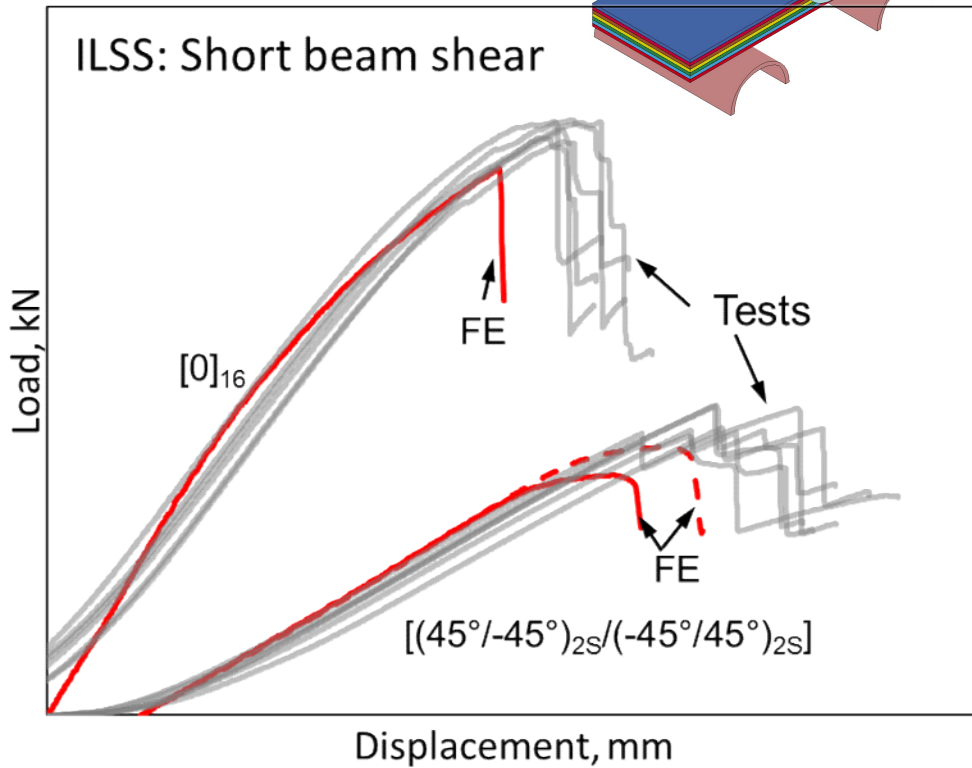
Calibration for Interface fracture toughness



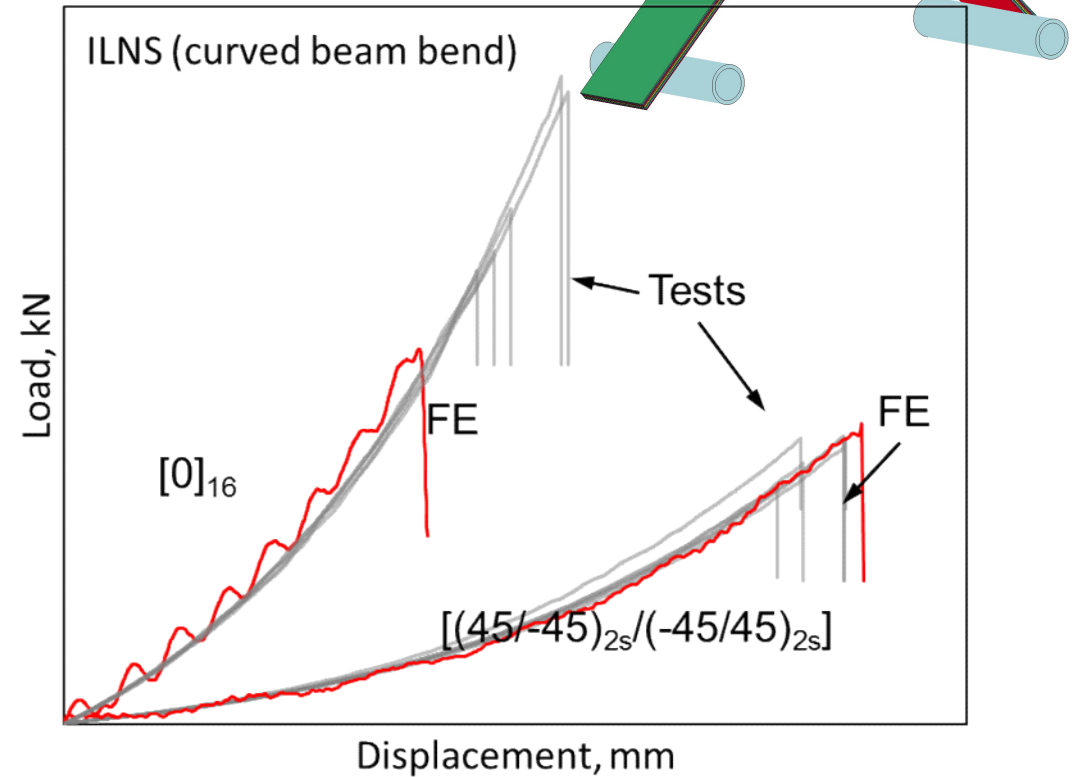
Calibration for Interface strengths



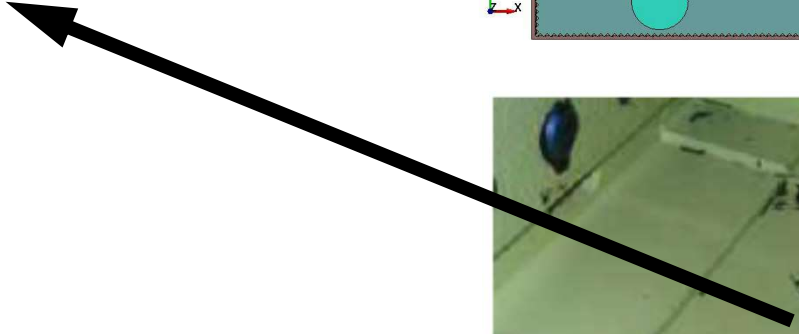
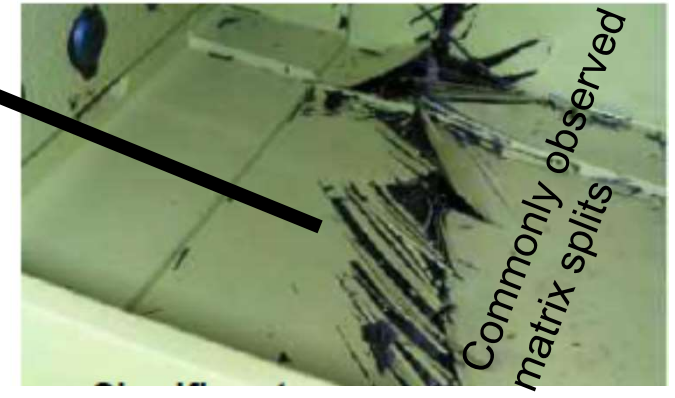
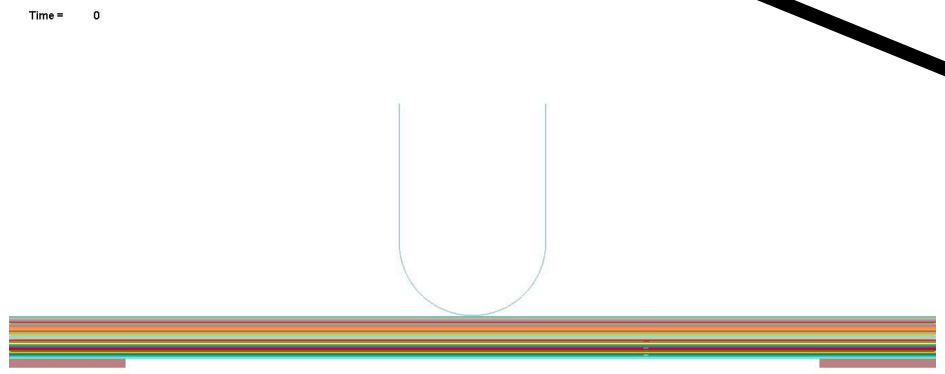
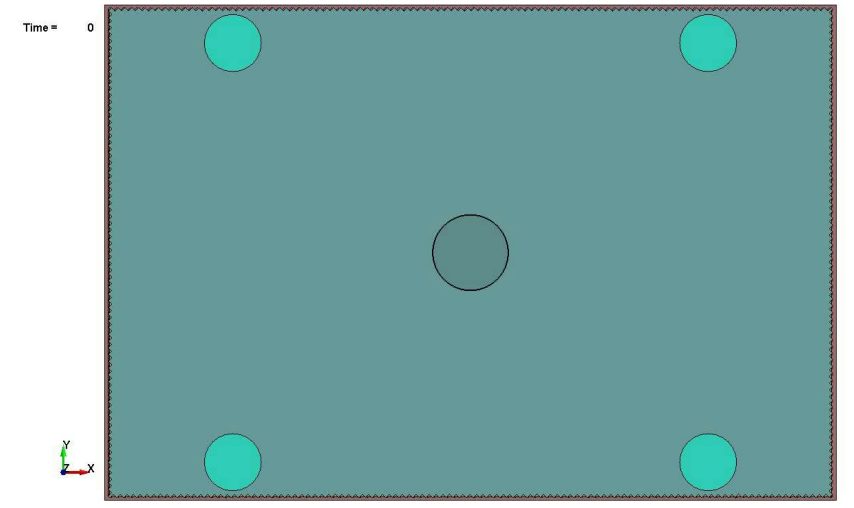
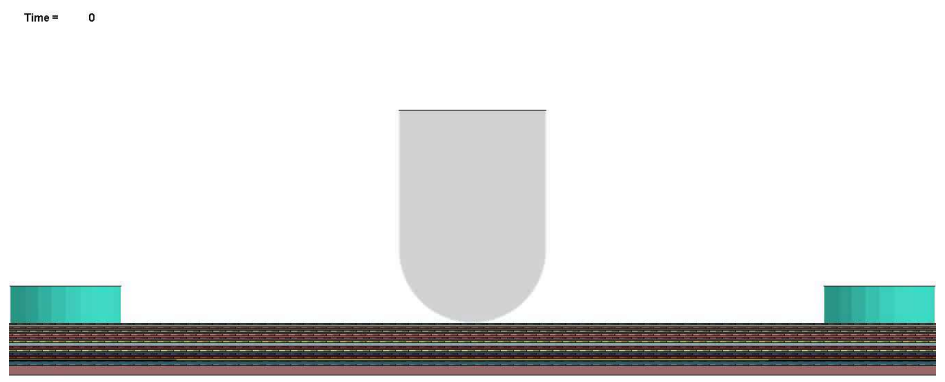
ILSS: Short beam shear



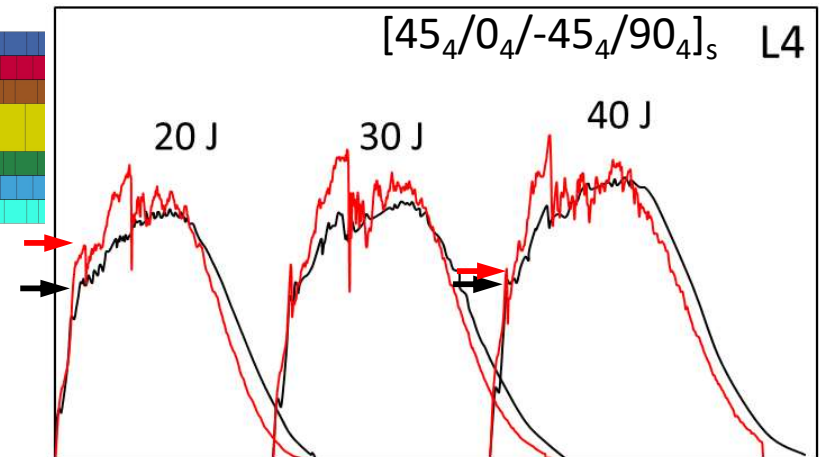
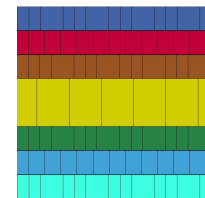
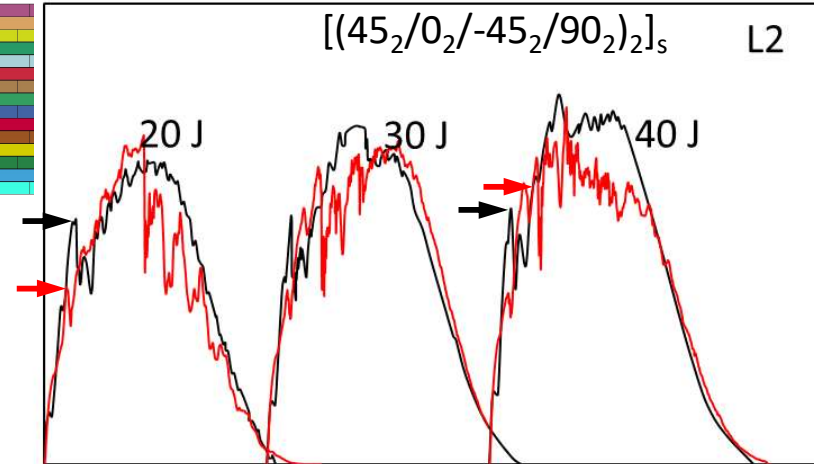
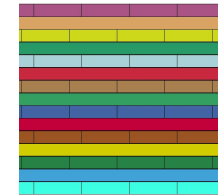
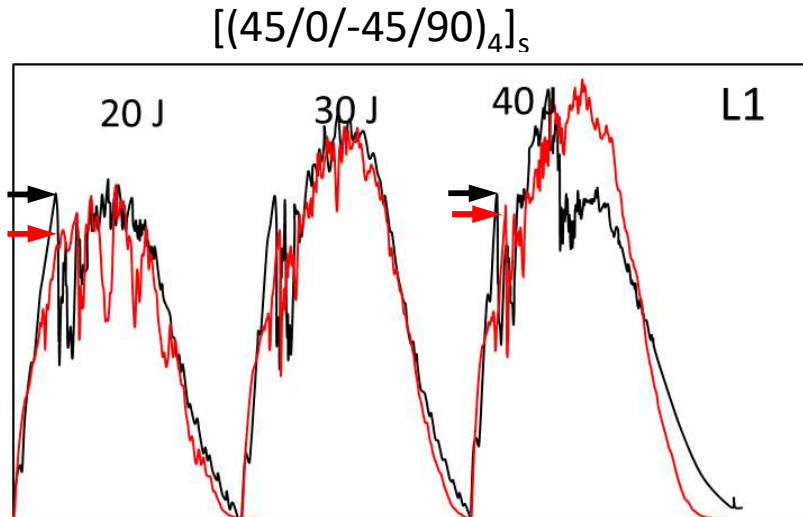
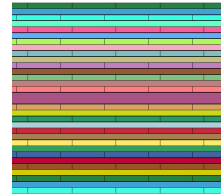
ILNS (curved beam bend)



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Overview: Force-time response curves

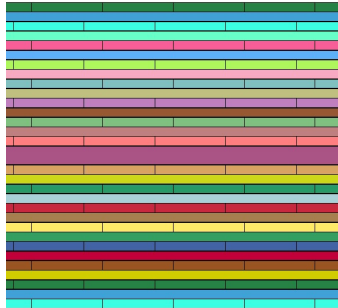


FE:GDTech
Tests

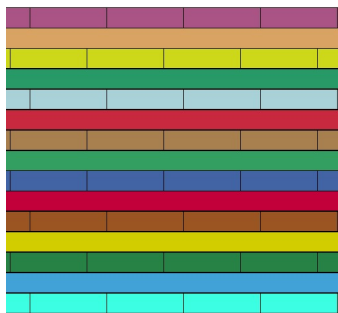
- Delaminatin initiation
- Peak force
- Impact duration

Summary-Top view

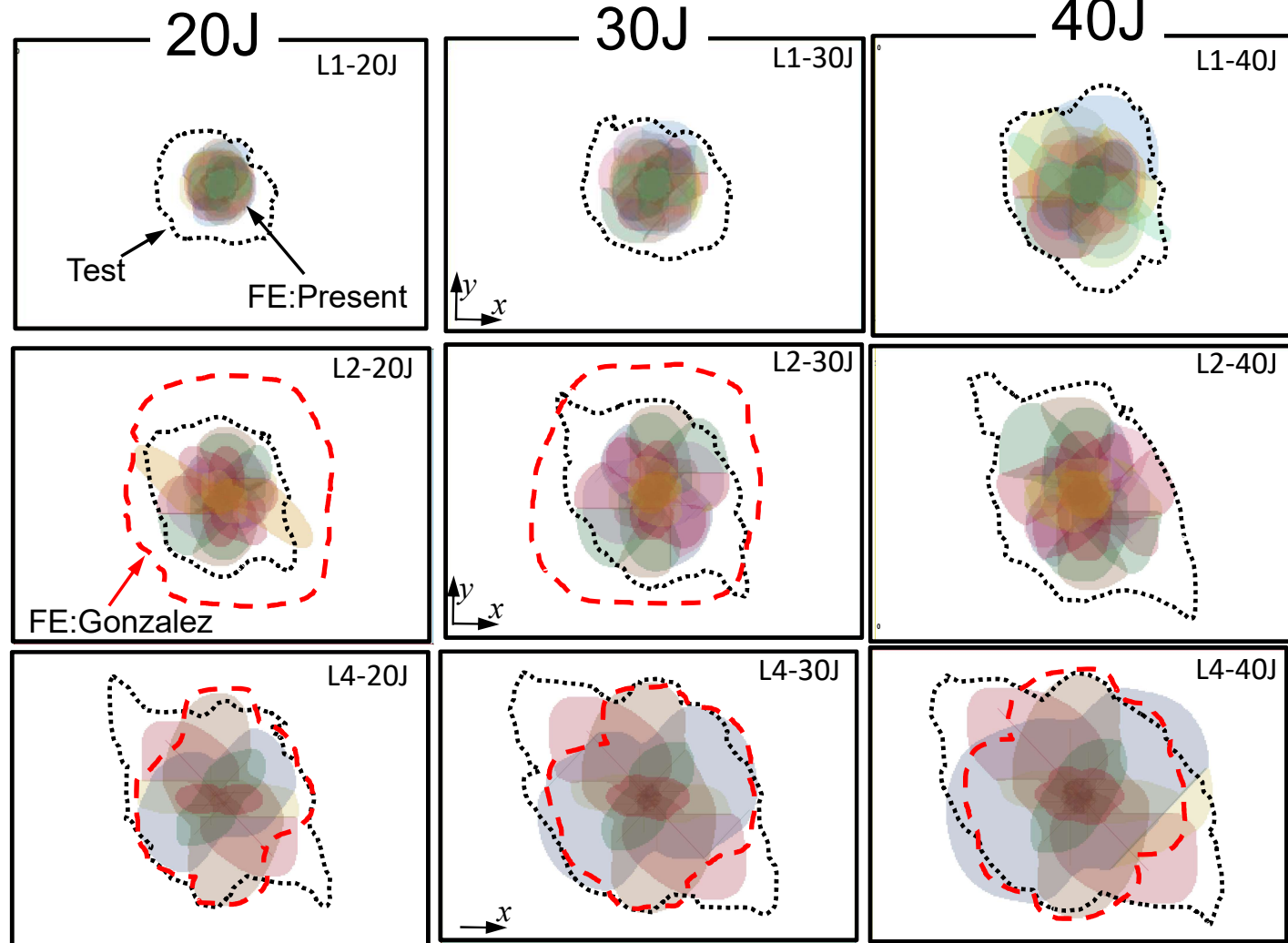
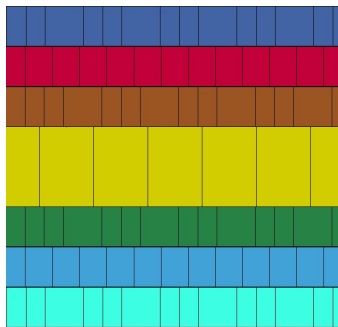
$[(45/0/-45/90)_4]_s$



$[(45_2/0_2/-45_2/90_2)_2]_s$

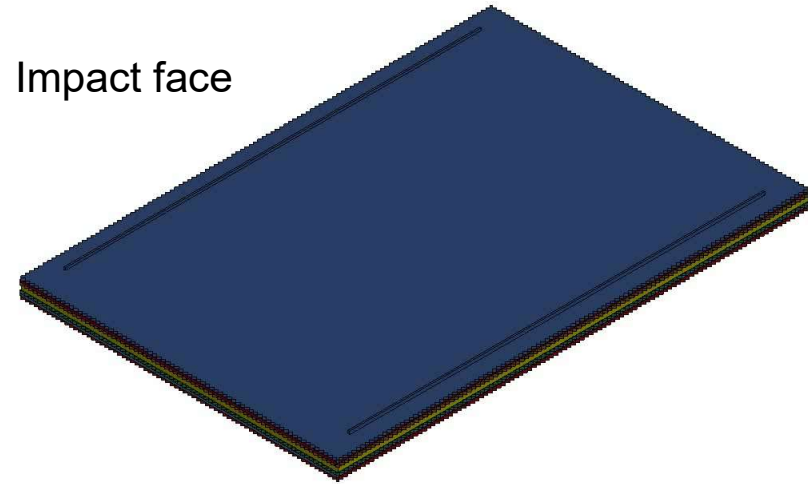


$[45_4/0_4/-45_4/90_4]_s$

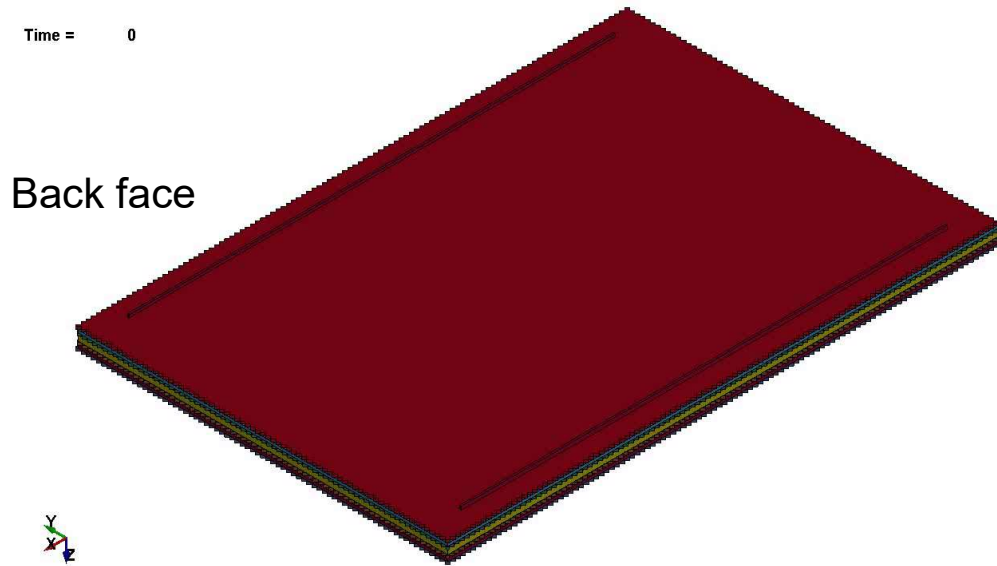


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Time = 0



Time = 0



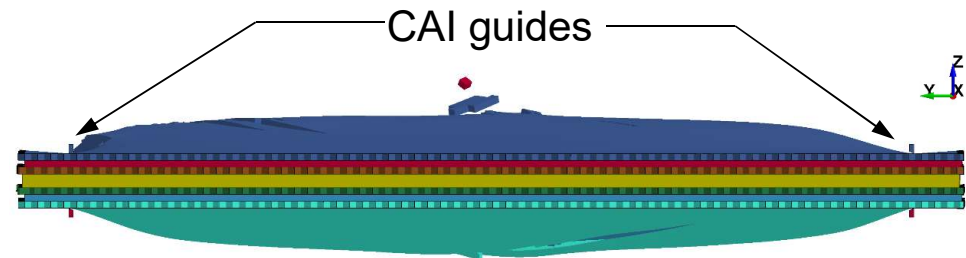
Typical CAI failure

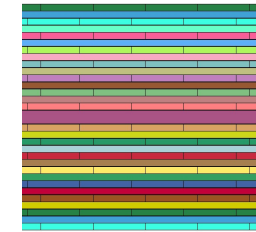
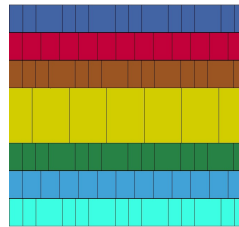
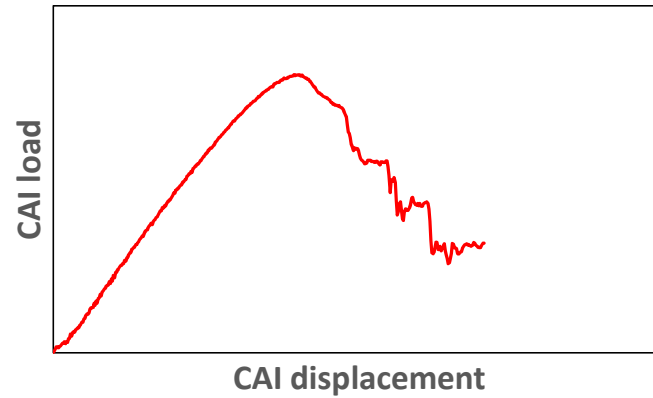
Time = 0

Impact side



Back side



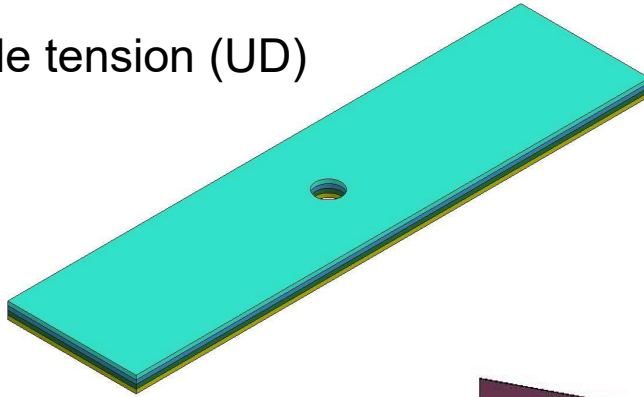


Impact energy	L4: $[45_4/0_4/-45_4/90_4]_s$			L2: $[(45_2/0_2/-45_2/90_2)_2]_s$			L1: $[(45/0/-45/90)_4]_s$		
	Test	FE pre	FE/Test	Test	FE pres	FE/Test	Test	FE	FE/Test
20	105	111	1.06	134	99.2	0.74	133	132	1.00
30	103	84.8	0.82	100	91.4	0.91	103	117	1.13
40	98	73.2	0.75	90	80	0.89	96	116	0.83

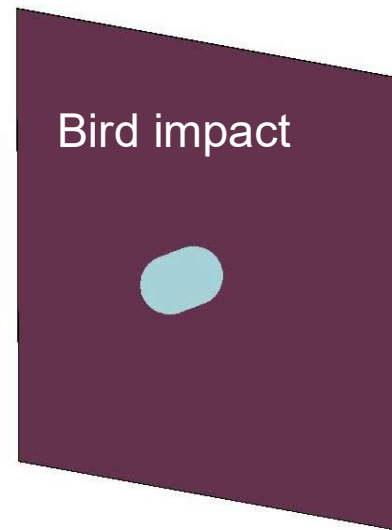
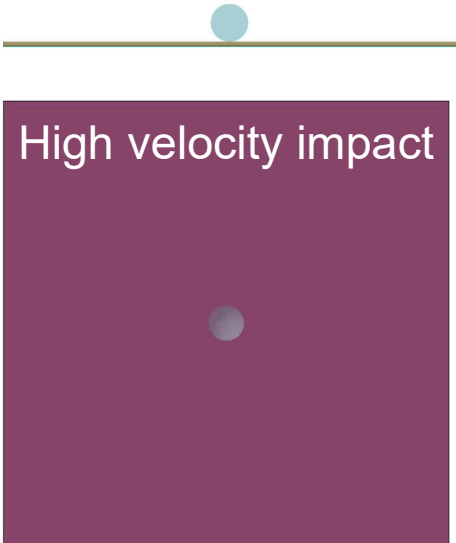
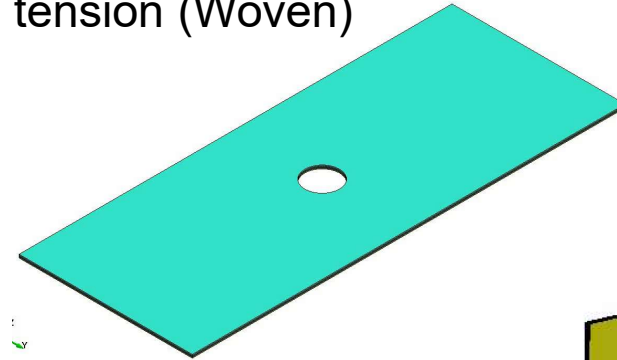
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- LVI and CAI response of composites is studied:
 - FE models are enriched towards virtual certification.
 - Pyramid approach is followed.
 - GDTech material models are used.
 - Proposed GDTech models are capable of blind-predictions.

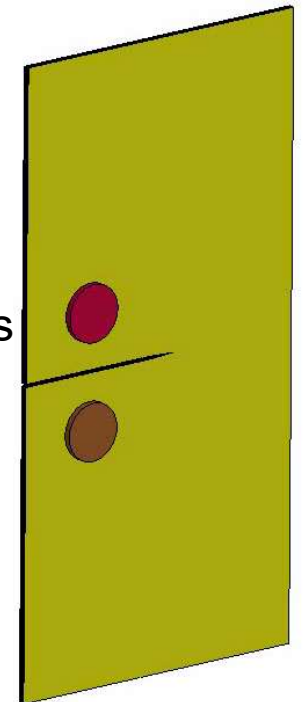
Open hole tension (UD)



Open hole tension (Woven)



Fracture toughness
OCT test



- ↪ Part of the results presented here were obtained in the frame of the **SW_TECCOMA (grant 7281)** and **WINGS (grant 8441)** research projects.
- ↪ The authors acknowledge the support of Wallonia (SPW) and Skywin





Thank you !

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