EVALUATING THE INTRALAMINAR TENSILE FRACTURE BEHAVIOR OF COMPOSITE MATERIALS UNDER HIGH RATE LOADING THROUGH ACOMBINED EXPERIMENTAL AND NUMERICAL METHODOLOGY

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P. Maimí	*(Universitat de Girona)*
E. De Blanpre	*(Dassault Aviation)*
V. Jacques	*(Dassault Aviation)*

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This project has received funding from the Clean Sky 2 Joint Undertaking (JU) under grant agreement No. 886519. The JU receives support from the European Union's Horizon 2020 research and innovation programme and the Clean Sky 2 JU members other than the Union

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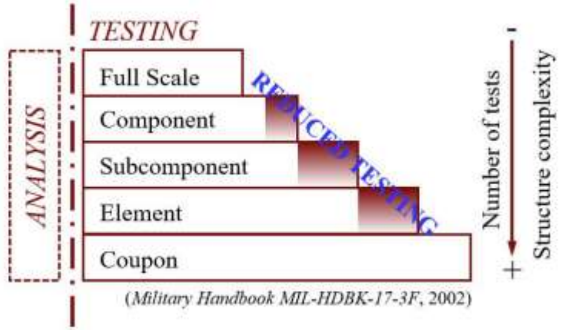
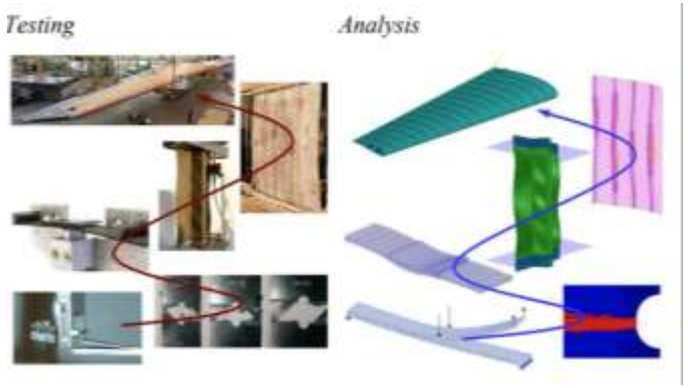
Introduction

Composite Materials

→ NUMERICAL SIMULATION

→ EXPERIMENTS





Under QUASI-STATIC CONDITIONS

Well-established techniques (even for some cases of fatigue)

Under DYNAMIC CONDITIONS

→ NUMERICAL SIMULATION
- *Based on static characterization properties*
- *Model formulation without sensitivity to strain rates*

→ EXPERIMENTS
- *Methods under development. No standardization*
- *There is no consensus in the literature*

BEDYN's GOAL
Define a methodology for numerical simulation and experiments for dynamic loadings

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Dynamic characterization

"Coupons" → Composite material

DYNAMIC		Tester
TASK	**TEST**	
T2.1 / T3.1 / T5.2 Coupons	**Longitudinal compression (at 0º)**	SHPB-C
	Transverse tensile + off-axis	SHPB-T
	Transverse compression + off-axis	SHPB-C

"Element"

DYNAMIC	
TASK	**TEST**
T2.3 / T3.3 / T5.4 Elements	**Flexural effect: three point bending**
	Notch effect: Filled Hole Tension (FHT)
	Notch effect: Filled Hole Compression (FHC)
	Notch effect (and fracture toughness): Compact Tension (CT)
	Bearing effect: Pinned Hole Tension

"Coupons" → Interlaminar / bonded joint

DYNAMIC		
TASK	**TEST**	
T2.2 / T3.2 / T5.3 Coupons	**Interlaminar characterization**	**DCB (pure mode I)**
		ENF (pure mode II)
		SLB (mixed-mode X%)
	Co-bonded adhesive joint	**Mode I strength: steel adherents**
		Mode II strength: Single Lap Shear
		DCB (pure mode I)
		ENF (pure mode II)
		SLB (mixed-mode X%)

"Structure"

DYNAMIC	
TASK	**TEST**
T2.4 / T3.4 / T5.4 Structures	**Gelatin impact on CFRP panel**

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Dynamic characterization

"Coupons" → Composite material

DYNAMIC		Tester
TASK	TEST	
T2.1 / T3.1 / T5.2 Coupons	Longitudinal compression (at 0º)	SHPB-C
	Transverse tensile + off-axis	SHPB-T
	Transverse compression + off-axis	SHPB-C

"Element"

DYNAMIC	
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T2.3 / T3.3 / T5.4 Elements	Flexural effect: three point bending
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Previous work

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Justus Hoffmann[a,*], Hao Cui[b], Nik Petrinic[a]

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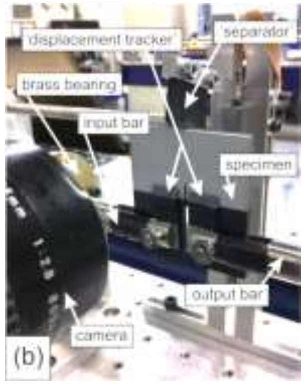

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[a] Advanced Composites Research Group (ACRG), School of Mechanical and Aerospace Engineering, Queen's University Belfast, Belfast BT9 5A
[b] Technical University of Munich, Department of Mechanical Engineering, Boltzmannstraße 15, 85748 Garching, Germany
[c] Department of Mechanical and Industrial Engineering, UNIDEMI, Faculty of Sciences and Technology, NOVA University of Lisbon, 2829-516

Paper	Method	Material	QS G_{IC} [KJ/m^2]	Dyn G_{IC} [KJ/m^2]
McCarrol (2011)	CT	IM7/8552	74.9	67.8
Hoffman et al. (2018)	CT	IM7/8552	196.2	82.0
Kuhn et al. (2018)	DENT	IM7/8552	195.5	241.0
Yoo et al. (2022)	DENT	IM7/8552	281.5	371.8
Cheng et al. (2022)	CT	T700/LT03A	166.5	112.9

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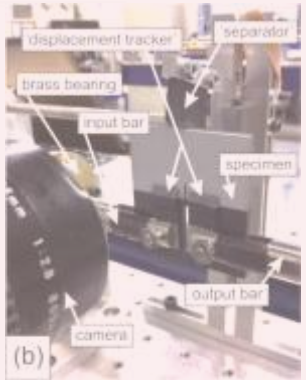

Same geometry/data reduction as QS
Appropiate for cohesive law determination

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Less size scale effect law (3 geom in HR vs 6 in QS)

Int J Fract (2009) 158:211–223
DOI 10.1007/s10704-009-9366-z

ORIGINAL PAPER

A procedure for superposing linear cohesive laws to represent multiple damage mechanisms in the fracture of composites

Carlos G. Dávila · Cheryl A. Rose · Pedro P. Camanho

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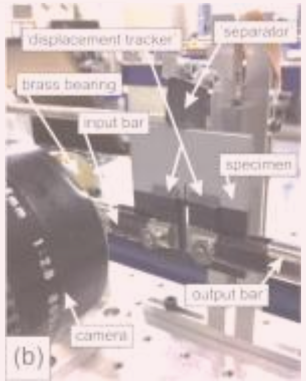

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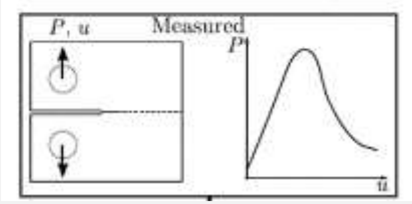

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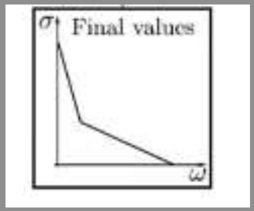

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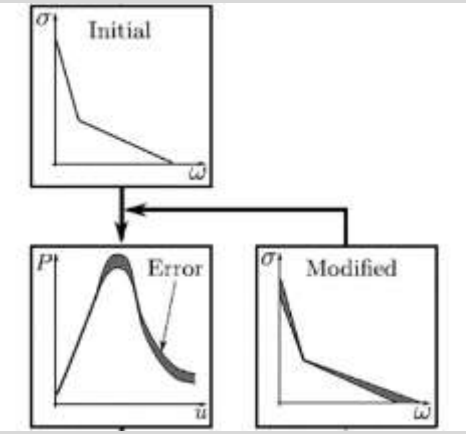

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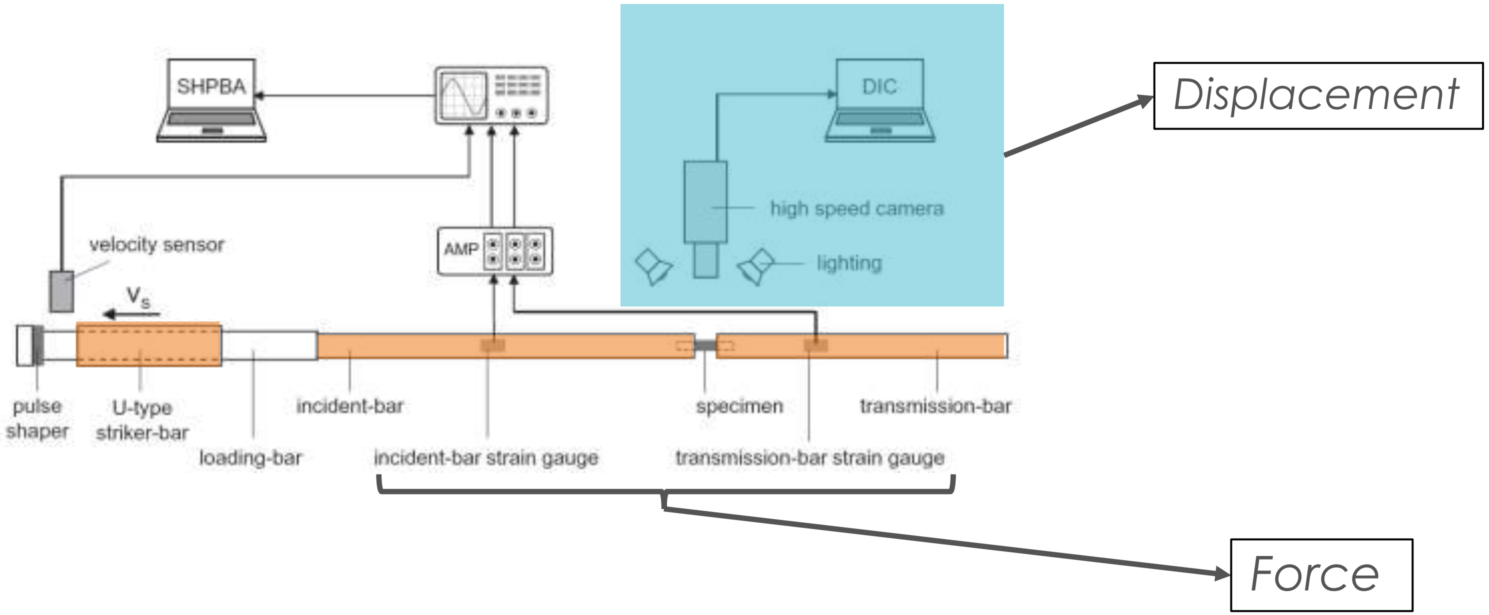
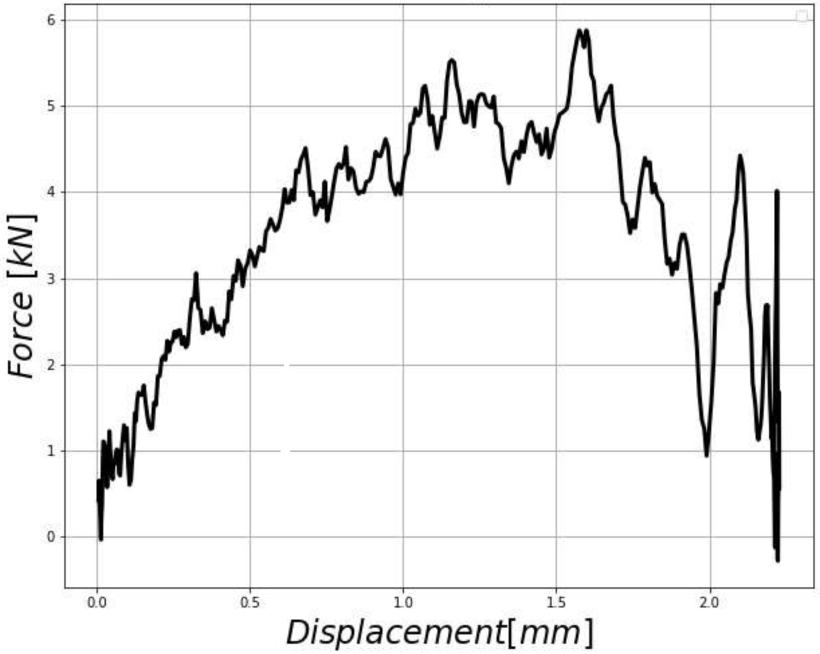
Split Hopkinson Pressure Bar





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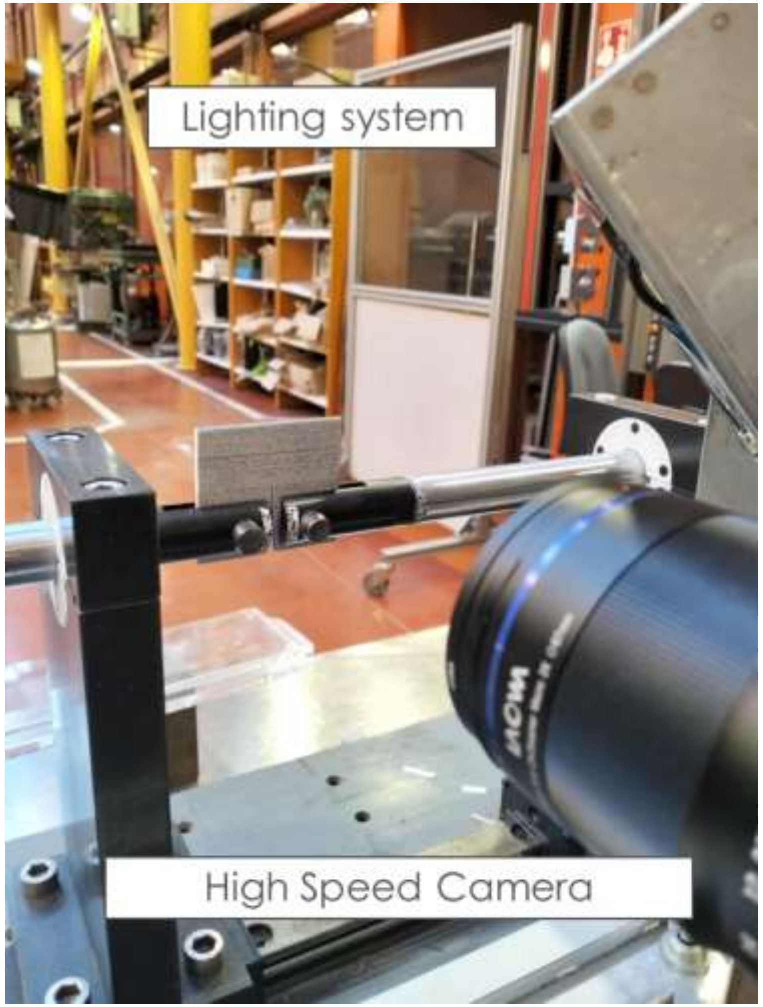
Experimental methodology

- **Dynamic** — Universidad Carlos III de Madrid (uc3m)
- **Split Hopkinson Pressure Bar:**
  - *Incident: 4.6m Steel bar Ø22mm*
  - *Transmitted: 1.4m Steel bar Ø22mm*
- **Pulse shaper:**
  - *Cupper ring: Ann th: 2mm Th: 0.5mm*
- **Specimen:**
  - *CFRP CT: 60*65*4.28 mm^3*
  - *Three laminates*

Cross ply

L1 (50% 0°)

L2 (QI)



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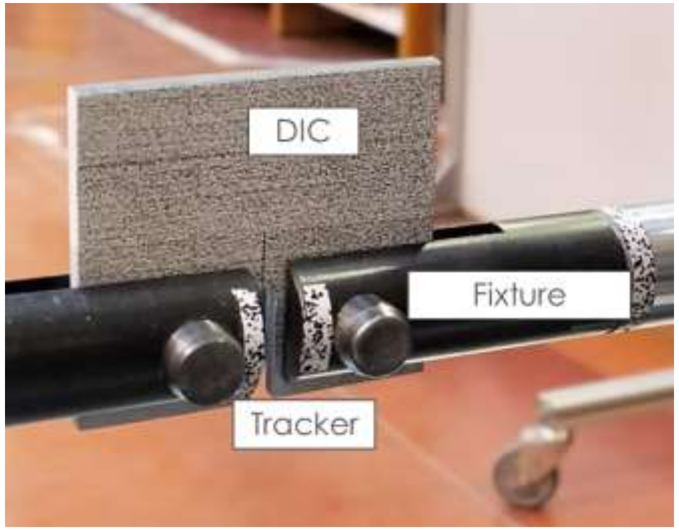

High Speed video Camera
Phantom TMX 6410 @ 530kfps
- *In-plane strains by DIC*
- *Opening trackers*

- **Quasistatic** AMADE Universitat De Girona

- *INSIGHT 100kN (0.5mm/min)*
- *Clip-On COD extensometer*
- *Optical system traveller (Canon 550D + macro EF) to monitor the crack growth*

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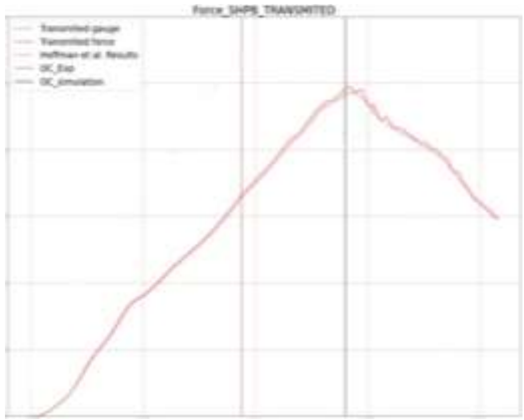
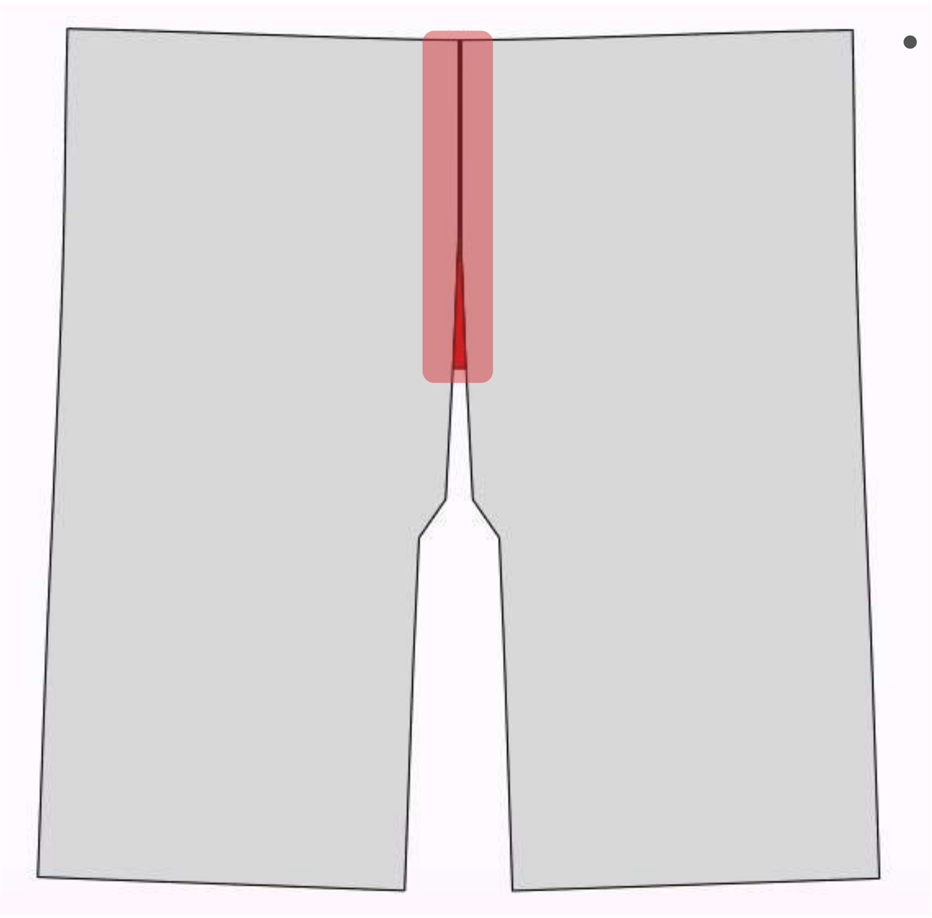
Numerical methodology

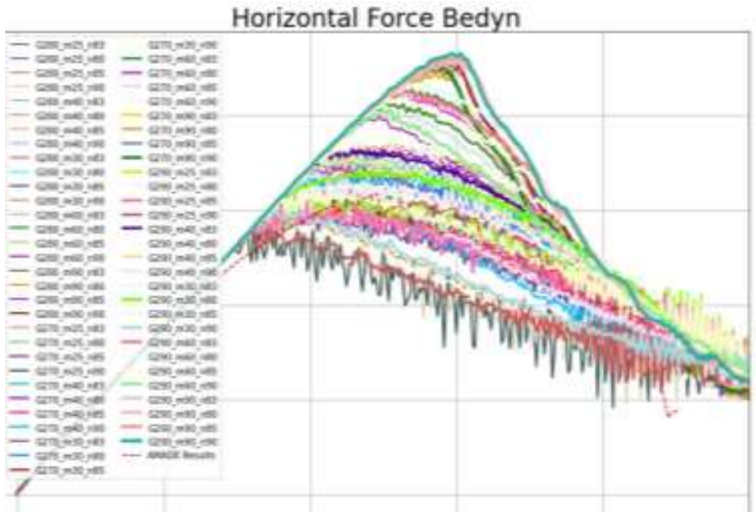
- **Explicit model**
- **Simplified model:** *Displacement data is obtained from input bar.*



- **Specimen:**
  - *2D Shell elements*
  - *Elastic properties of the laminate*



- **Cohesive elements**
  - *Quadratic stress initiation criteria*
  - *Linear and bi-linear softening*
  - *B-k mixed mode*



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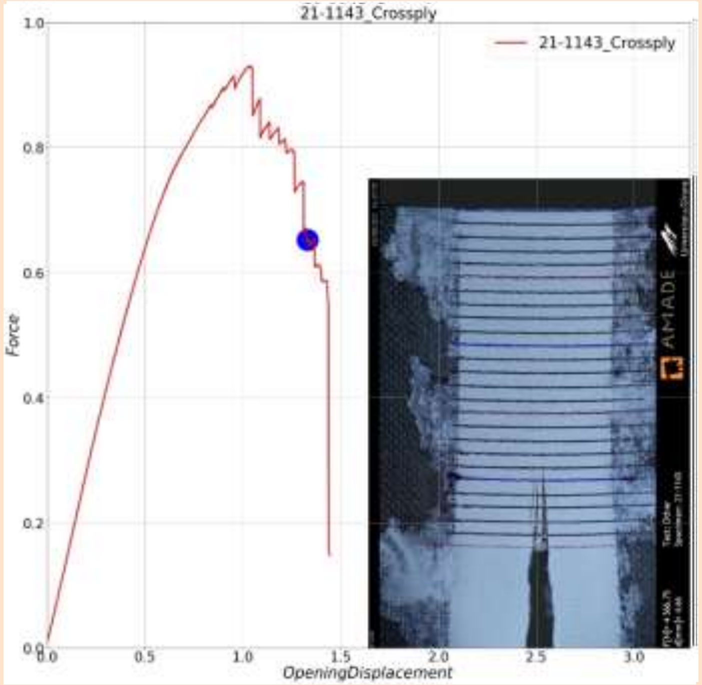
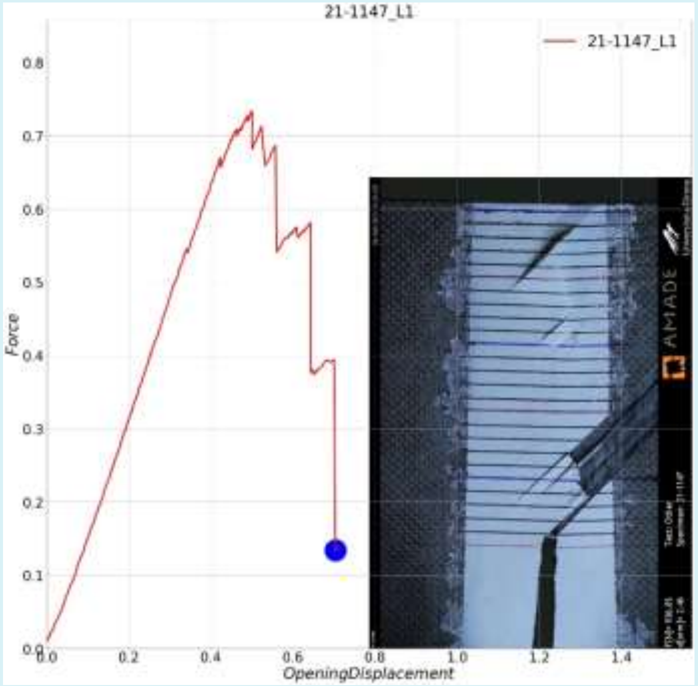
Results Quasistatic test

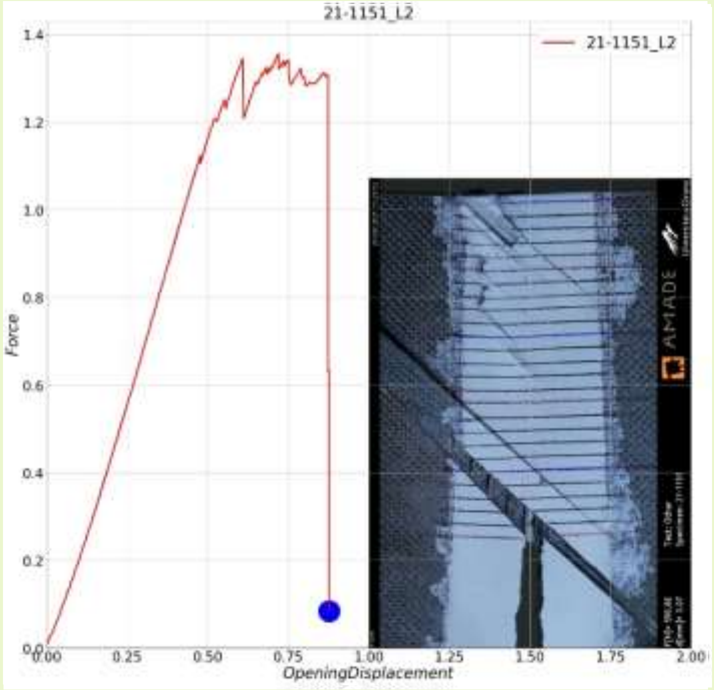
Cross ply



L1 (50% 0°)



L2 (QI)



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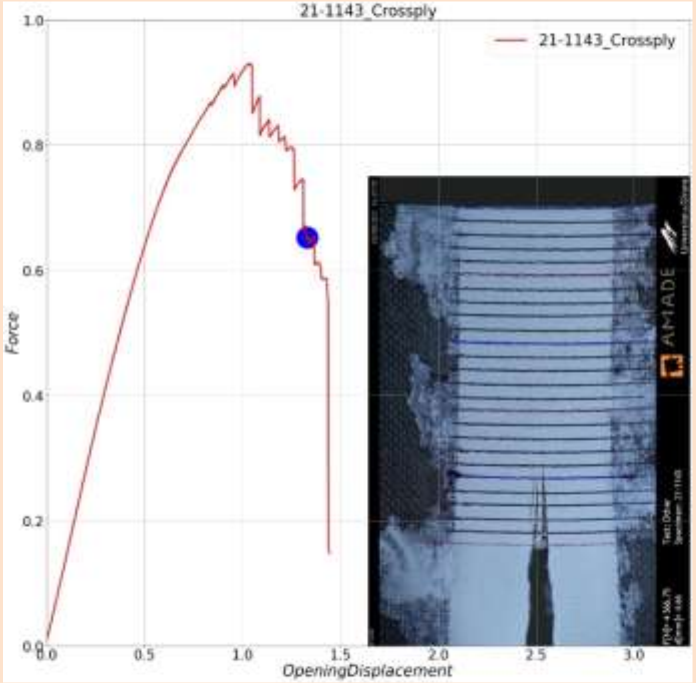

Area method

$G_{Ic} = G_{IcQS}$

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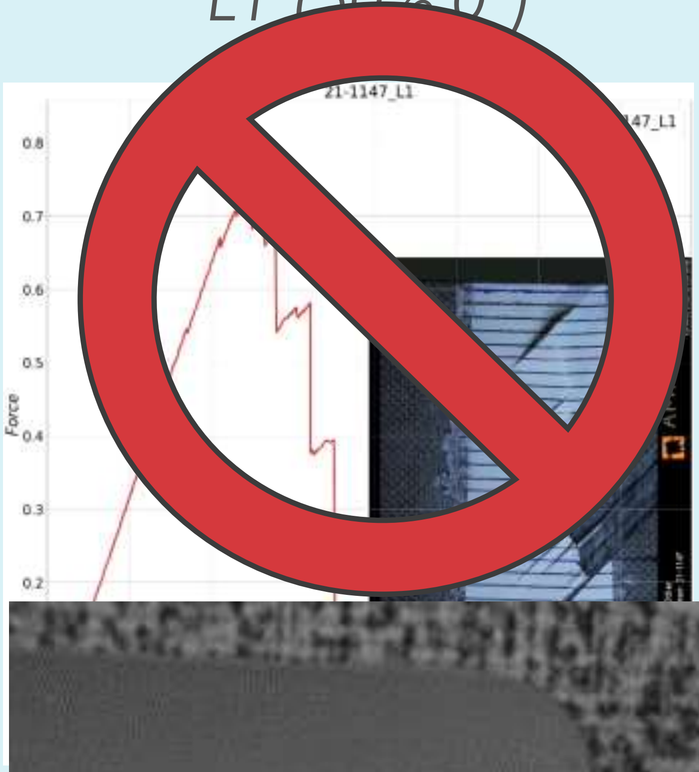

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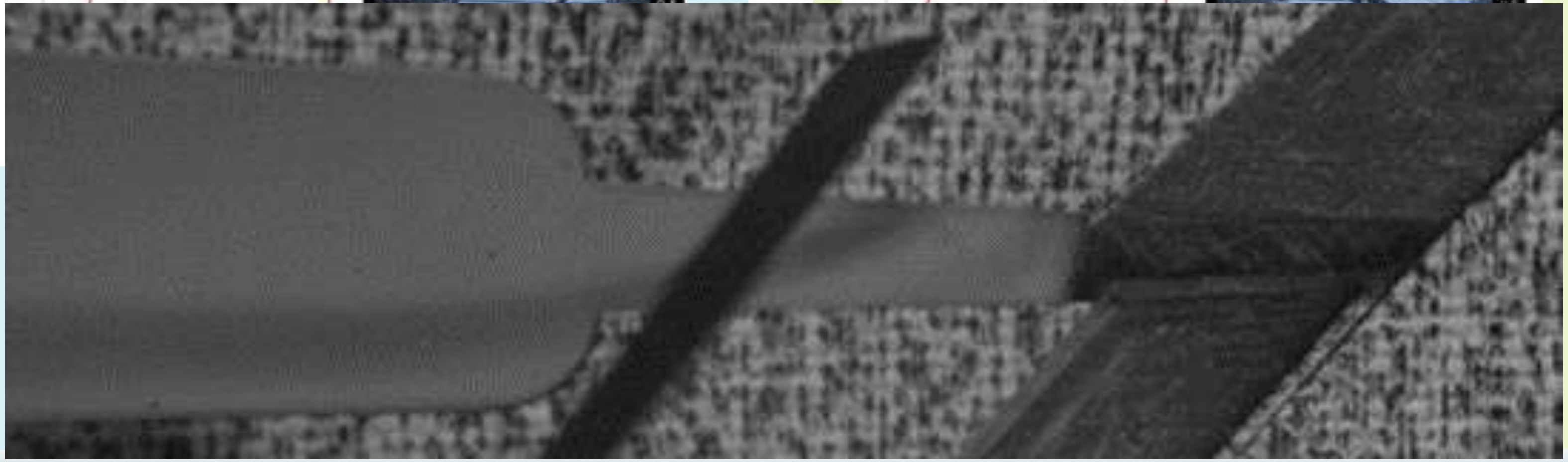

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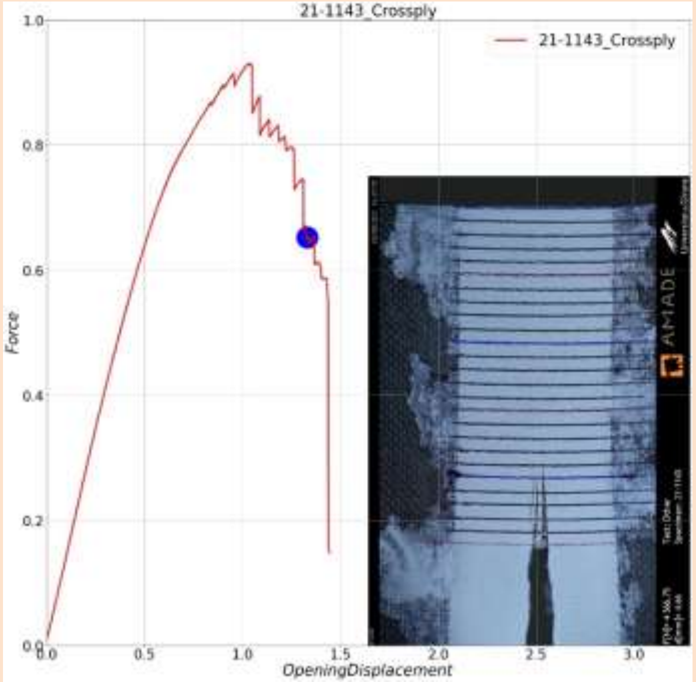

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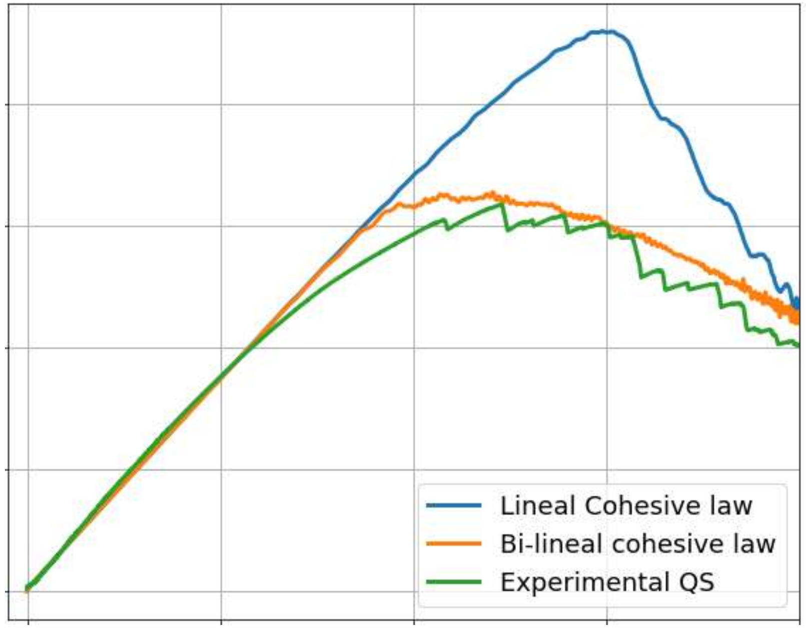

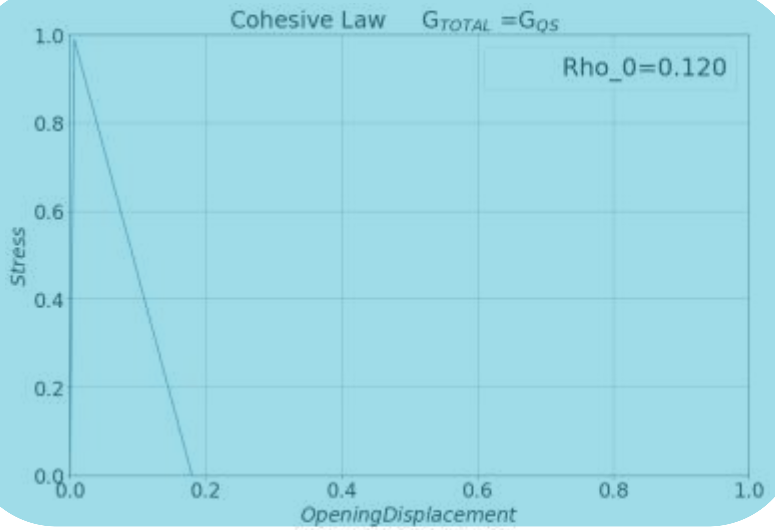

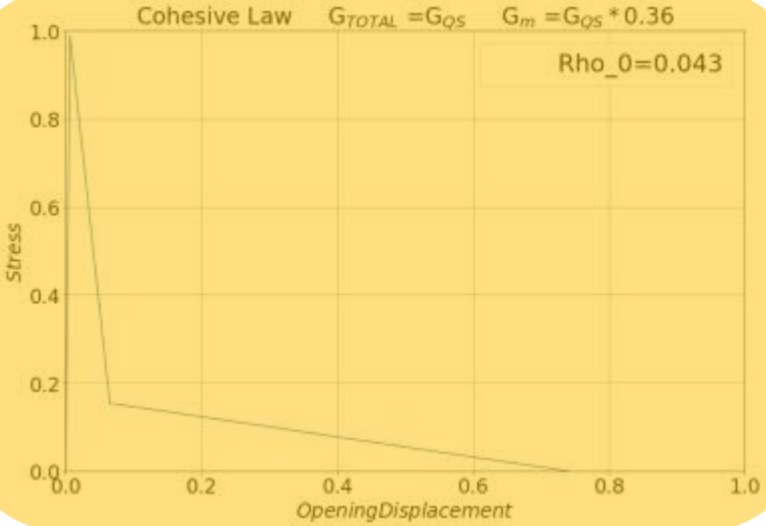

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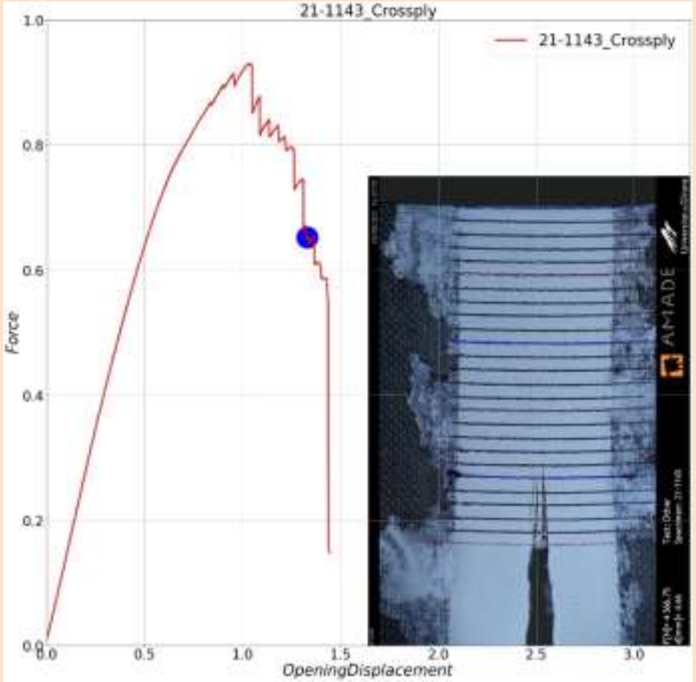

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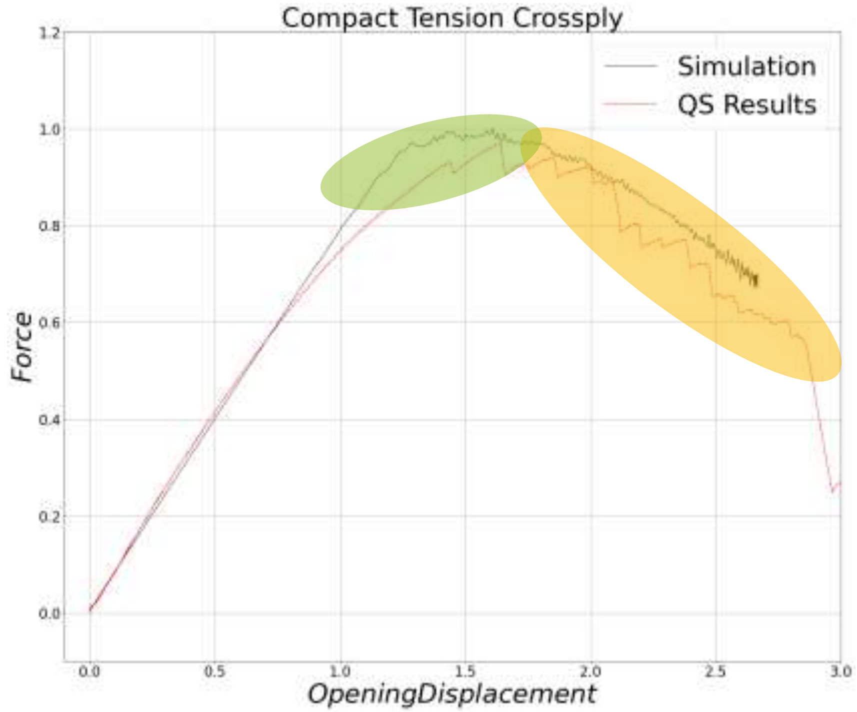
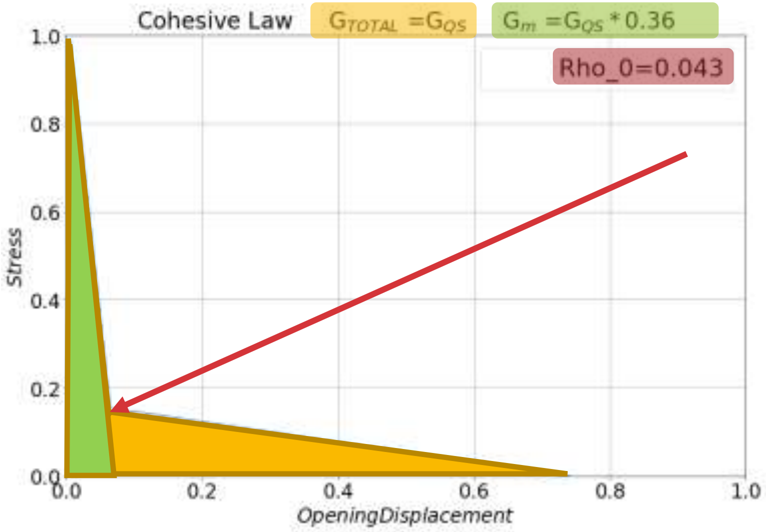


Valid for all laminates sinces no crack measure is needed



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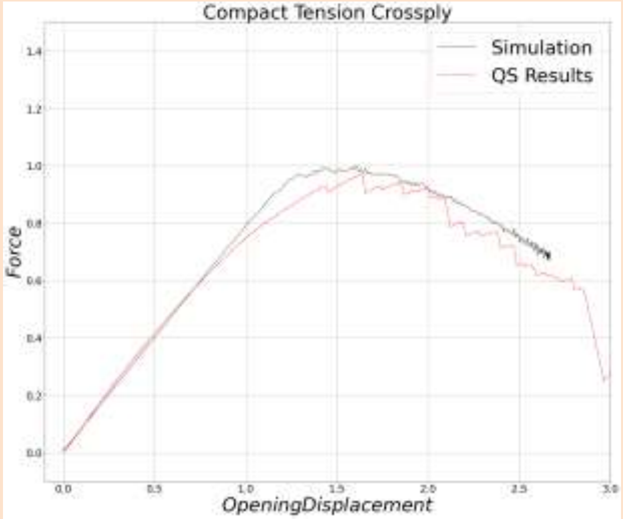

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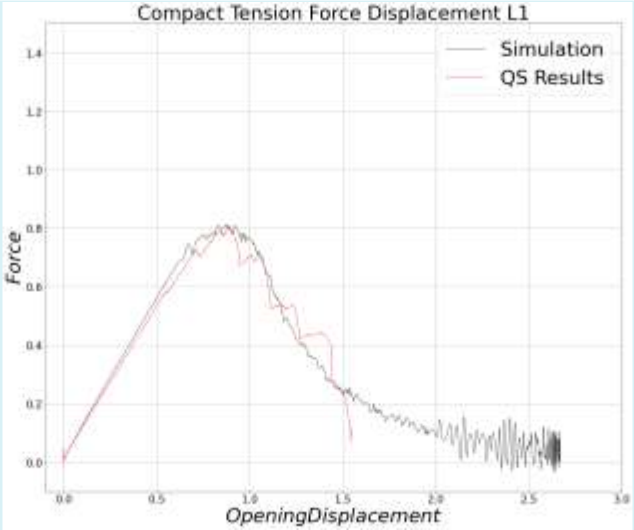

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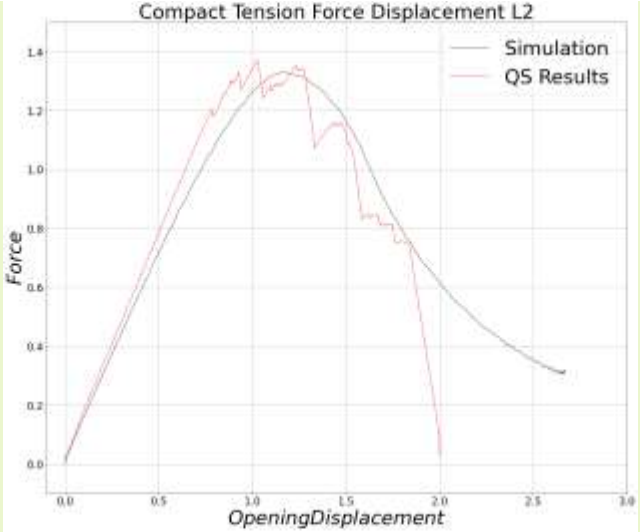

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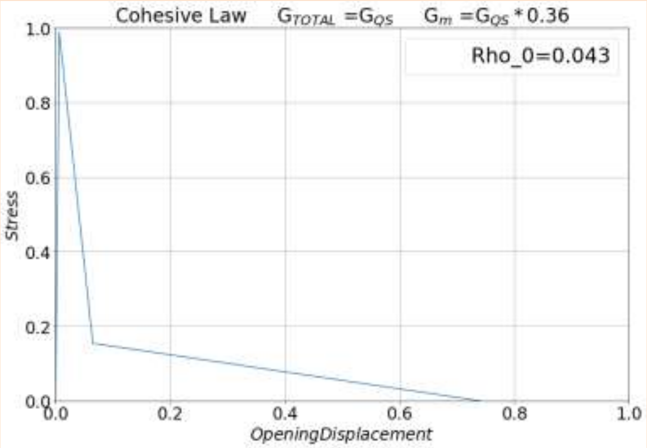

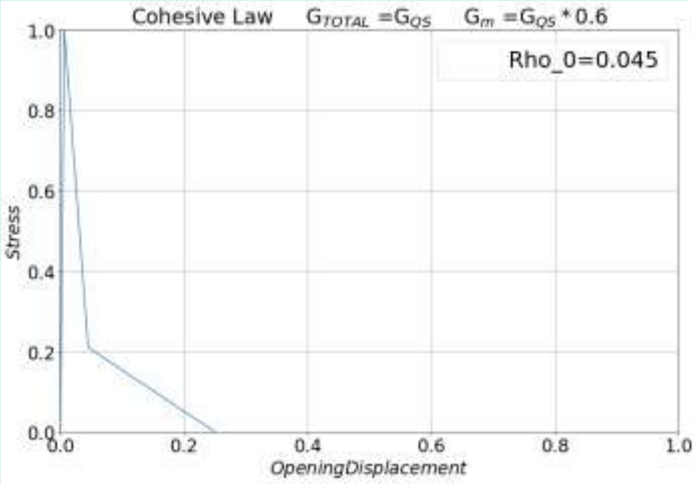

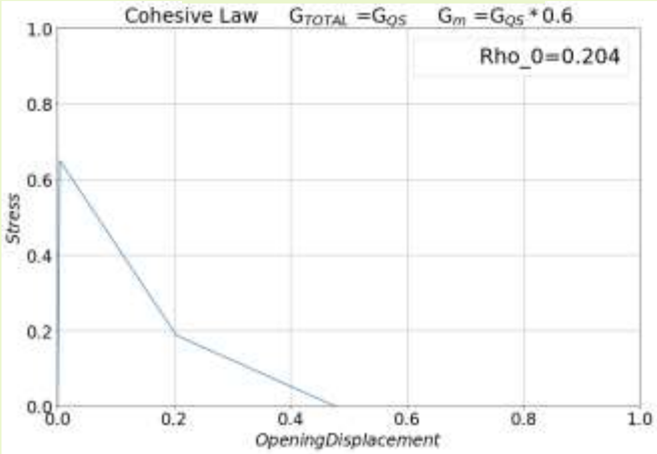

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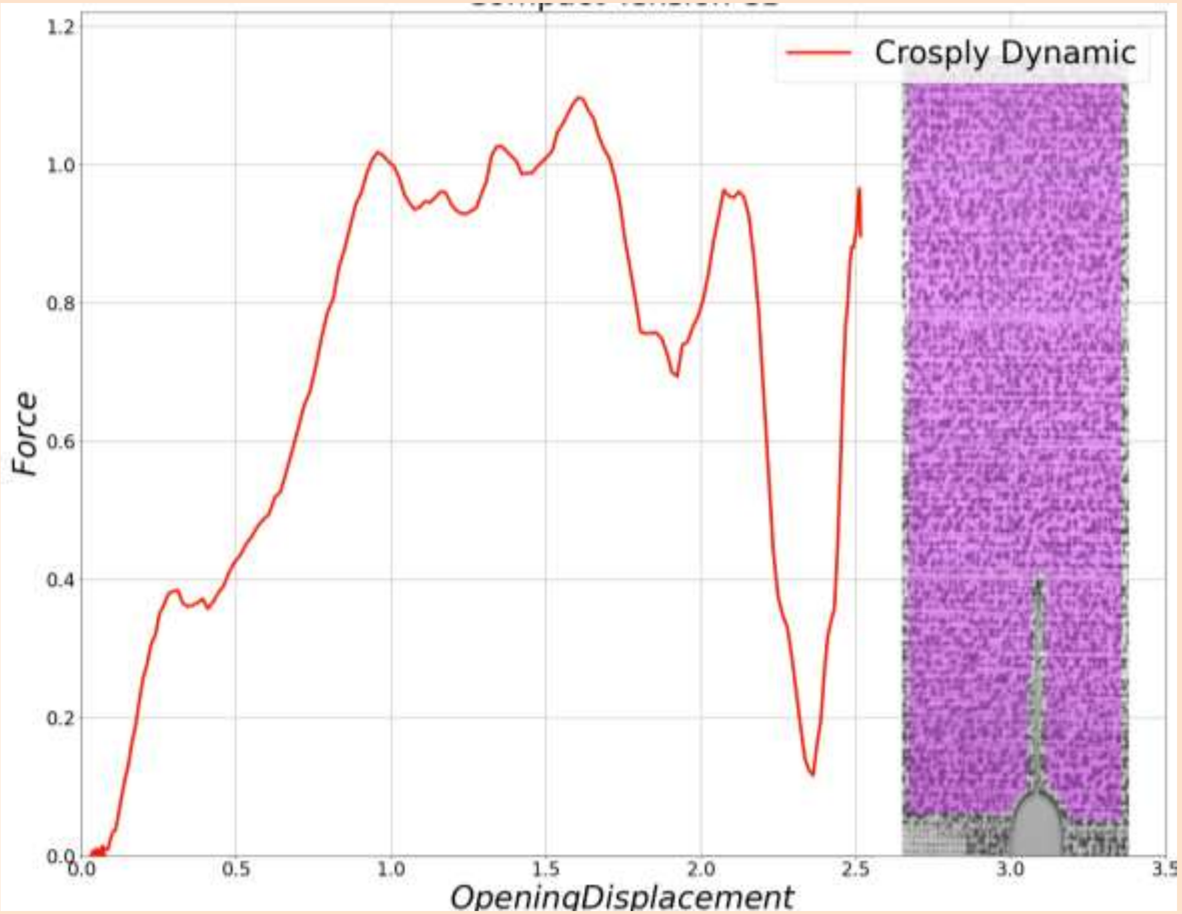
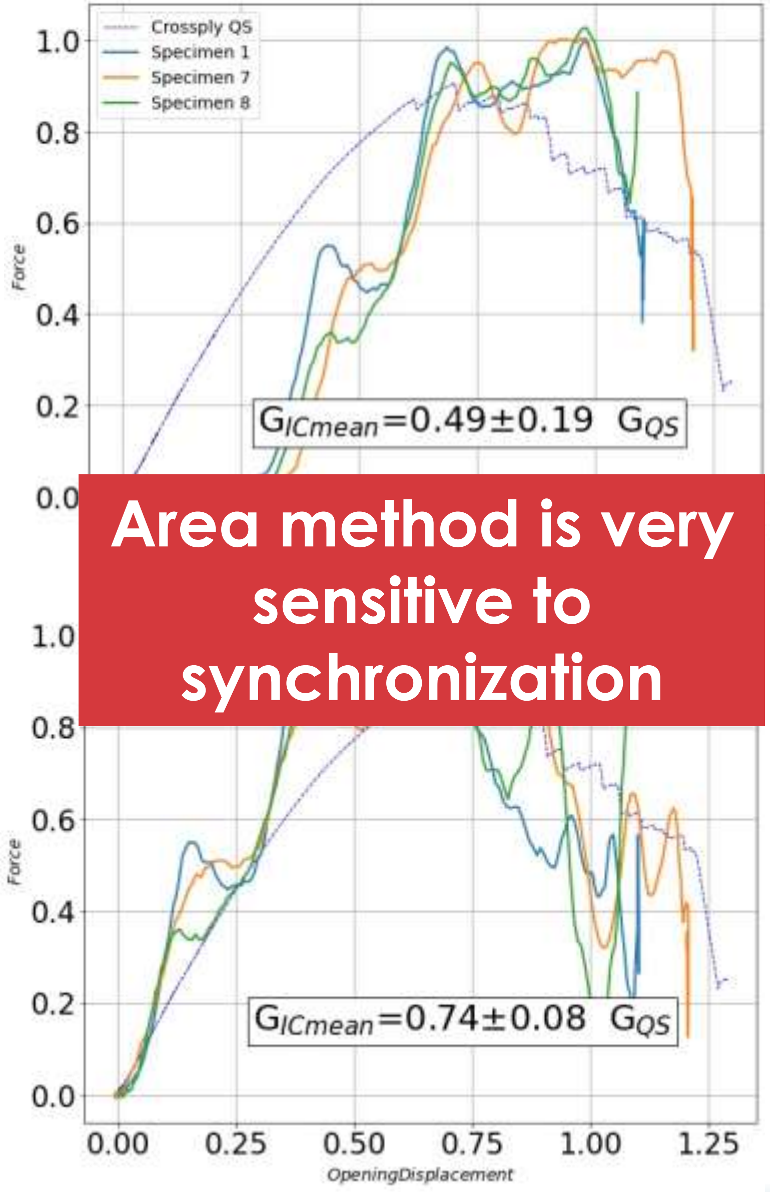
Results Dynamic test

Cross ply





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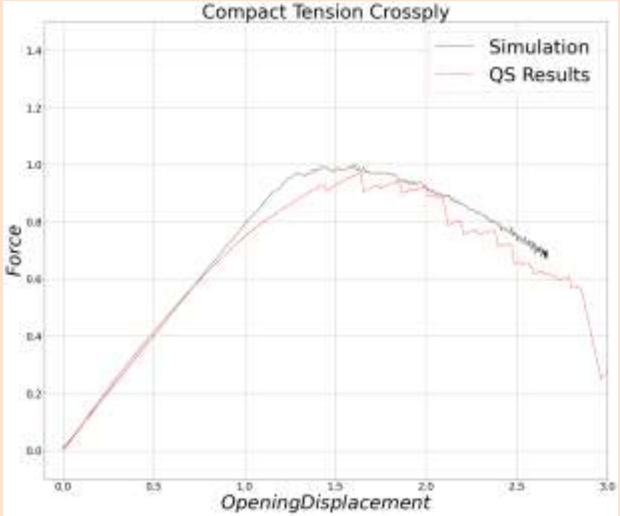
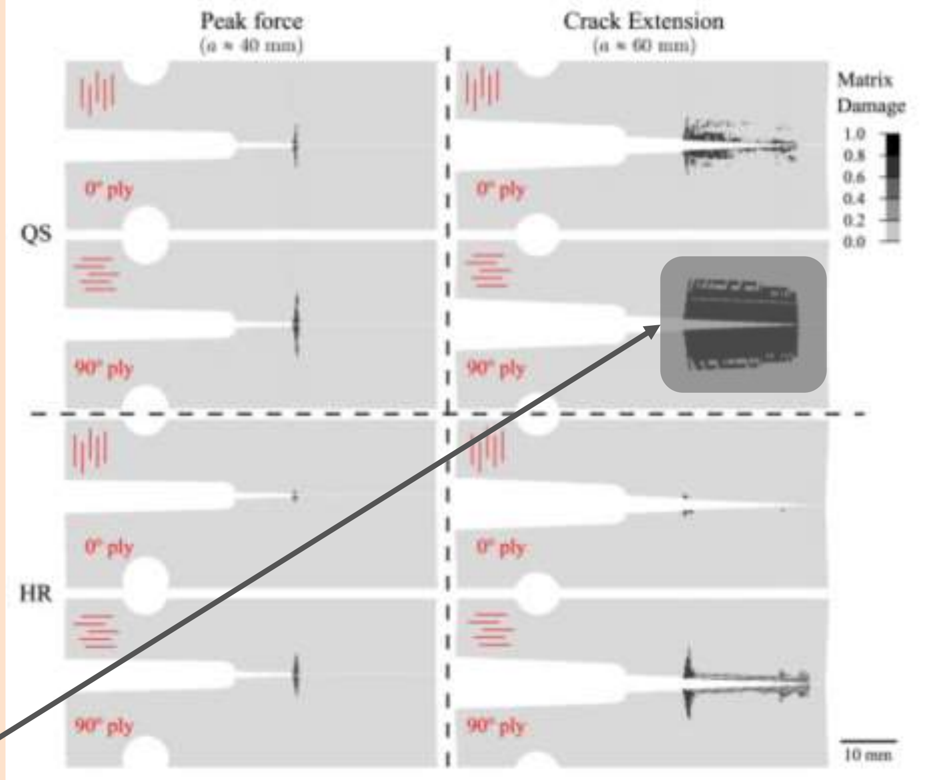
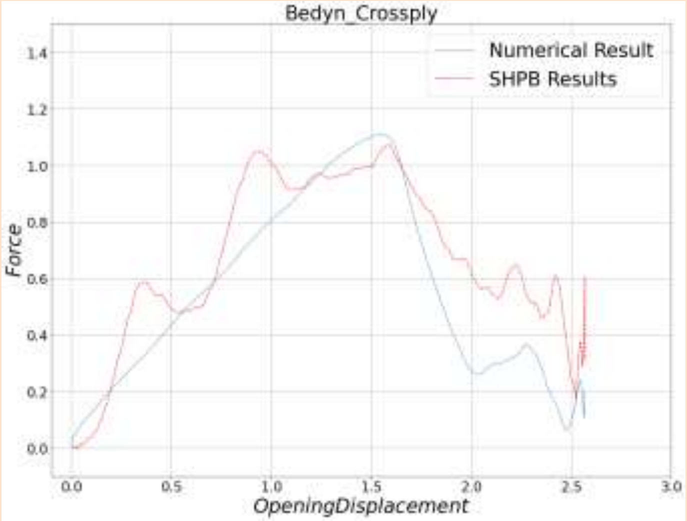
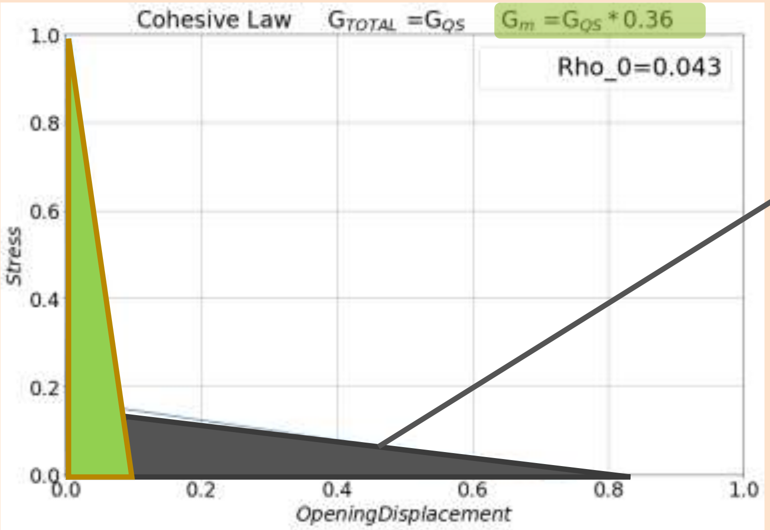
Results Dynamic test   Cross ply



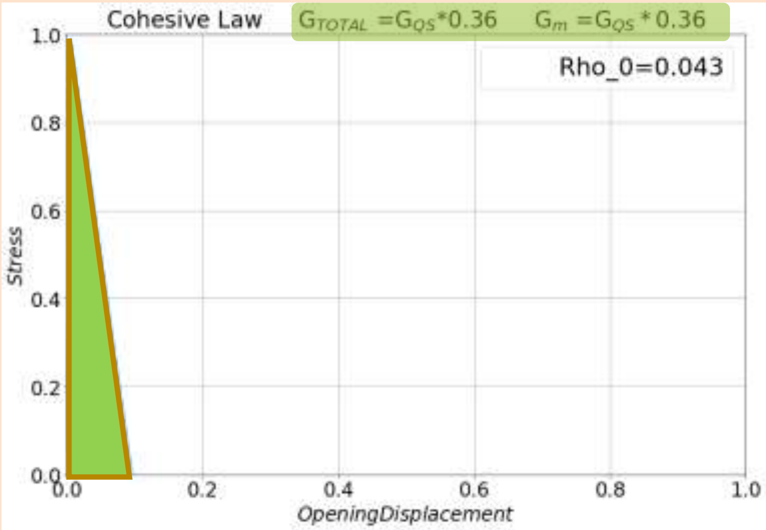






Numerical modelling of quasi-static and dynamic compact tension tests for obtaining the translaminar fracture toughness of CFRP

Drew E. Sommer, Daniel Thomson, Justus Hoffmann, Nik Petrinic



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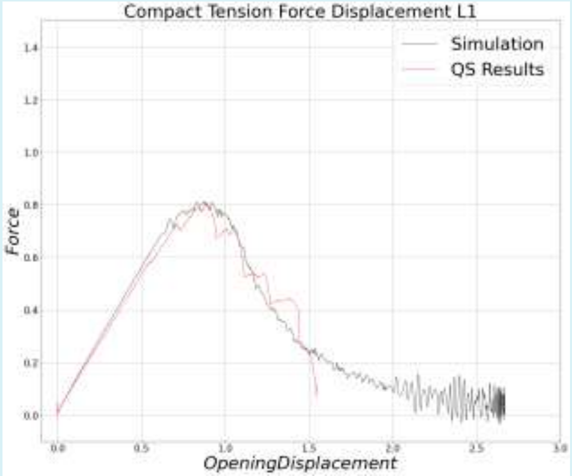
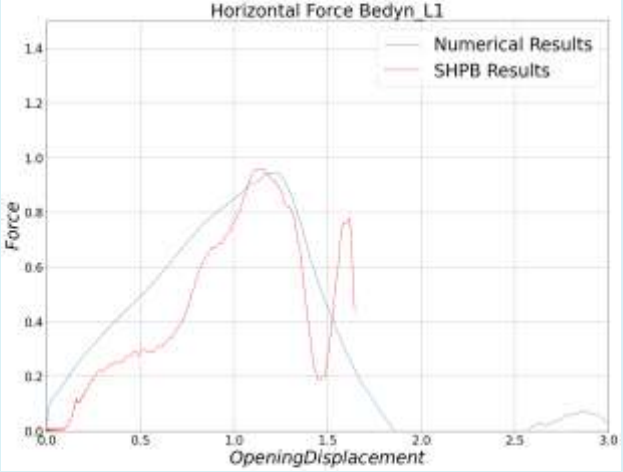
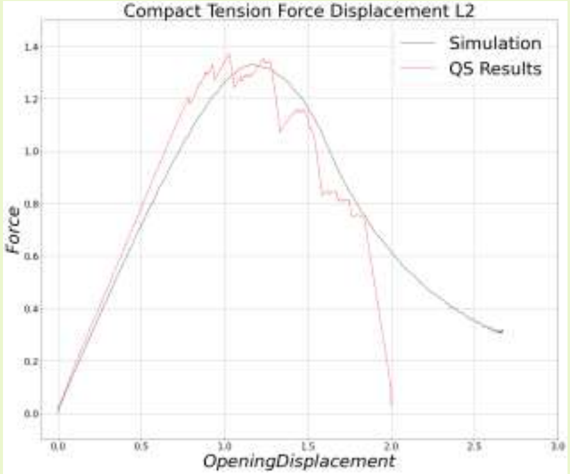
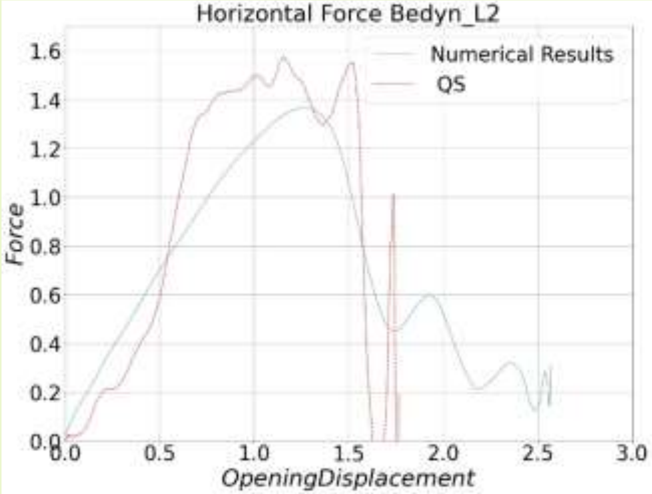
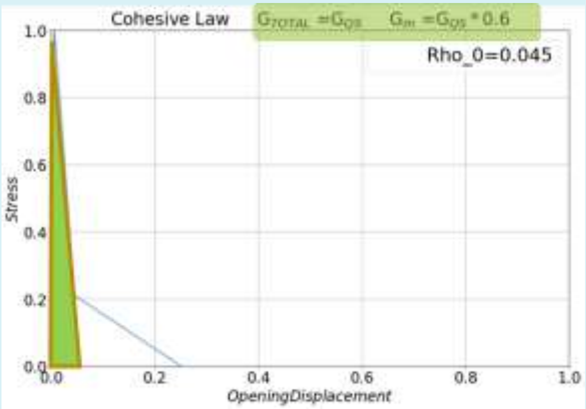
Results Dynamic test L1 (50% 0°) L2 (QI)

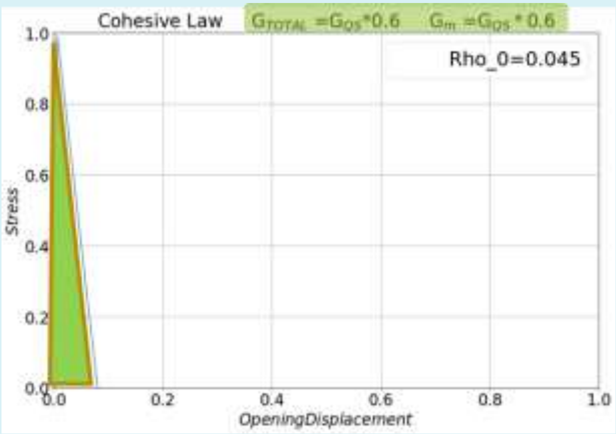


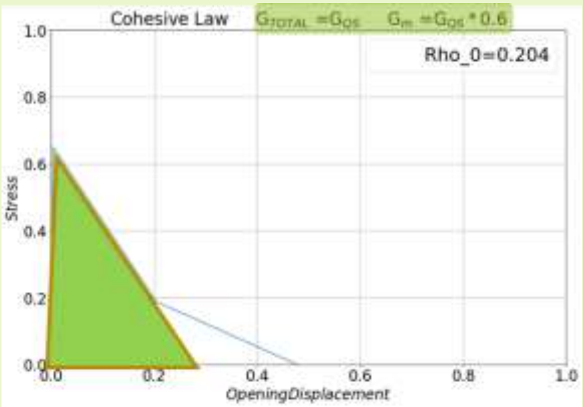


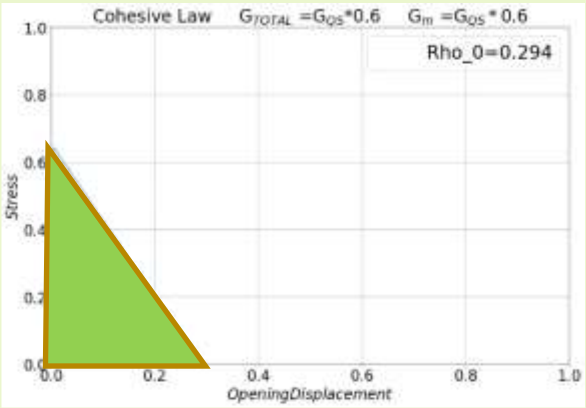












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Outline

- Introduction
- Methodology
- Results
- Conclusions

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Conclusions

- *Experimental tests and numerical analysis of CT specimen under dynamics loadings has been done.*

Cross ply	L1 (50% 0°)	L2 (QI)

- *Combined numerical and experimental methodology shows a good agreement in quasistatic conditions.*
- *Proposed methodology is valid to obtain cohesive law for different stacking sequences.*
- *Area method is very sensitive to synchronization.*
- *Proposed methodology is valid to obtain cohesive law at high rate taking into account uncertainties due to specimen wave propagation.*
- *Laminate fracture toughness is reduced at high rate due to the reduction on damage area around the crack*

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EVALUATING THE INTRALAMINAR TENSILE FRACTURE BEHAVIOR OF COMPOSITE MATERIALS UNDER HIGH RATE LOADING THROUGH ACOMBINED EXPERIMENTAL AND NUMERICAL METHODOLOGY

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11th International Conference on Composite Testing and Model Identification (COMPTEST 2023)

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