ICAF

International Committee on Aeronautical Fatigue and Structural Integrity

Topical National Review
Structural Integrity of Composite Structures

Daniele Fanteria – University of Pisa |June 11, 2025

Structural Integrity of Composite Structures

Contents

- Overview of the topic in the National Reviews and in the ICAF 2025 Program
- Topics related to Structural Integrity of composite structures taken from the National Review of Brazil.
- Topics related to Structural Integrity of composite structures taken from the National Review of the United Kingdom.
- Topics related to Structural Integrity of composite structures taken from the National Review of France.
- Topics related to Structural Integrity of composite structures taken from the National Review of Italy.

Overview of the topic in NRs and in ICAF 2025 Program

- About **23% of topics in NRs** are about SI for composite structures
- **More than 20 presentations**, including posters, are about SI for composite structures, that is about **27% of the total**
- Sub-topics about SI for composite structures
  - Fatigue, Damage Tolerance & Durability of Composites
  - Delamination fatigue & fracture
  - Structural Integrity of Joints
  - Composite repairs
  - NDI and SHM
  - Damage (impact, crash,...) and failure of Laminates/Structures
  - Structural Integrity interactions with Design
  - Modeling & Simulation for Composite Structural Integrity
  - Structural Integrity interactions with environmental conditions
  - Structural Integrity and Buckling

Structural Integrity of Composite Structures by sub-topics in NRs

Subtopic	#	Contributing Countries
• Fatigue, DT & Durability of Composites	3	The Netherlands (3)
• Delamination fatigue & fracture	14	Brazil (4), Israel (4), Italy (2), Japan, The Netherlands (3)
• Structural Integrity of Joints	7	Brazil, Canada (2), Finland, Italy, Japan, Sweden
• Composite repairs	5	Australia, China, France (2), Japan
• NDI and SHM	4	Italy, Poland, Sweden, United Kingdom
• Damage (impact, crash,…) and failure of Laminates/Structures	9	Australia, Brazil, Canada, China, Finland, Italy, The Netherlands (2), United Kingdom
• Structural Integrity interactions with Design	6	Brazil, Canada, China (2), Israel, Japan
• Modeling & Simulation for Composite Structural Integrity	5	Australia (2), Brazil, China, Israel
• Structural Integrity interactions with environmental conditions	4	Australia, China, Sweden, Italy
• Structural Integrity and Buckling	2	Canada, China

Structural Integrity of Composite Structures by subtopics in the program of ICAF 2025

Fatigue, Damage Tolerance & Durability of Composites

	Type	Day
Residual strength analysis of composite stiffened panels after stiffener debonding using an industrial numerical damage model	O	3
Research of sub-components fatigue standard test method for thick-section composite laminate of rotor dynamic components	O	3
The effect of printing direction on the mechanical performance of 3D-printed CF/PEEK TPMS structures	P	2
Experimental study on narrow-band random vibration fatigue of composite plate structures	P	3

Delamination fatigue & fracture

	Type	Day
Fatigue propagation of interface damages in layered composites	O	1
Mode II fatigue delamination growth of CFRP composite laminates – effect of interface angles	O	1
New data reduction methods for measurement of the interlaminar fracture toughness of composite materials	O	2
Delamination growth behavior and its characterization of composite multi-directional laminates	O	3
Fatigue failure behaviors of composite with delamination defect under bending load	P	1

Structural Integrity of Composite Structures by subtopics in the program of ICAF 2025

Structural Integrity of Joints

	Type	Day
• Fatigue strength test analysis of composite metal fuselage panel connection structure for civil aircraft	O	1
• Parameter calibration and static analysis method for composite bolted joints considering uncertainty	P	3

Damage (impact, crash,…) and failure of Laminates/Structures

	Type	Day
• A novel impact fatigue testing machine based on electromagnetic technology	O	3
• The Low Velocity Impact (LVI) and Compression After Impact (CAI) of carbon fiber reinforced thermoplastic composites	O	3
• Damage prediction and strength analysis method for composite aircraft inlet based on Hashin criterion	P	1
• Evaluation and prediction methodology for failure modes in full-scale metallic airframe-composite vertical tail assembly with BVID (Barely Visible Impact Damage) impact	P	3

Structural Integrity of Composite Structures by subtopics in the program of ICAF 2025

Structural Integrity interactions with Design

	Type	Day
• A preliminary design scheme for composites scarf bonding structures combining mechanical analysis and machine learning methods	O	1
• Composite layup design for hat-stiffened panel of composite fuselage based on buckling stability	P	2

Modeling & Simulation for Composite Structural Integrity

	Type	Day
• Multiscale strength analysis of c/sic composite materials consideri ng oxidative damage	O	3
• Nonlinear failure investigation of ±45° composite panels using finite element modeling	O	3

Structural Integrity interactions with environmental conditions

	Type	Day
• Effect of thermal and external load on mechanical behaviour of CFRP/aluminium hybrid joints	O	3

Structural Integrity and Buckling

	Type	Day
• Research on the buckling and fatigue characteristics of composite hat-stiffened panel	P	2

Overview of the topic in NRs and in ICAF 2025 Program – some remarks

- **Structural integrity for composite structures** is a **topic of interest** within the ICAF community, as evidenced by the numerous presentations given at the 2025 event.
- Almost **¼ of the topics covered by National Reviews** are related to the **Structural Integrity of composite structures**. NRs have received a particularly high number of contributions on the following subtopics (more details in the appendix):
  - Delamination fatigue & fracture (14 contributions)
  - Damage (impact, crash,…) and failure of Laminates/Structures (9 contributions)
  - Structural Integrity of Joints (7 contributions)
  - Structural Integrity interactions with Design (6 contributions)
  - Modeling & Simulation for Composite Structural Integrity (5 contributions)
  - Composite repairs (5 contributions)
- As US NR is not yet available, one of the National Delegates provided a comment on the status of the topic from his perspective: "USAF continues to develop simulation capabilities to enable damage tolerance approaches for life management of polymer matrix composites".

Topics related to Structural Integrity of composite structures taken from the National Review of Brazil

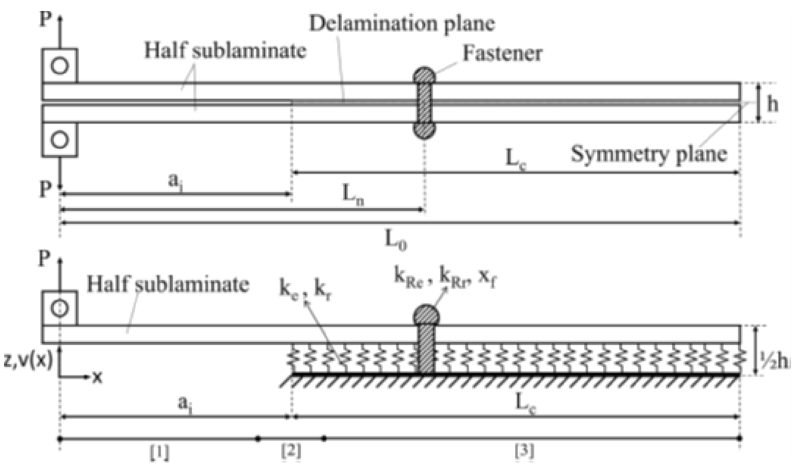
Topics related to Structural Integrity of composite structures taken from the NR of Brazil.

- A numerical and experimental study of fasteners as a delamination arrest mechanism in composite laminates under Mode I loading - ITA
- Evaluation of the effect of fiber orientation on fatigue crack propagation in CFRP: Finite fracture mechanics modelling for open-hole configuration - ITA
- Investigation on Induced Intra/Interlaminar Damage Propagation in CFRP Subjected to Cyclic Tensile Loading After Impact - ITA
- Data reduction methods in the fatigue analysis of the Double Cantilever Beam - USP
- Progressive intralaminar damage in woven composite materials under mixed-mode fracture - ITA
- Manufacturing deviations in composed fastened joints - EMBRAER
- EVE-100 EVTOL development - EMBRAER

A numerical and experimental study of fasteners as a delamination arrest mechanism in composite laminates under Mode I loading – ITA

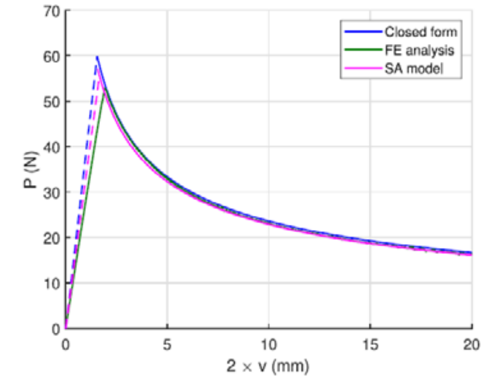
- Semi-Analytical model to investigate **Mode I delamination** in Double-Cantilever Beam (DCB), **incorporating** the presence of **holes and fasteners**
- **First known analytical method capable of including holes** and **fasteners** in Mode I delamination analysis
- Model **validated** through combination of **experimental tests and FEA**, using Cohesive Zone Modelling (**CZM**)
- Proposed **model accurately predicts delamination behaviour**, while significantly **reduces computational costs**

A numerical and experimental study of fasteners as a delamination arrest mechanism in composite laminates under Mode I loading – ITA

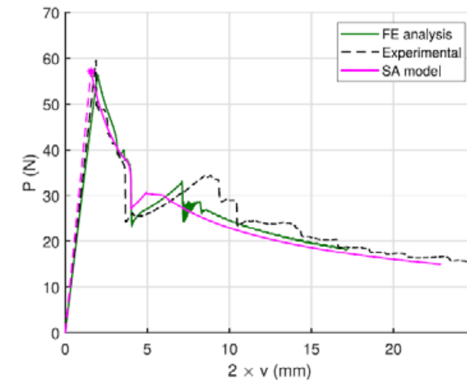


Model Representation

Semi analytical model of a plain DCB specimen against theory



Semi analytical model with a hole against FEA and experimental data



Manufacturing deviations in composed fastened joints - EMBRAER

- Mechanical **tests at coupon level** addressing the **effect of manufacturing and assembly deviations on the strength of composite fastened joints**
- Several types of manufacturing and assembly deviations assessed, such as **reduced fastener edge**, **reduced fastener pitch**, hole with bad quality, and **excessive washer and shim usage**
- **Data** obtained allowed a better **assessment of the criticality of each defect** type by engineering teams when giving disposition on non-conformities in the manufacturing of composite components

Topics related to Structural Integrity of composite structures taken from the National Review the United Kingdom

Topics related to Structural Integrity of composite structures taken from the NR of the United Kingdom

- Structural Health Monitoring, Manufacturing and Repair Technologies for Life Management Of Composite Fuselage (SHERLOC) - Imperial College London
- Developing the contour method for estimating residual stress in carbon fibre composite laminates - Coventry University, Cranfield University

Structural Health Monitoring, Manufacturing and Repair Technologies for Life Management Of Composite Fuselage (SHERLOC) - Imperial College London

- Overall objective:
  - To combine advanced **SHM & smart repair technologies** with a probabilistic design philosophy, & hence to develop **new maintenance concepts** to **reduce** the direct operative **costs** without lowering the **operational safety**.
- The main achievements of SHERLOC can be summarised as:
  - Attainment of TRL6 (from TRL3), for SHM technologies and methodologies following a unique and dedicated building block (BB) approach, in parallel to mechanical BB for validation and verification of 5 main structural items.
  - Development of **reliability-based methodologies for detecting** and localising **BVID** in composite structures, **validated** for composite fuselage panel under **operational conditions**.

SHERLOC – Imperial College London

- The main achievements continued..
  - The most **comprehensive and detailed testing**, verification and validation of **SHM technologies** and methodologies under **operational** and environmental **conditions**, representative of **regional aircraft**.
  - Development of a high-performance computing (HPC) **SHM/NDI virtual platform** featuring a smart fuselage barrel. The platform is capable of structural **analysis** and structural **health monitoring**, resulting in the **residual strength** analysis.
  - SHERLOC achievements are verified and validated through the **building block** approach at three levels of **coupon**, **element** (skin/stringer, aft, window frames, floor structures) and **subcomponent** (real scale flat and curved composite panels). The operational conditions are taken into account to demonstrate the **SHM technology operating in industrially relevant conditions (TRL6).**

Developing the contour method for estimating residual stress in carbon fibre composite laminates

Coventry University, Cranfield University

- **Measurement of residual stress (RS) in CFRP is often avoided** due to challenge presented by its non-crystalline microstructure and anisotropic material behaviour.
  - Non-consideration of RS may lead to under or overdesign structures.
- **Contour method (CM)** is an elastic stress relaxation technique based on Bueckner's elastic **superposition principle.**

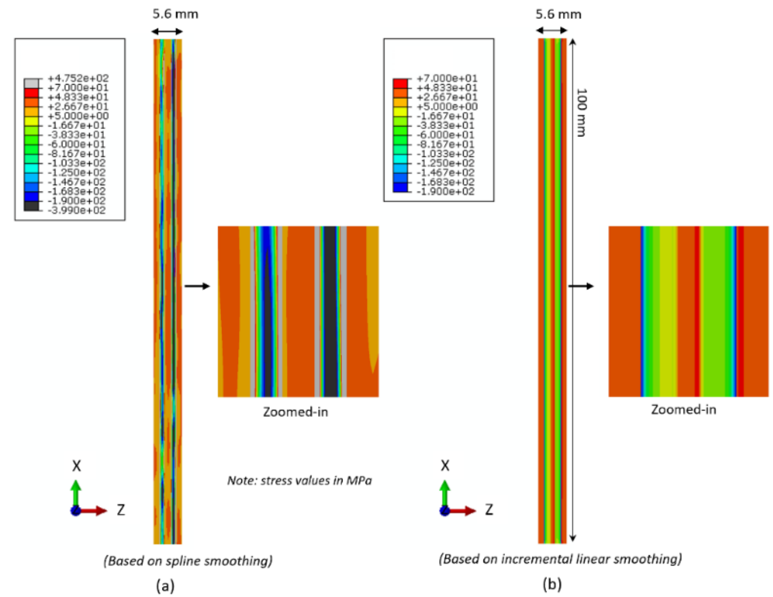


Figure 1: (a) residual stress map obtained with spline smoothing, (b) residual stress map obtained with incremental linear smoothing.

Developing the contour method for estimating residual stress in carbon fibre composite laminates

Coventry University, Cranfield University

- In this study, an **incremental linear smoothing** approach (rather than spline smoothing) was introduced to smooth the surface displacements in CFRP.
  - Incremental linear smoothing/ approximation offered **a better fit for the displacement data of CFRP** than the spline smoothing approach.
  - **Good correlation between CM** result based on incremental linear smoothing and **classical laminate theory**.
  - Study showed the importance of CM data smoothing.

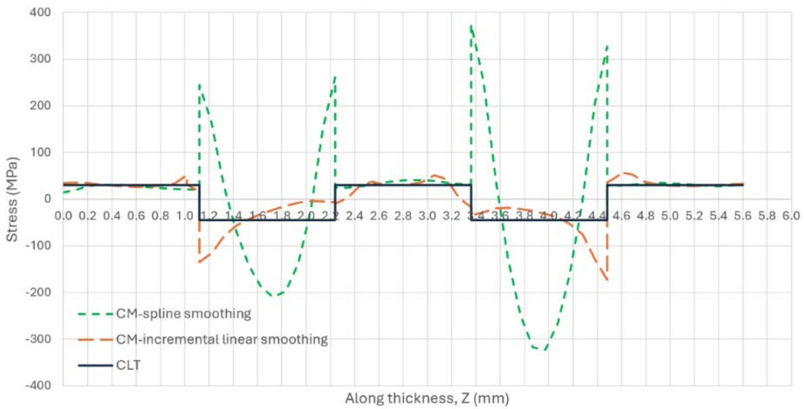


Figure 2: Comparison of stress profiles obtained from the contour method (CM) and the classic laminate theory (CLT). Note: the plotted data for CM were taken from mid-width (X) location.

International Committee on Aeronautical Fatigue and Structural Integrity

Topics related to Structural Integrity of composite structures taken from the National Review of France

Topics related to Structural Integrity of composite structures taken from the NR of France

- Experimental characterization of two structural bonded composite repairs
- Methodology for predicting the performance of bonded structural composite repairs in aeronautics

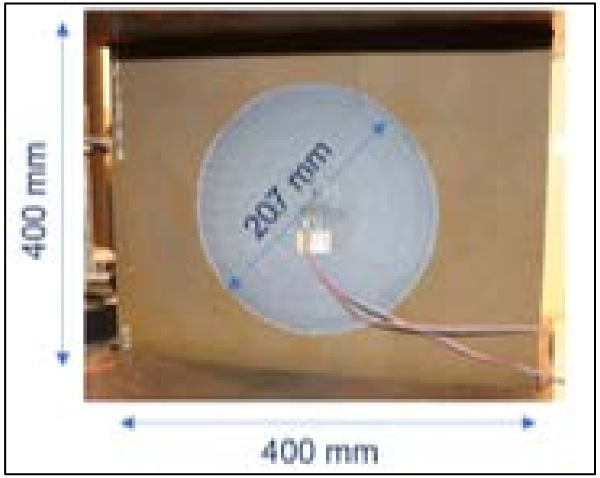
Experimental characterization of two structural bonded composite repairs

- **Introduction and Methodology of Repairs**

  Structural repairs are necessary to restore the mechanical properties of damaged composite parts, including strength, durability, and damage tolerance. Common repair methods for primary structures include bolted or hybrid (bolted and bonded) repairs, as non-destructive techniques for detecting weak bonds are lacking.

- **Advantages :**

  Bonded repairs offer benefits such as weight savings and uniform load transfer. This study explores the behavior of bonded repairs and their failure mechanisms by investigating two repair strategies on a 400 mm by 400 mm panelf bonded repairs.



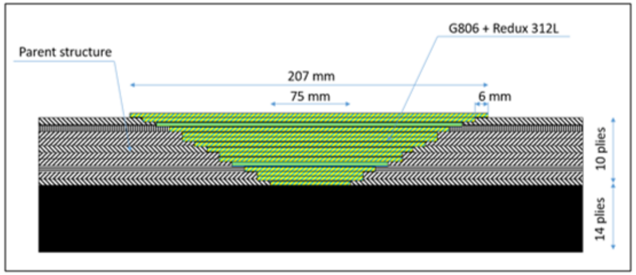
- **Repair strategies**

  Two repair strategies are studied: a **flush wet lay-up** (WLU) repair with **dry fabric** and **film adhesive**, and an external **pre-cured patch** bonded with the same adhesive

Experimental characterization of two structural bonded composite repairs

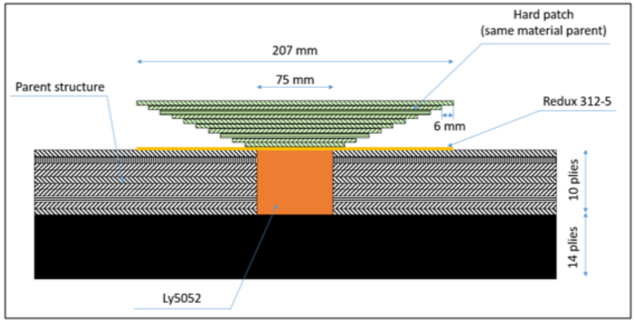
- **Fabrication of composite panels**

  The parent composite panels were made of 24 plies of UD carbon fiber/epoxy prepreg, cured in an autoclave at 180°C. **The initial damage** consisted of a **machined hole with a 75 mm diameter** and a **depth of 10 plies**



- **First repair: Flush repair**

  The first repair is a flush repair composed of 6 mm long steps, laid up with carbon fabric and film adhesive. An over-ply was added for protection and stiffness at the joint tips.



- **Second repair: External pre-cured patch repair**

  The second repair uses an external pre-cured patch with a modified stacking sequence for a symmetrical layout. The hole is filled with paste adhesive, and the patch is bonded using a film adhesive and a thermal blanket

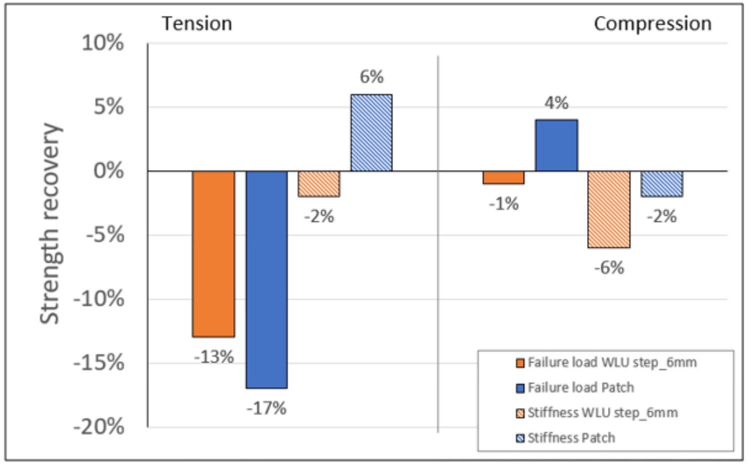
Experimental characterization of two structural bonded composite repairs

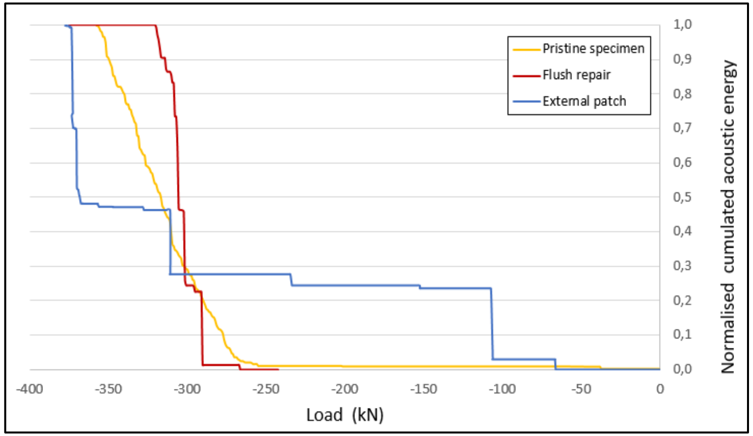
- **Mechanical results**

  Both repair strategies show almost **identical strength recovery** compared to the pristine state. The flush repair offers the highest strength recovery (87%) with a slight loss of stiffness (-2%) in tension and almost the same strength recovery (99%) and stiffness loss (-6%) in compression.

- **Fatigue behavior**

  The first repair is a flush repair composed of 6 mm long steps, laid up with carbon fabric and film adhesive. An over-ply was added for protection and stiffness at the joint tips.

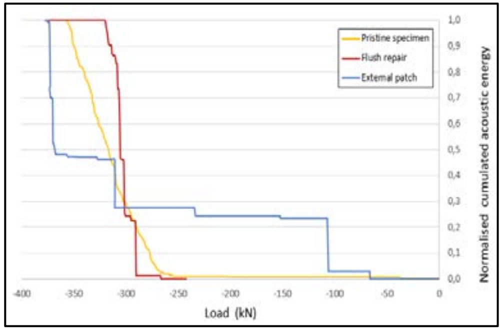




Experimental characterization of two structural bonded composite repairs

- **Conclusion**

The results show **better mechanical performance for the flush repair**. Acoustic emission data reveal significant **differences in damage initiation** and propagation between the two configurations. **External patch** repairs show damage **initiation at very low loads**, followed by **slow damage evolution**.



	Fatigue life > 5.10^5 cycles without debonding	
Pristine	60 %	Of tensile failure strength of pristine panel
Flush WLU repair	40%	
External patch repair	20%	

Methodology for predicting the performance of bonded structural composite repairs in aeronautics

- ## Advantages of Bonded Repairs :

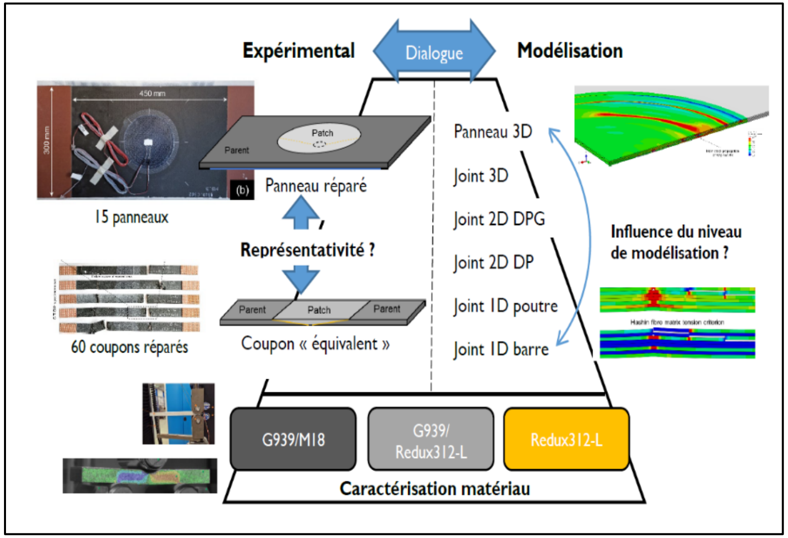
  Bonding assembly offers great potential for repairing composite structures compared to mechanical assembly using bolts or rivets. Bonding eliminates the need to drill holes and limits added mass. However, there is no standard for predicting the strength of bonded repairs, which are currently limited to non-structural applications.

- ## Objective of the Study :

  This thesis aims to understand the **sizing of bonded composite repairs** and propose a cost-effective approach for use in a design office. The study uses a **double pyramid of modeling** and experimental **tests** to study the representativeness of different scales of bonded repair studies

- ## Case Study :

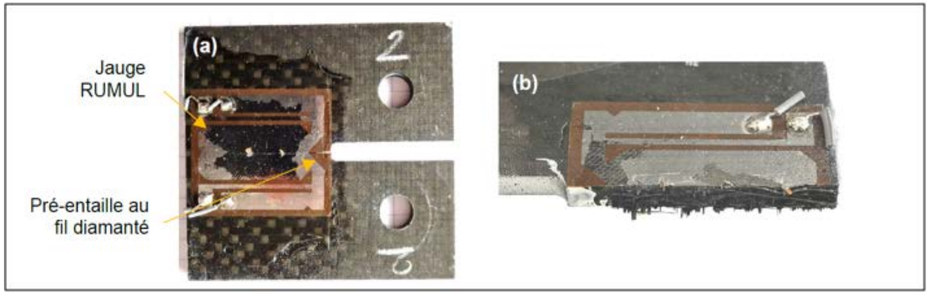
  The case study is a **co-bonded repair** on a Tiger **helicopter structure**, using materials and processes representative of in-situ repairs. The approach involves material characterization tests and a dialogue between tests and modeling at different scales.



Methodology for predicting the performance of bonded structural composite repairs in aeronautics

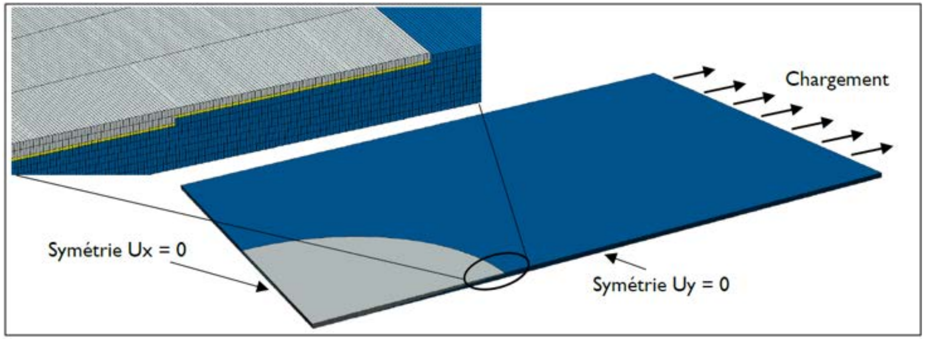
- **Characterization Tests:**

  Characterization tests were conducted on the materials G939/M18 and G939/Hexbond 312-L. The **tests** focused on **intralaminar** and **interlaminar** behavior, as well as the behavior of Hexbond 312-L as an adhesive in a confined state.



- **Modeling and Simulation :**

  A comparative study of different modeling scales of a stepping repair was carried out. **Six** different **models** of a repaired panel and its equivalent joint were **compared**. The study showed that **generalized plane strain** modeling provides a **good approximation** of the stress state and rupture scenario.



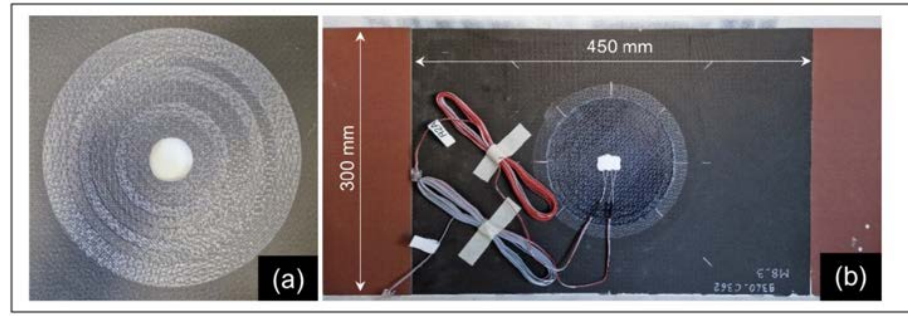
Methodology for predicting the performance of bonded structural composite repairs in aeronautics

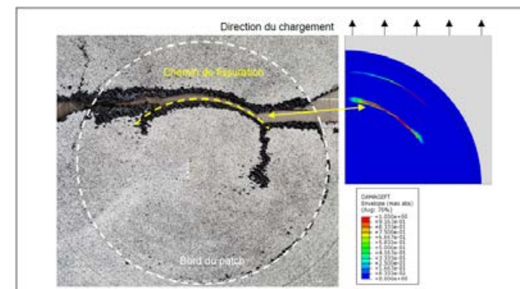
- ## Experimental Validation:

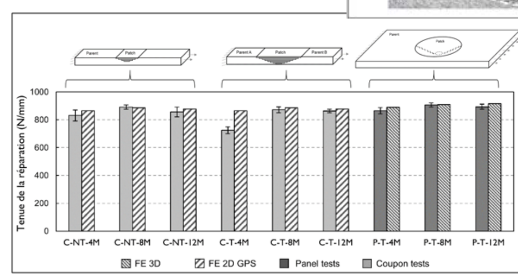
  Experimental tests were conducted with parameters such as step length, damage depth, and patch draping. The tests showed that **step edges are weak points** and that coupon-scale tests provide a good approximation of the admissible transfer by repaired panels.

- ## Results and Validation:

  The **models** provided **results consistent** with tests in terms of **stiffness** and breaking force. However, the **models underestimate** the **breaking force for short steps** and do not account for mixed fracture faces. A parametric script was developed for automatic generation of repair models.



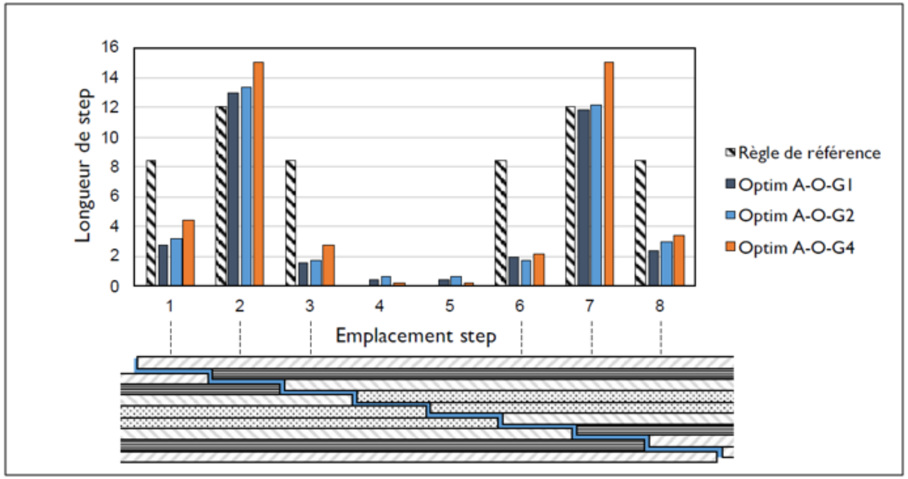




Methodology for predicting the performance of bonded structural composite repairs in aeronautics

- **Optimization Strategy :**

  An optimization strategy for stepping repair was proposed, taking into account the behavior of the entire repair. Numerical tests showed that the proposed method correctly retrieves the logic of the reference method, with potential gains in theoretical encumbrance.



- **Perspectives :**

  Further work is needed to increase confidence in the sizing models and move towards certification requirements. Studies on **sensitivity to material properties**, damage kinetics, and other **load cases** are recommended. The **durability** of **repairs** and process control approaches are also **important areas for future research.**

Topics related to Structural Integrity of composite structures taken from the National Review of Italy

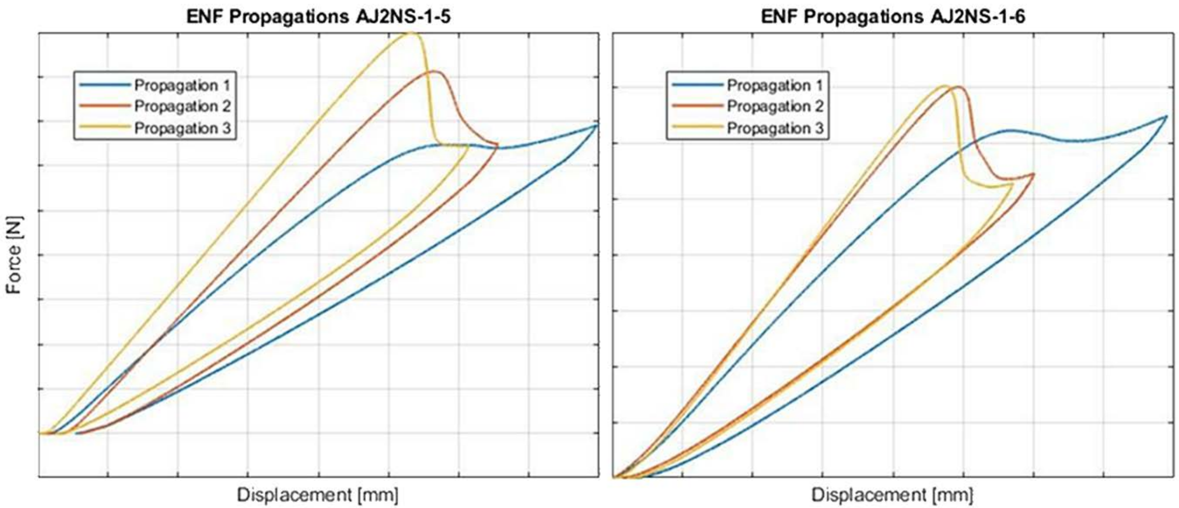
Topics related to Structural Integrity of composite structures taken from the National Review of Italy

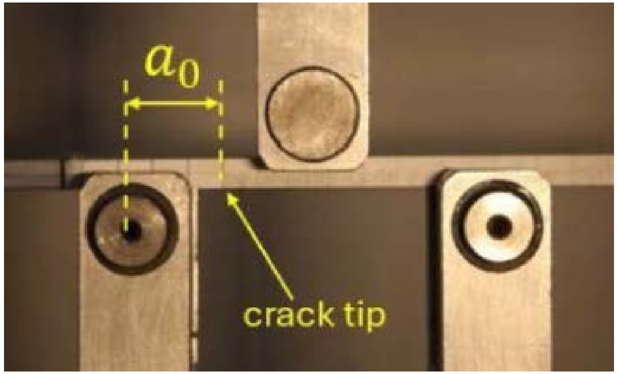
- Fatigue in Adhesively Bonded Joints – Univers. of Bologna
- Propagation of interface damage in adhesive joint and interlaminar layers in static and fatigue loading – Milan Polytechnic
- Hygrothermal ageing and monitoring – Milan Polytechnic
- Economic Impact Assessment of SHM Systems in Composite Aeronautical Structures – Milan Polytechnic
- CFRP Fracture Properties for Crash Application – Univers. of Bologna
- Interlaminar properties of various composite materials – Univers. of Pisa

Propagation of interface damage in adhesive joint and interlaminar layers in static and fatigue loading

- Milan Polytechnic

- 3-point End Notched Flexure (ENF) to characterize mode II fracture toughness
- A sharp crack tip was created using a razor blade.
- After the first propagation, specimens were re-tested to evaluate the effects of a pre-developed process zone.



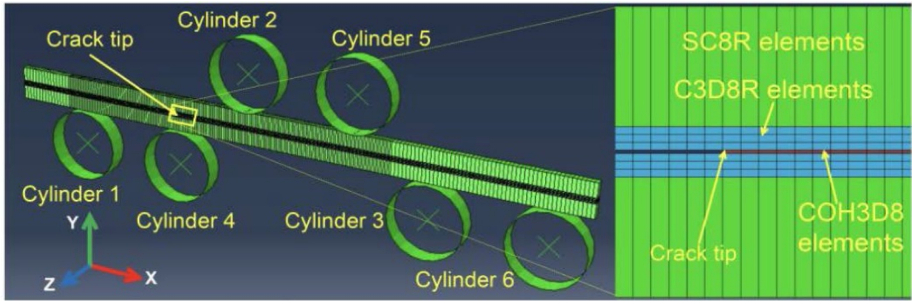


Experiments used to calibrate a traction-separation cohesive law

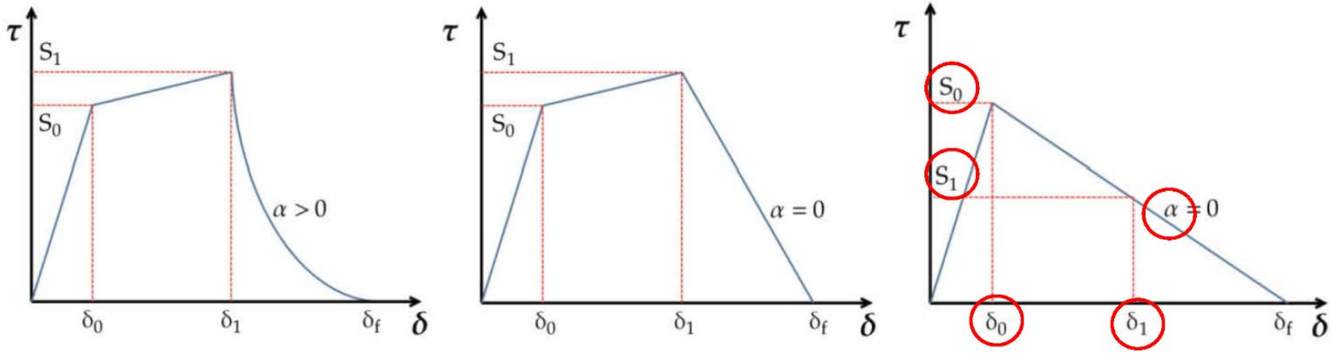
Propagation of interface damage in adhesive joint and interlaminar layers in static and fatigue loading

- Milan Polytechnic

- A finite element model was developed where two sets of cylinders were used to simulate the first opening, the unloading, and the subsequent re-loading of the specimens.



- A parameterized analytical cohesive law was developed, with three possible options:
  - bilinear with exponential softening,
  - bilinear with linear softening,
  - triangular bilinear.



Propagation of interface damage in adhesive joint and interlaminar layers in static and fatigue loading

- Milan Polytechnic

- Simulations were assessed by a suitable **Figure of Merit** (mean error compared to experiments) and stored in a database used to train a Surrogate Model (SM) based on an Artificial Neural Network.

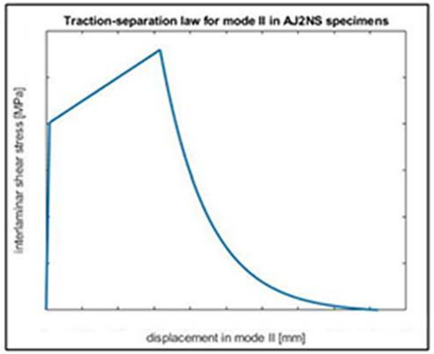
- A **Genetic Algorithm** was then applied to the SM to **identify the cohesive law parameters**.

- The best fit was obtained with a bilinear law with exponential softening.

$$MSE_i = \frac{1}{u^{end} - u^{start}} \int_{u^{start}}^{u^{end}} \left| \frac{w^{exp}}{w^{num}} F_{num}(u) - F_{exp}(u) \right| du$$

$$MSE = P \times MSE_1 + (1 - P) \times MSE_2$$

ANN name	ANN type	Node number per layer	Number of hidden layers	Training Function	Dataset partition [Training/ Validation/ Test]
ANN 1	Regres sion	3	3	Levenberg-Marquardt backpropag ation	[70/15/15]
ANN 2	Regres sion	3	3	Levenberg-Marquardt backpropag ation	[70/15/15]



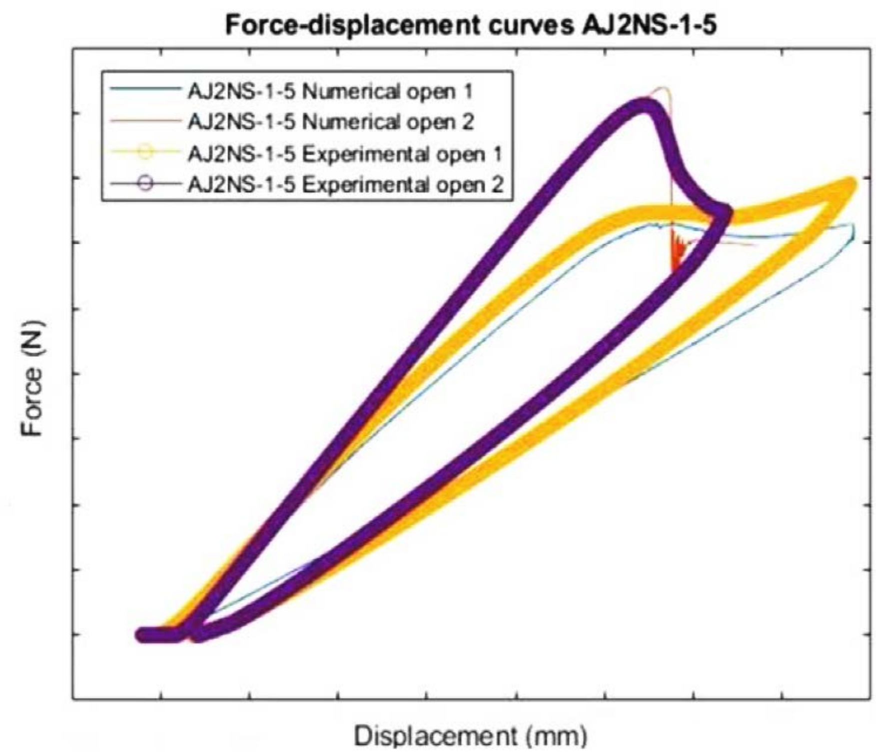
Propagation of interface damage in adhesive joint and interlaminar layers in static and fatigue loading

- Milan Polytechnic

The **bilinear law with exponential softening captured** both **the stable propagation from a sharp crack** and the **unstable propagation** with a pre-existing process zone.

The research highlights:

- the **significant influence of the initial damage state** on debonding propagation
- The **potentiality of Machine Learning** techniques in **identifying complex cohesive behaviors**.



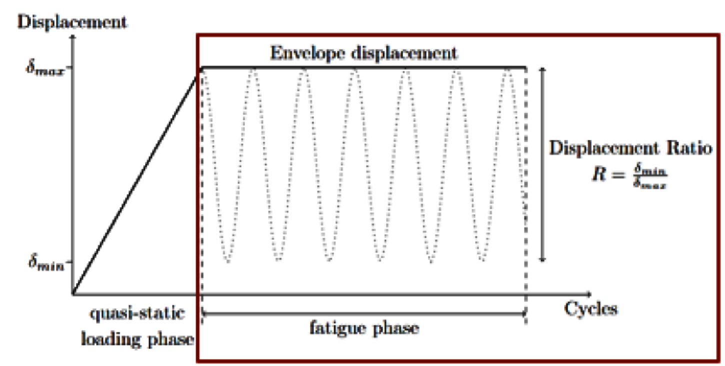
Fatigue in Adhesively Bonded Joints
– University of Bologna

- A **CZM** has been implemented in Abaqus **to simulate high-cycle fatigue behaviour**. The objective of the study is to understand how **variations in adhesive thickness affect the fatigue performance** of bonded joints.
- The adhesive's constitutive law is assigned to standard cohesive elements via a **user-defined material** (UMAT) subroutine within Abaqus. This also **enables** the **simulation of crack growth under cyclic loading conditions**.
- Crack growth under CA opening is driven by a Paris' Law like approach linking the interface damage rate to the amplitude of the strain energy release rate variation

$$\frac{da}{dN} = C\left(\frac{\Delta G}{G_C}\right)^m$$

$$\frac{\partial d}{\partial N} = \frac{\partial a}{\partial N}\frac{\partial d}{\partial a}$$

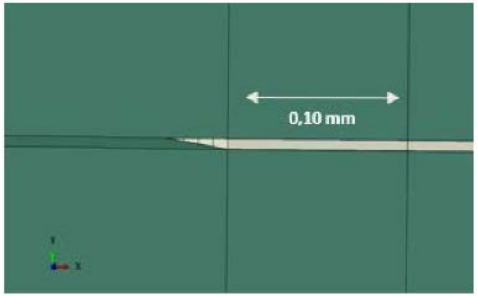
Relation between damage and crack length



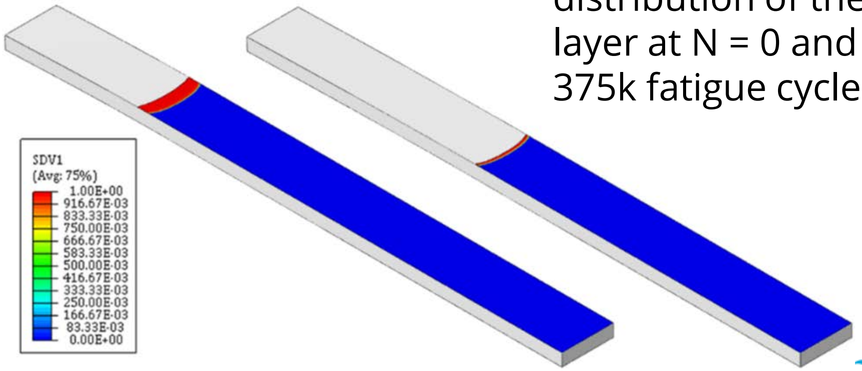
Fatigue in Adhesively Bonded Joints

– University of Bologna

- The proposed cohesive zone model was **validated** by comparing simulation results with **experimental data of (DCB) specimens** obtained bonding two 2024-T3 arms by an epoxy film adhesive with varying thicknesses.
- A three-dimensional model was used where the adhesive was represented as a cohesive zone. Near the tip of the disbonded region a refined mesh was used for the cohesive zone.
- **Two-dimensional models' results were also developed** for comparison (thick cohesives to model the adhesive, zero thickness cohesive zone located at the mid-plane of the adhesive layer)

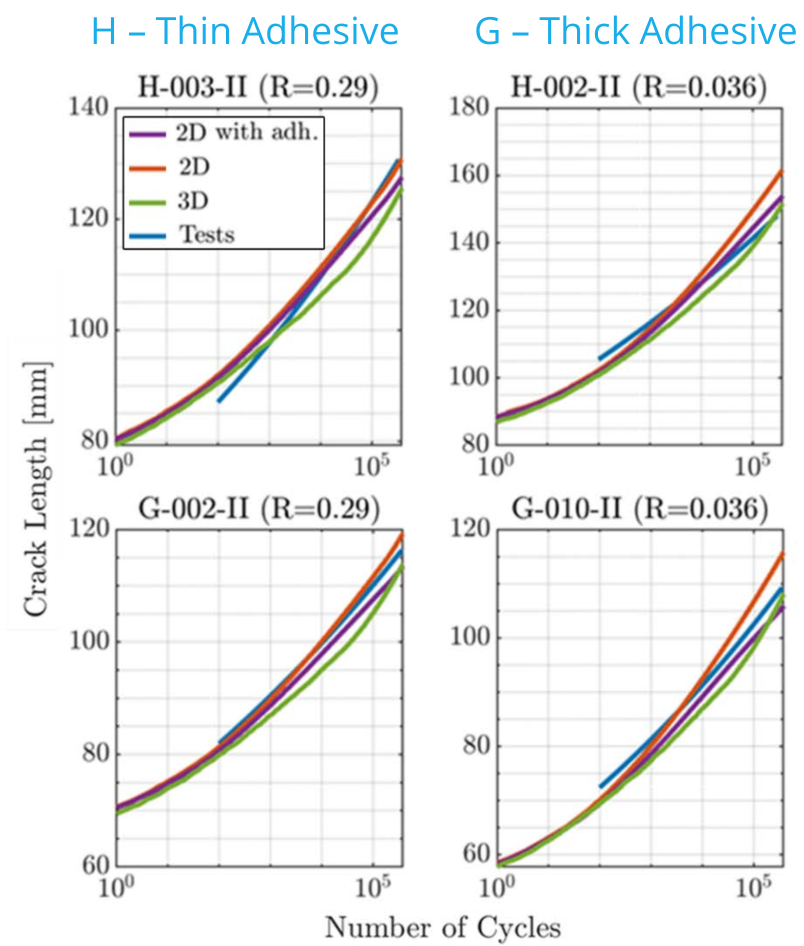


Example of damage distribution of the adhesive layer at N = 0 and after 375k fatigue cycles.



Fatigue in Adhesively Bonded Joints
– University of Bologna

- The **numerical results closely matched the experimental data**
- The **adhesive thickness** had a significant **impact on the fatigue behavior**, particularly at low ERRs.
- The **3D model provided the most detailed representation of crack front evolution** and strain energy distribution (preferred).
- The **two-dimensional model**, in which the adhesive was replaced by a cohesive zone, proved to be the **most effective option**, while still delivering accurate predictions for pure Mode I fatigue loading.



A look into the near future …

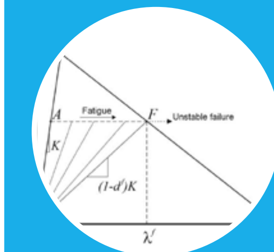
LIFEComp Project:
Local approach to Integrity & Fatigue analysis of aErospace Composites

Started January 2025

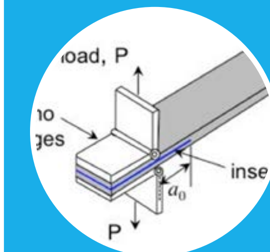
LEONARDO

POLITECNICO MILANO 1863

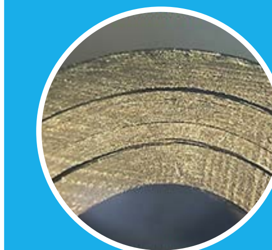
UNIVERSITÀ DI PISA



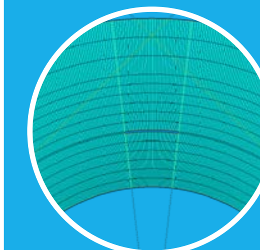
WP 1
Theoretical and numerical framework



WP 2
Baseline Characterization



WP 3
Design and Prediction for Validation Experiments



WP 4
Experiments, Simulations, and Correlation

Acknowledgments

The results shown in this presentation are the outcome of the work of many people whose commitment is gratefully acknowledged. My particular gratitude for their support, goes to:

- Dr. Carlos E. Chaves (Embraer), National Delegate for Brazil
- Dr. David Hallam (Defence Science and Technology Laboratory), National Delegate for the United Kingdom
- Mr. Laurent Touzet (DGA Techniques Aérospatiale), National Delegate for France
- Dr. Eric Lindgren (Air Force Research Laboratory), National Delegate for US
- Prof. Alessandro Airoldi of Milan Polytechnic
- Prof. Enrico Troiani of the University of Bologna - Forlì Campus

Thanks for your attention !

International Committee on Aeronautical Fatigue and Structural Integrity

Appendix A
Contributions related to Structural Integrity of Composite Structures by subtopics in NRs

Structural Integrity of Composite Structures by subtopics in NRs

Fatigue, Damage Tolerance & Durablity of Composites

• High-cycle fatigue of propeller blades	The Netherlands
• Thermoplastic composites - fatigue, damage tolerance and durability	The Netherlands
• D-STANDART project	The Netherlands

Delamination fatigue & fracture - part I

• Progressive intralaminar damage in woven composite materials under mixed-mode fracture	Brazil
• Data reduction methods in the fatigue analysis of the double cantilever beam	Brazil
• The effect of fiber orientation on fatigue crack propagation in CFRP	Brazil
• A numerical and experimental study of fasteners as a delamination arrest mechanism in composite laminates under mode I loading	Brazil
• Effect of fiber bridging on mode I fatigue delamination behavior of uni-directional composites	Israel
• Fracture toughness resistance curves for a delamination in CFRP MD laminate composites under mixed-mode deformation	Israel

Structural Integrity of Composite Structures by subtopics in NRs

Delamination fatigue & fracture - part II

Topic	Country
• Effect of number of fatigue cycles on fatigue data for prepreg and wet layup CFRPs	Israel
• Fatigue delamination propagation: various effects on results	Israel
• Propagation of interface damage in adhesive joint and interlaminar layers in static and fatigue loading	Italy
• Interlaminar properties of various composite materials	Italy
• Numerical analysis of fatigue evolution of laminated composites using cohesive zone model and extended finite element method	Japan
• Determination of mode I fatigue delamination propagation in unidirectional fibre-reinforced polymer composites	The Netherlands
• Planar delamination	The Netherlands
• Static and fatigue mode I delamination propagation in thermoplastic composites	The Netherlands

Structural Integrity of Composite Structures by subtopics in NRs

Structural Integrity of Joints

• Manufacturing deviations in composite fastened joints	Brazil
• Damage modelling of an F/A-18 Ti-to-composite lap joint for assessing residual strength	Canada
• Development of numerical modelling for assessing disbond and strength of a F/A-18 step-lap joint specimen	Canada
• Surface quality inspection for adhesively bonded joints	Finland
• Fatigue in adhesively bonded joints	Italy
• Effect of interface microstructure on interlaminar fracture toughness in dissimilar joints of thermoplastic CFRP and aluminum alloys	Japan
• Experiments and modelling of composite-aluminium bolted joints	Sweden

Structural Integrity of Composite Structures by subtopics in NRs

Composite repairs

• Thoughts on the importance of similitude and multi-axial loads when assessing the durability and damage tolerance of adhesively bonded doublers and repairs	Australia
• The methods to predict the strength of composite scarf repairs bonded with ductile adhesive	China
• Experimental characterization of two structural bonded composite repairs	France
• Methodology for predicting the performance of bonded structural composite repairs in aeronautics	France
• Experimental study of intrinsically conductive resin as a functional repair for CFRP laminates against simulated lightning strike	Japan

NDI and SHM

• Economic impact assessment of SHM systems in aeronautical structure	Italy
• NDT and SHM techniques for evaluation and prediction of condition and residual strength of aircraft structures	Poland
• Structural health monitoring for composites	Switzerland
• Structural health monitoring, manufacturing and repair technologies for life management of composite fuselage (SHERLOC)	United Kingdom

Structural Integrity of Composite Structures by subtopics in NRs

Damage (impact, crash,...) and failure of Laminates/Structures

• Post-impact multi-axial load response of aero representative stiffened composite structures	Australia
• Investigation on induced intra/interlaminar damage propagation in CFRP subjected to cyclic tensile loading after impact	Brazil
• Effective hybrid damage modeling framework for composite laminate strength predictions	Canada
• Micromechanics-based composites failure criteria and applications	China
• High strain rate loading research	Finland
• CFRP fracture properties for crash application	Italy
• Fatigue after impact	The Netherlands
• Large damage capability of thermoplastic orthogrid fuselage	The Netherlands
• Developing the contour method for estimating residual stress in carbon fibre composite laminates	United Kingdom

Structural Integrity of Composite Structures by subtopics in NRs

Structural Integrity interactions with Design

• EVE-100 development	Brazil
• Strength design assessment of a wind tunnel composite rotor blade	Canada
• A high-confidence lightweight composite wing design method integrating static and dynamic loads	China
• Design and fabrication of high-performance multifunctional composite structures	China
• OPTICOMS project – optimized composite structures for small aircraft	Israel
• Ply curving termination for improving fatigue characteristics of composite ply drop-off	Japan

Modeling & Simulation for Composite Structural Integrity

• FEA digital twin of a scarf repair for a composite component	Australia
• Enhancing damage tolerance in tufted composites: finite element modelling and predictions	Australia
• Finite fracture mechanics modelling for open-hole configuration	Brazil
• Progressive damage analysis of 3D woven composite SENT test using a ternary model	China
• Numerical prediction of stringer de-bonding in composite stiffened panels subjected to combined axial and pull loading	Israel

Structural Integrity of Composite Structures by subtopics in NRs

Structural Integrity interactions with environmental conditions

• Effect of hygrothermal ageing temperature on the mechanical degradation of aerospace-grade carbon fibre epoxy laminates	Australia
• A finite crack growth energy release rate for interlaminar fracture analysis of compositematerial at different temperatures	China
• Mechanical performance of thin-ply composites for cryogenic applications	Sweden
• Hygrothermal ageing and monitoring	Italy

Structural Integrity and Buckling

• Experimental study and numerical prediction of buckling of composite panels	Canada
• Analysis and experimental evaluation framework for buckling and post-buckling of composite stiffened panels	China