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ILX-34 WINGBOX DEMONSTRATOR CASE STUDY

Warsaw, July 10,2019

Project realization:

Łukasiewicz Research Network – Institute of Aviation

- Center for Composite Technologies
- Materials & Structures Research Center
- Center of New Technologies

Presented by:

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ILX-34 AIRCRAFT- GENERAL OVERVIEW

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ILX-34 Aircraft - General Overview

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ILX 34 - CS23 class 9-seater multipurpose single turboprop aircraft

- More interior space
- More luggage capacity
- Better performance

Key features

•Better comfort

•Shorter trip time

•Lower fuel consumption

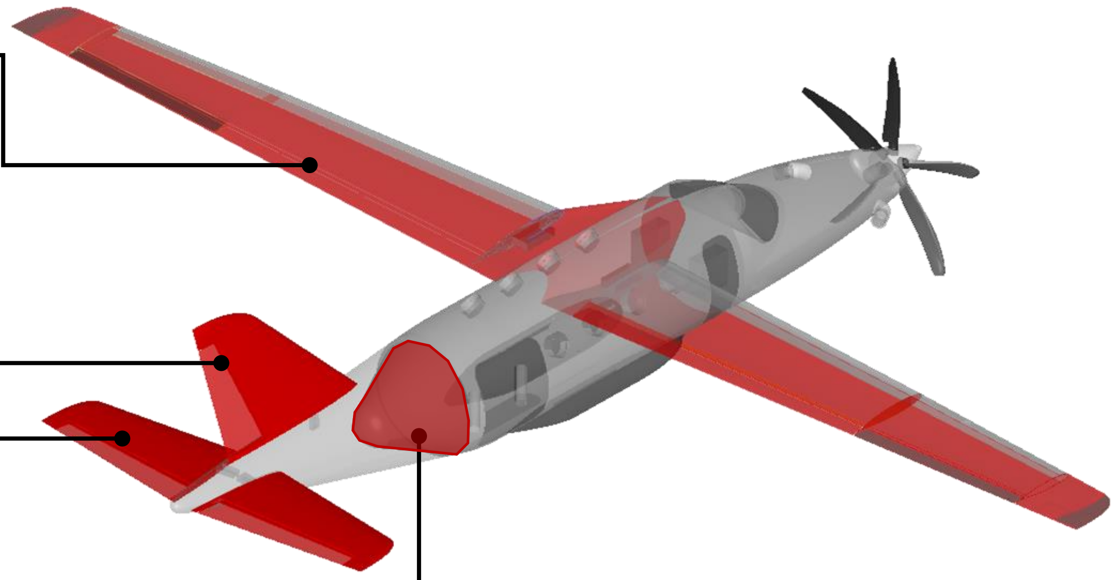
•Lower operating costs

•Greater airport accessibility

•Longer flying range

Composite components:

- Center wing and outer wings with control surfaces
- Vertical stabilizer and rudder
- Horizontal stabilizer and elevators
- Aft pressure bulkhead



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ILX-34 Wingbox demonstrator

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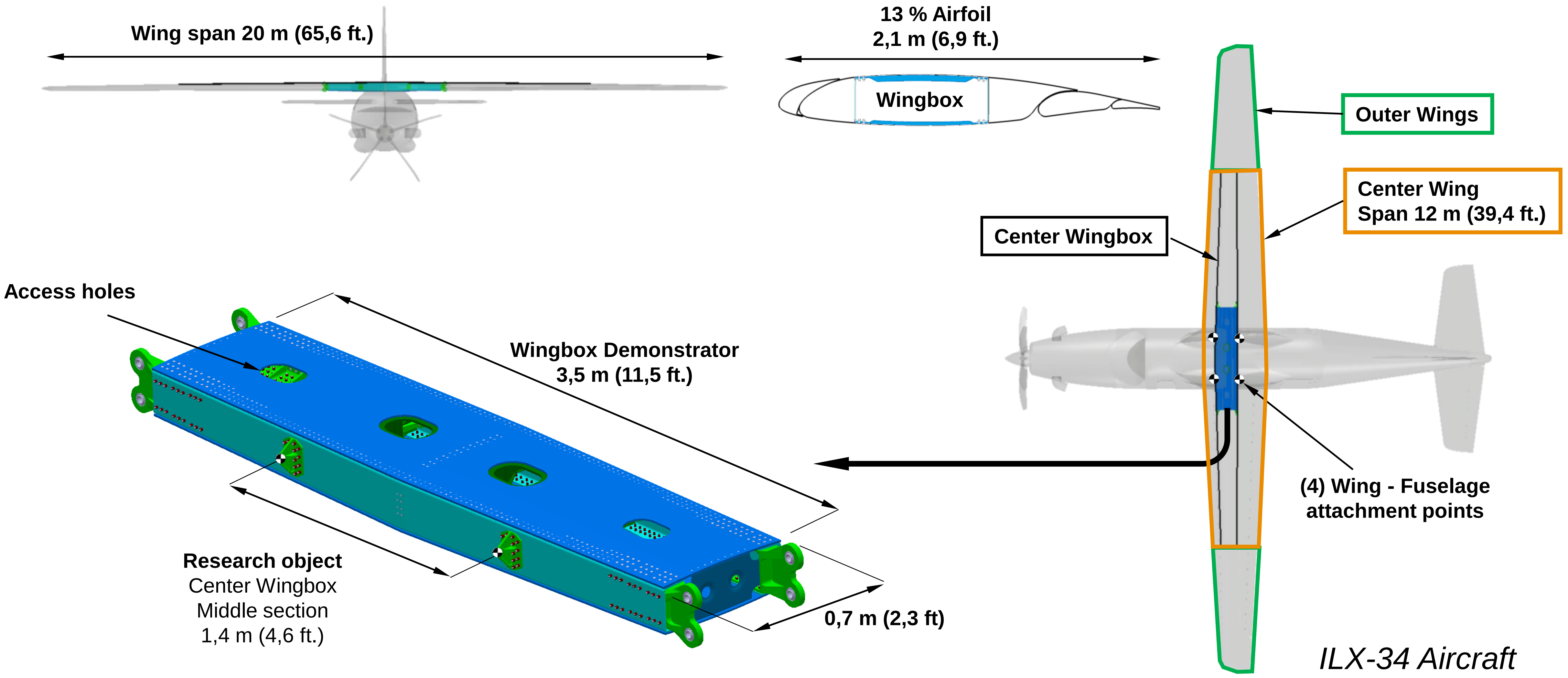

Wingbox Demonstrator = proof of design, selected materials and manufacturing technologies.
Main features: Access covers on top of the wing; Sandwich wing covers structure.

DESIGN & TECHNOLOGIES

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ILX-34 Wingbox demonstrator

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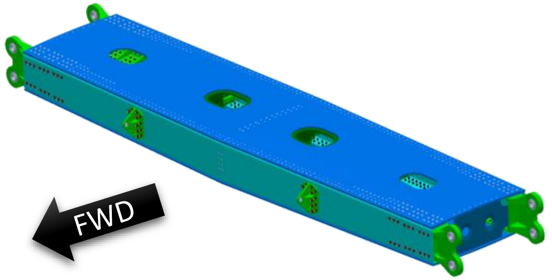
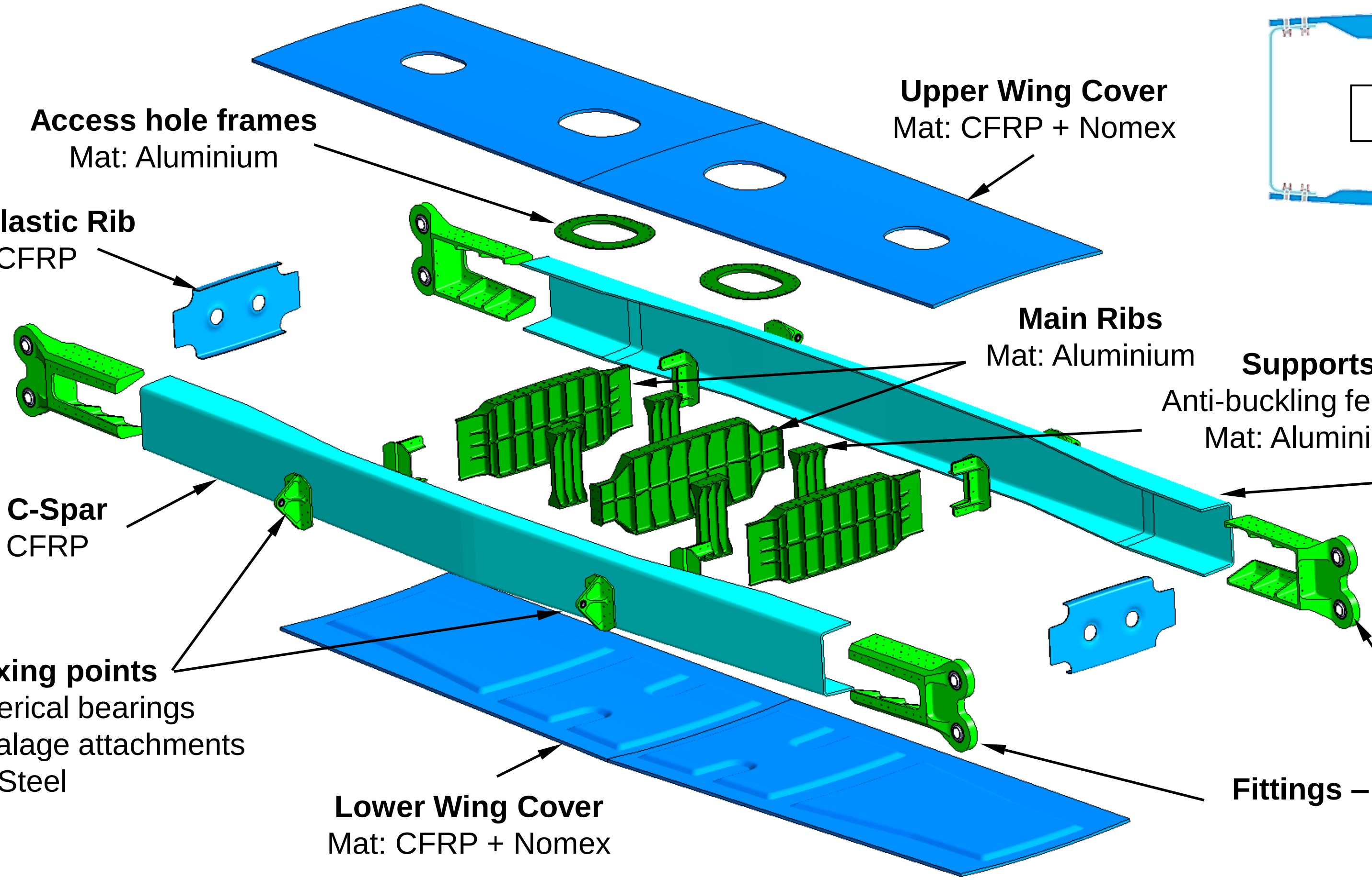
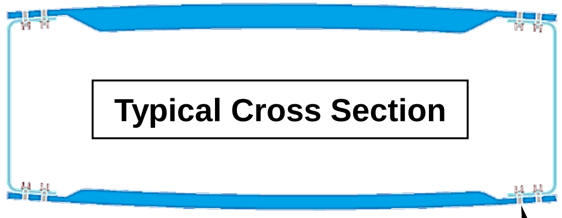
Assembly overview



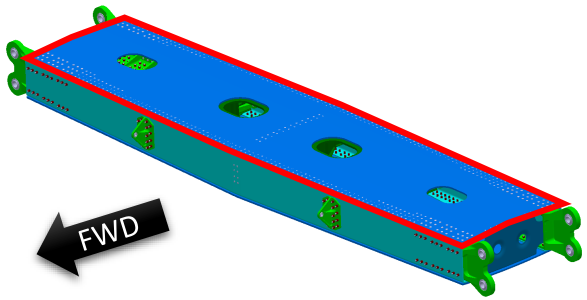




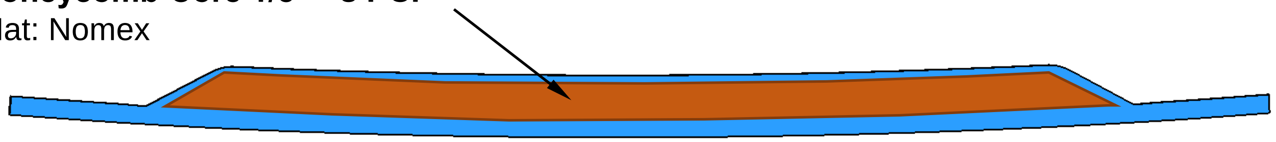
Main structure made of Composites. Bolted joint connections for safety and reliability .

Design & Technologies

Wing Covers

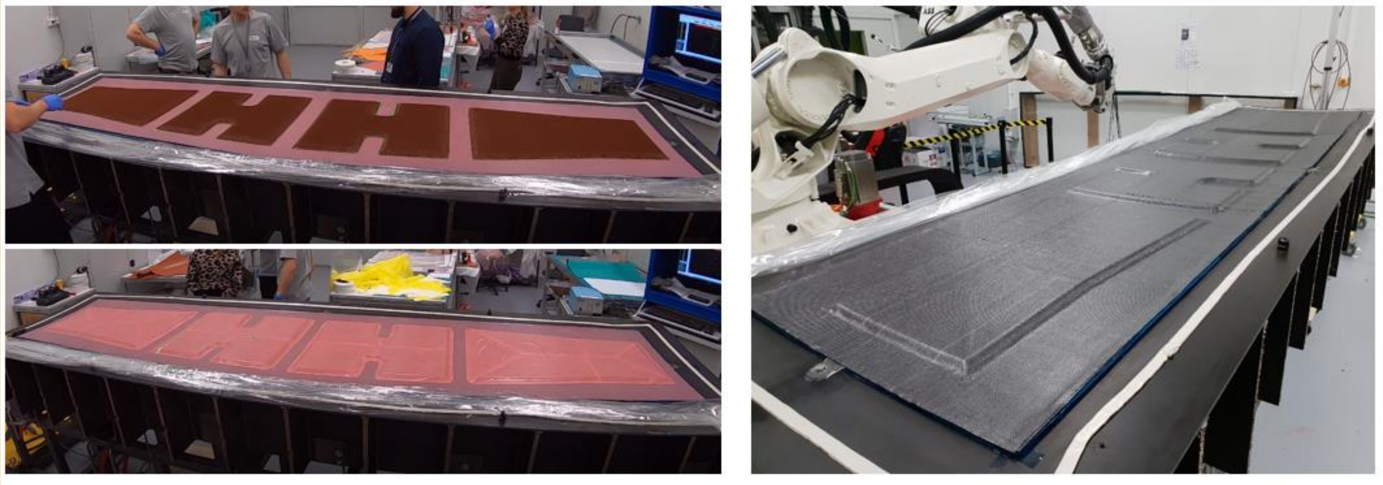


AFP and Hand layup of carbon prepreg combined with **2-Stage out-of-autoclave curing proces** results in acceptable ratio between strength and production cost for highly loaded components



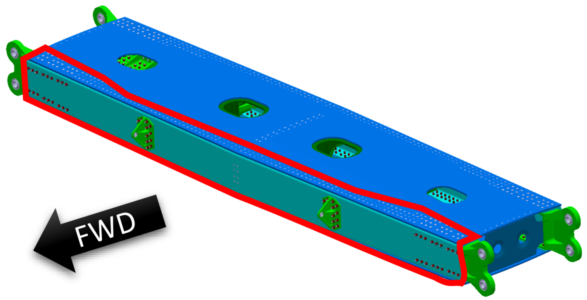
1st stage – Outer skin
AFP + Hand layup

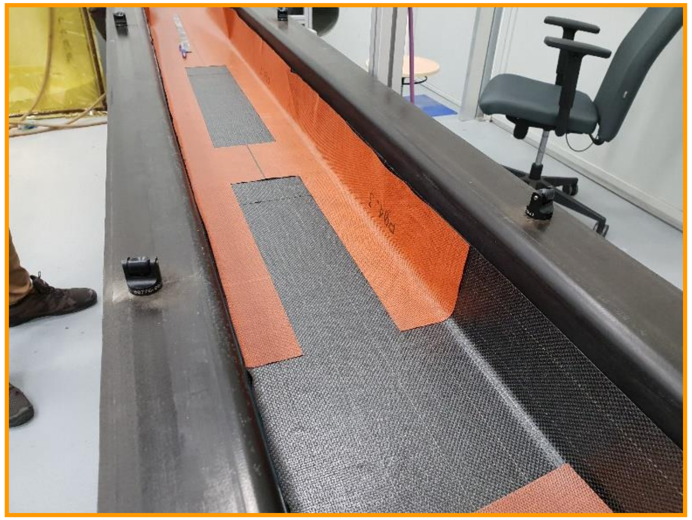
2nd stage – Core + Inner skin
Hand layup



Design & Technologies

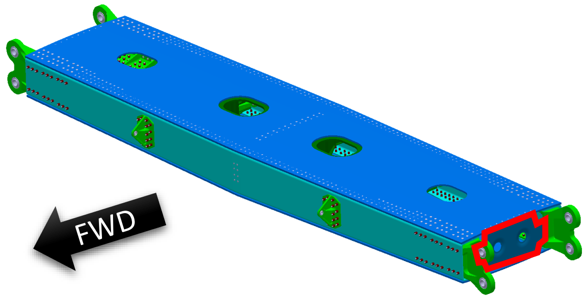
C-Spars

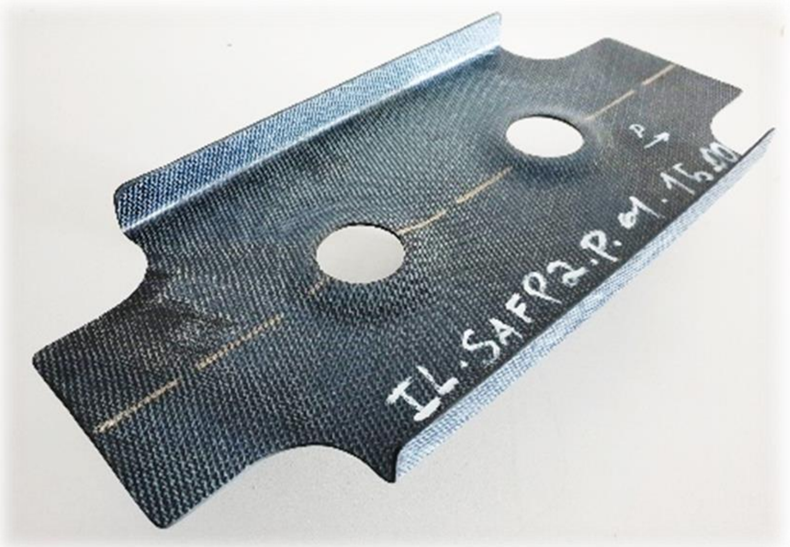


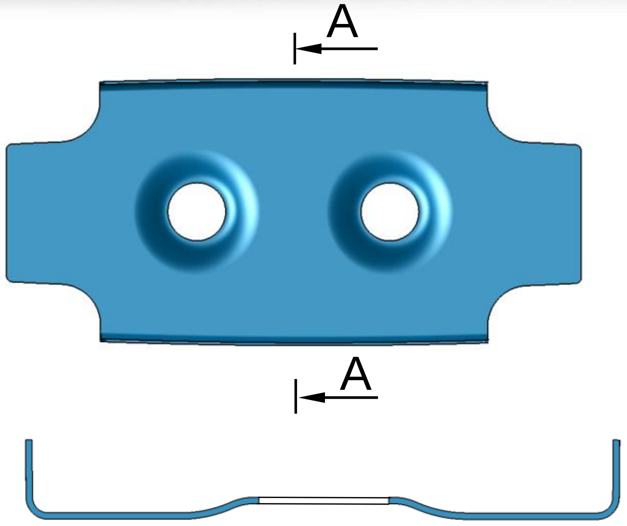


Hand layup of carbon prepreg combined with **out-of-autoclave curing process** results in acceptable ratio between strength and production cost for complex shape parts.

Thermoplastic Ribs







Section A-A

Key features:

- PEEK Thermoplastic prepreg cost similar to thermoset prepreg
- Part forming takes minutes vs. hours of oven curing
- Superior durability and chemical resistance

MATERIAL TESTING &
DESIGN VALUES DEVELOPMENT

Limited (1-Batch) Material Qualification

Lamina & Laminate testing

Materials Tested

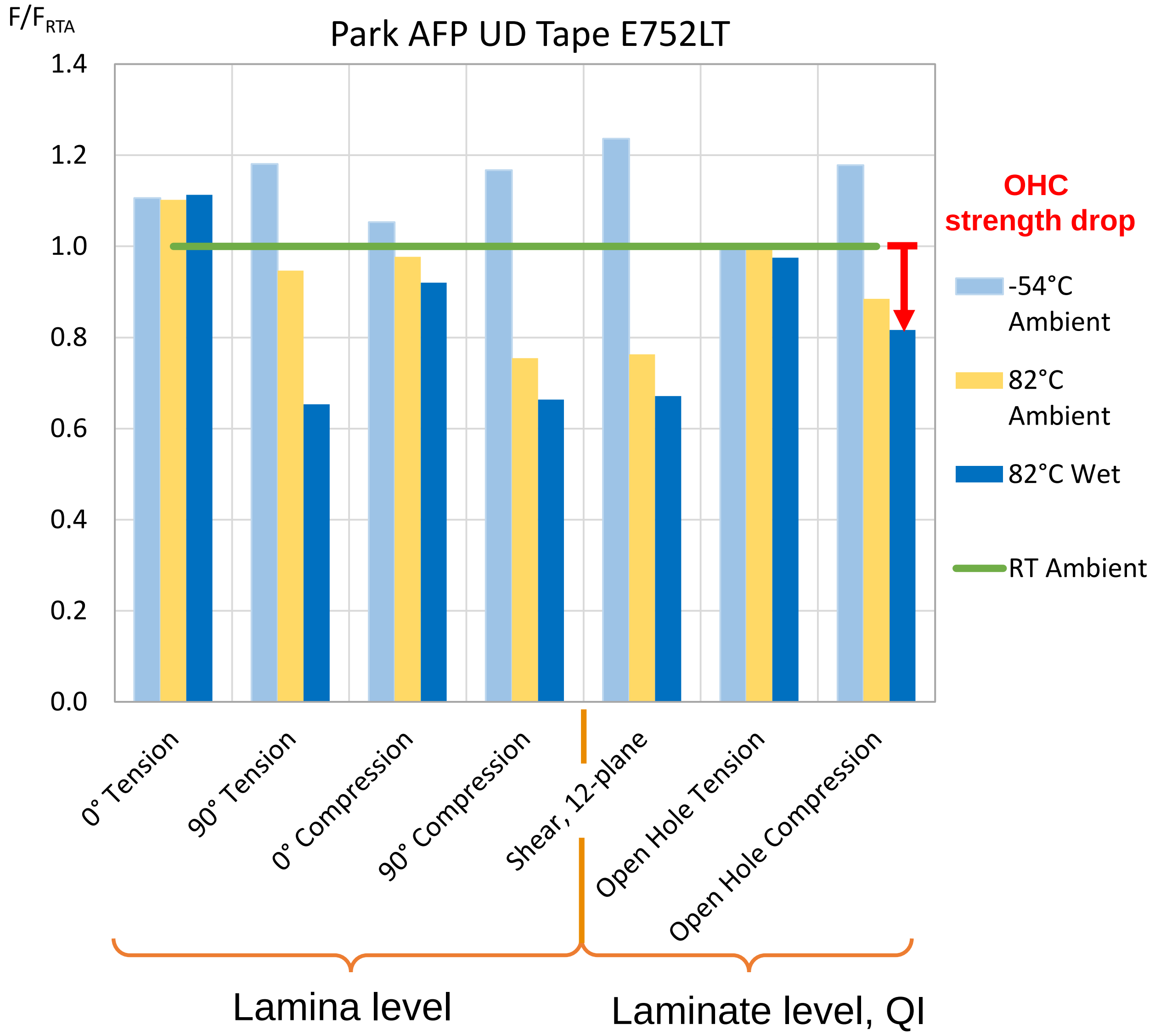
- Park AFP UD tape E-752LT
- Park PW E-752
- Tencate PEEK TC1200 (only RTA)

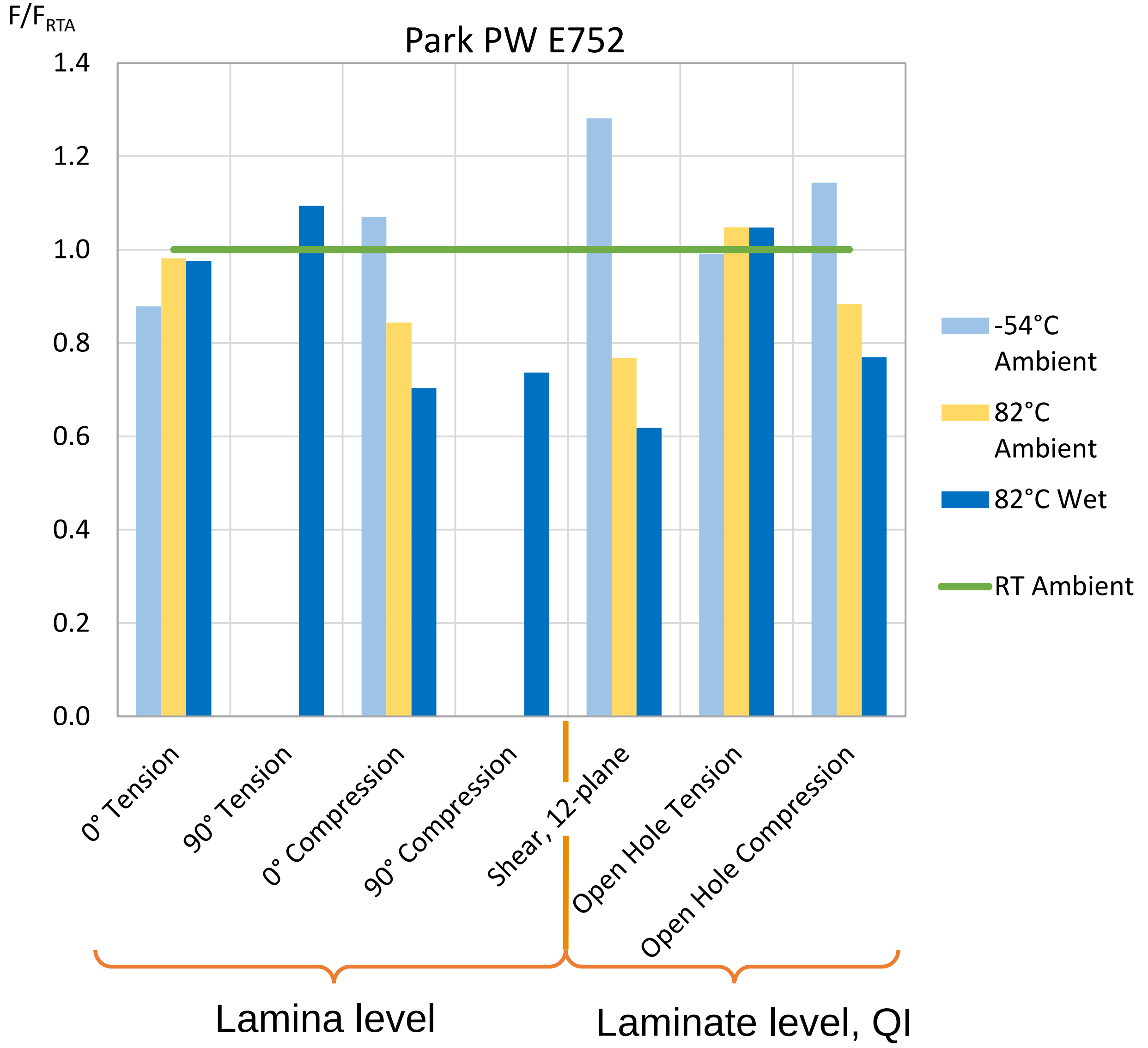
Test	Lay-up	Test Method	Coupons# Conditions -65D	RTD	180D	180W	RTW	Properties
Tensile 0°	$[0]_8$	ASTM D3039	3	6	3	6		F^{tu}_1; E_1; v_{12}
Tensile 90°	$[90]_{16}$	ASTM D3039	3	6	3	6		F^{tu}_2; E_2
Laminate tensile, QI	$[45/0/-45/90]_{2S}$	ASTM D3039	3	6	3	6		F^{tu}_{QI}
Compression 0°	$[0]_{16}$	ASTM D6641	3	6	3	6		F^{cu}_1; E^c_1
Compression 90°	$[90]_{16}$	ASTM D6641	3	6	3	6		F^{cu}_2; E^c_2
Laminate compression QI	$[45/0/-45/90]_{2S}$	ASTM D6641	3	6	3	6		F^{cu}_{QI}
In-plane shear	$[45/-45]_{4S}$	ASTM D3518	3	6	3	6		$\tau_{12}{}^m$, G_{12}
Open hole tension	$[45/0/-45/90]_{2S}$	ASTM D5766	3	6	3	6		F^{ohtu}
Open hole compression	$[45/0/-45/90]_{3S}$	ASTM D6484	3	6	3	6		F^{ohcu}
Short beam shear	$[0]_{16}$	ASTM D2344	3	6	3	3		F^{sbs}
DMA	$[0]_{16}$	ASTM D7028		3			3	Tg

Total coupons tested: 380

Test Results

Temperature & humidity effect on strength



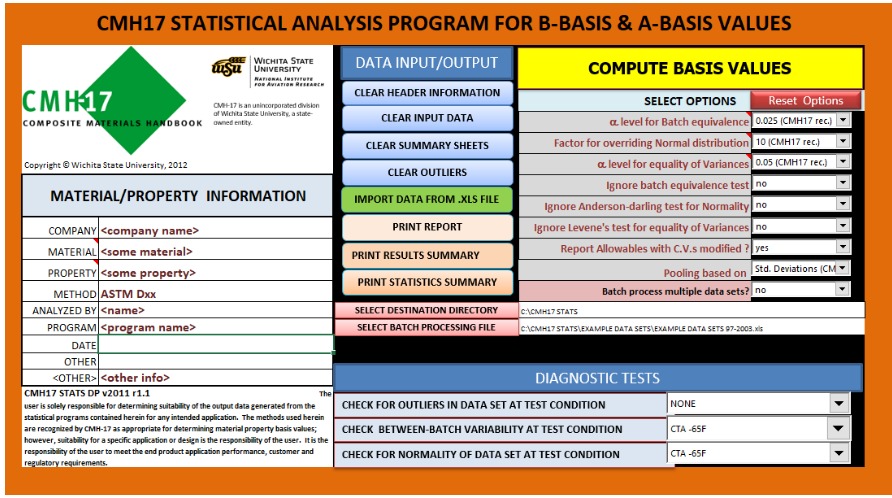


Environmental overload factor 1,25 determined based on OHC strength drop.

Design values development

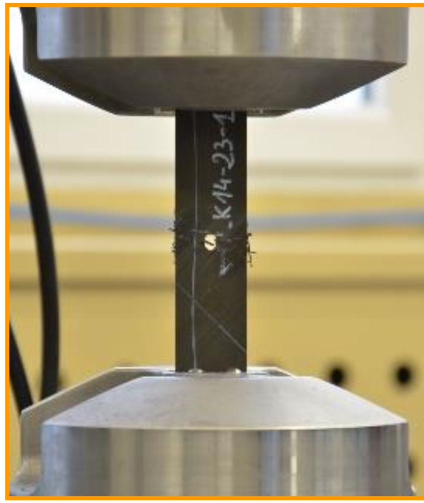
1. Mean strength values determined on lamina level testing
2. B-Basis material allowables generated using CMH-17 STATS Software for RTA and 82°C/Wet data points

B-Basis - 90% of the population of material strength values is expected to equal or exceed that strength value with 95% confidence



3. BVID factors (~0,5) determined based on QI OHC/OHT coupons testing (6,35 mm hole diameter)

$$k_{OH} = \frac{Open\ hole\ strength}{Pristine\ laminate\ strength}$$

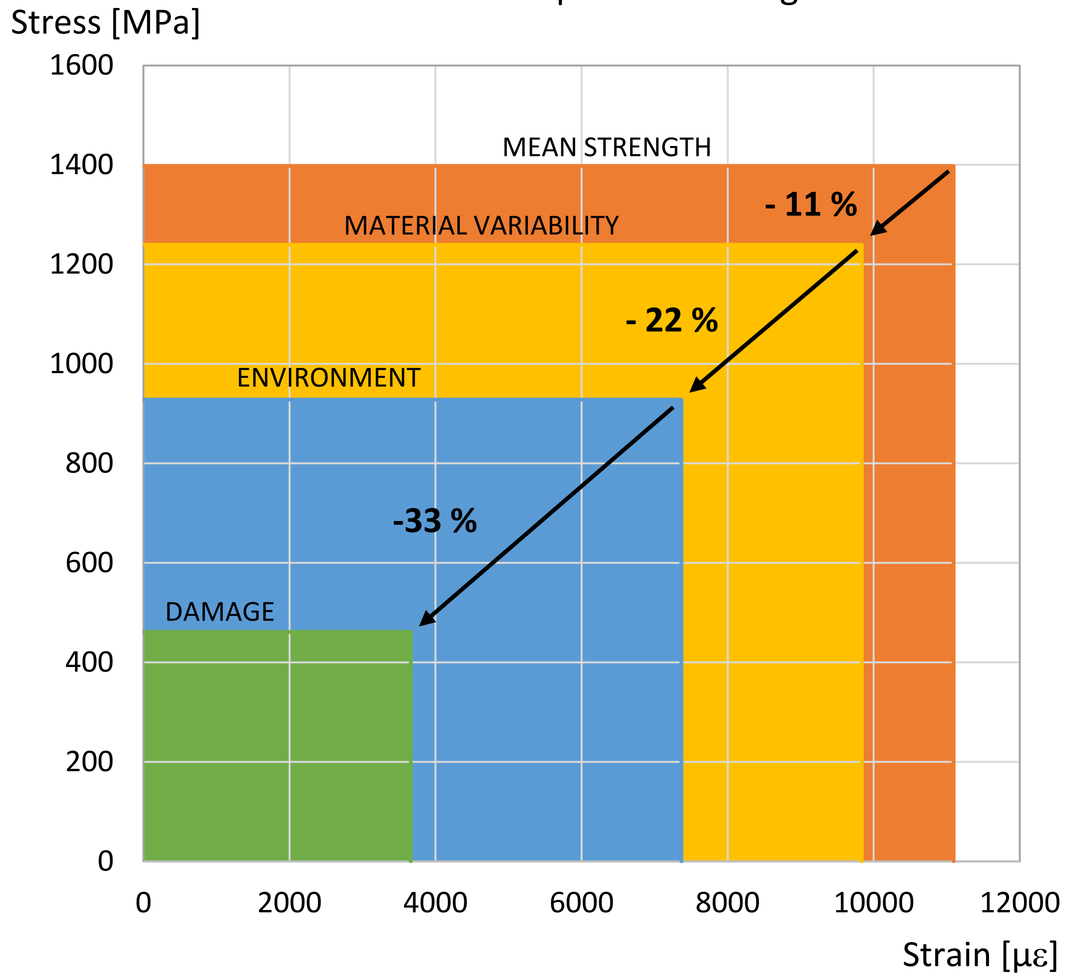


4. E1 and E2 determined as the mean values from tensile and compression testing in RTA
5. Design values validated on component (wing demonstrator) test level

Design values development

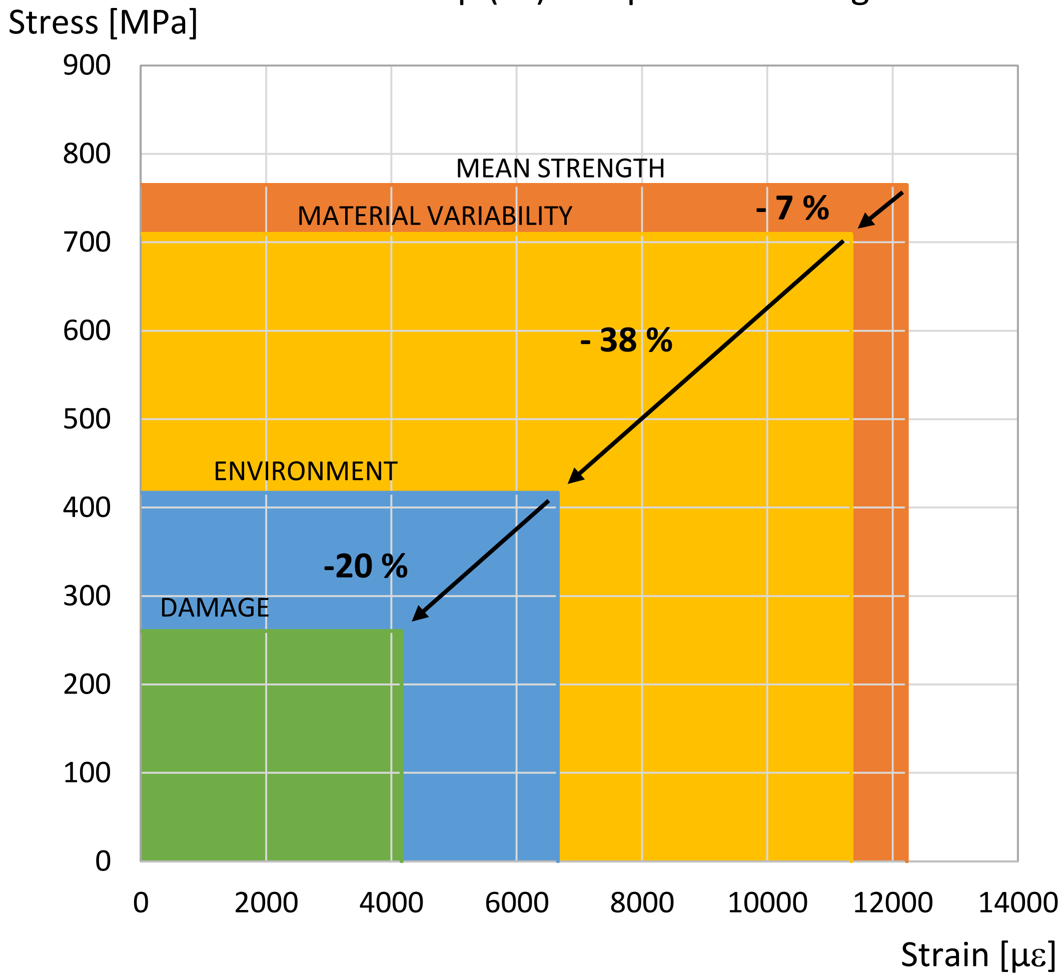
Park AFP UD Tape E752LT

0° compressive strength



Park PW E752

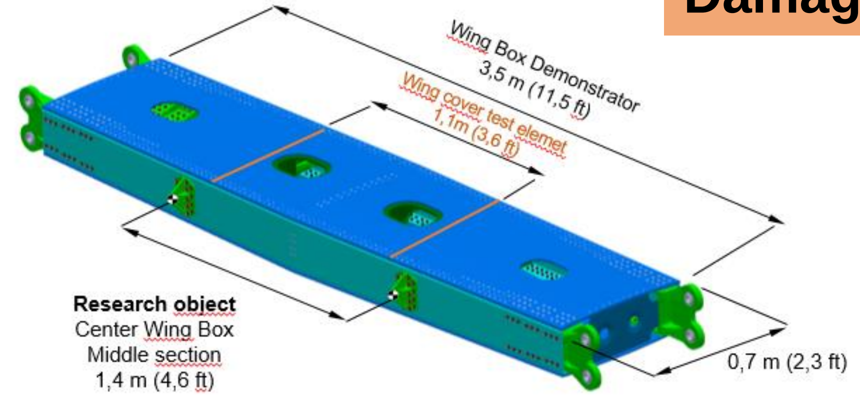
Warp (0°) compressive strength



Significant strain values reduction required for safe design.

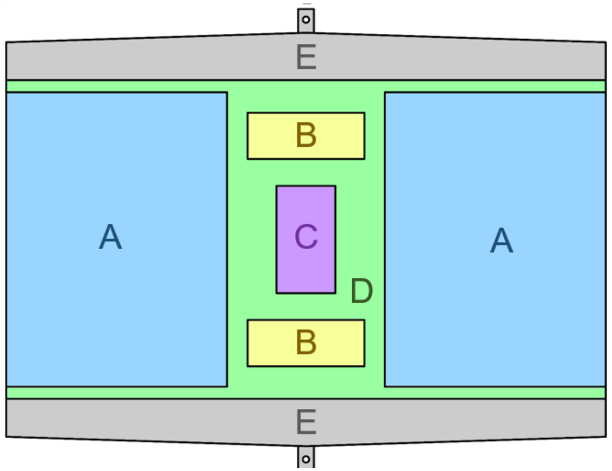
Impact survey

Damage resistance tests on wing cover



Selected element for testing:
Upper wing cover test element 1,1 m (3.6 ft)

Zone	Laminate thickness
A	7,9 mm (0.31 in)
B	6,8 mm (0.27 in)
C	5,4 mm (0.21 in)
D	Ply drop area
E	8,5 mm (0.33 in)



Category 1 - BVID damage

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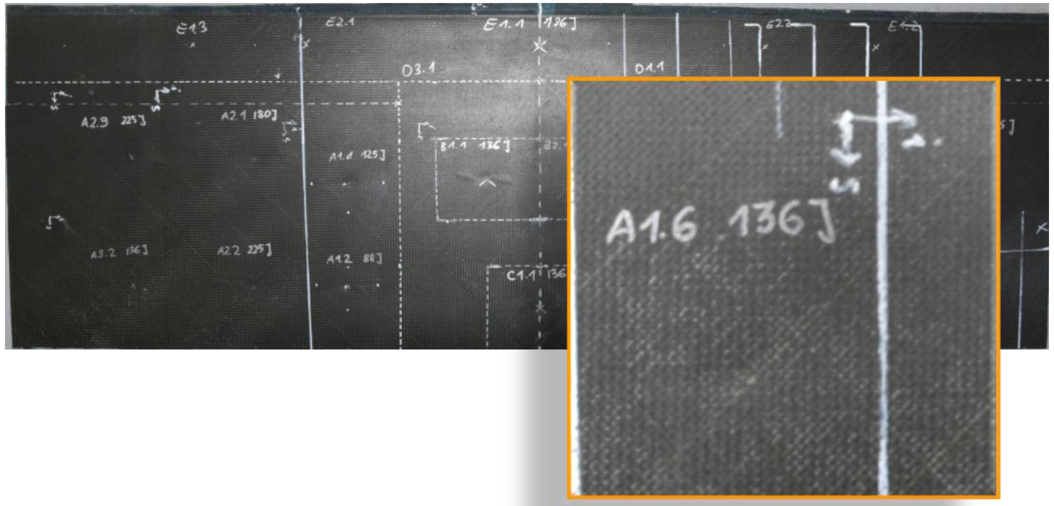
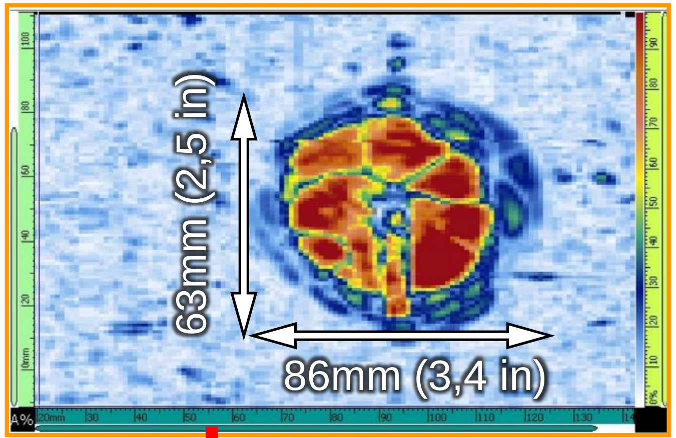
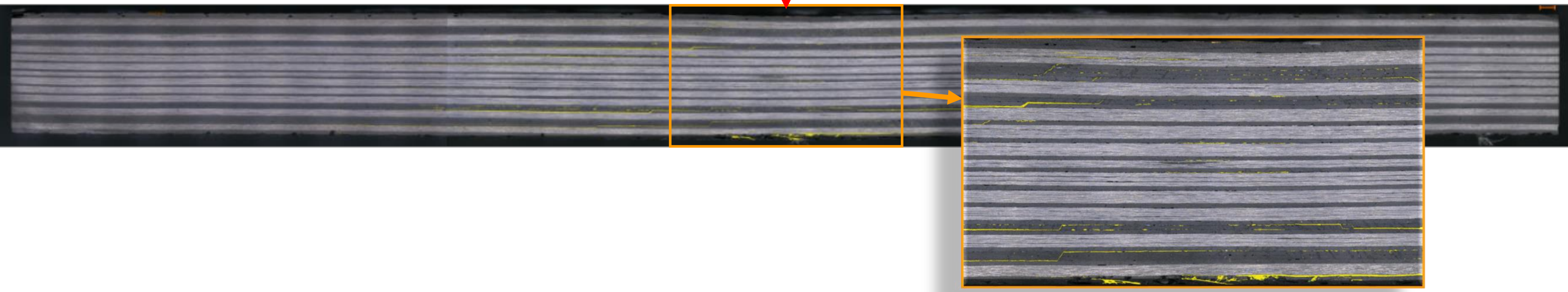
Severity assessment of 135 J (100 ft-lb) energy cutoff



Delamination (based on C-scan)



Laminate thickness: 7.9mm (0.31in)
Tip diameter: 25,4 mm (1in)
Energy level: 135 J
Dent depth: 0,37 mm (0.015in)



STRESS ANALYSIS

Stress Analysis

Main Goals:

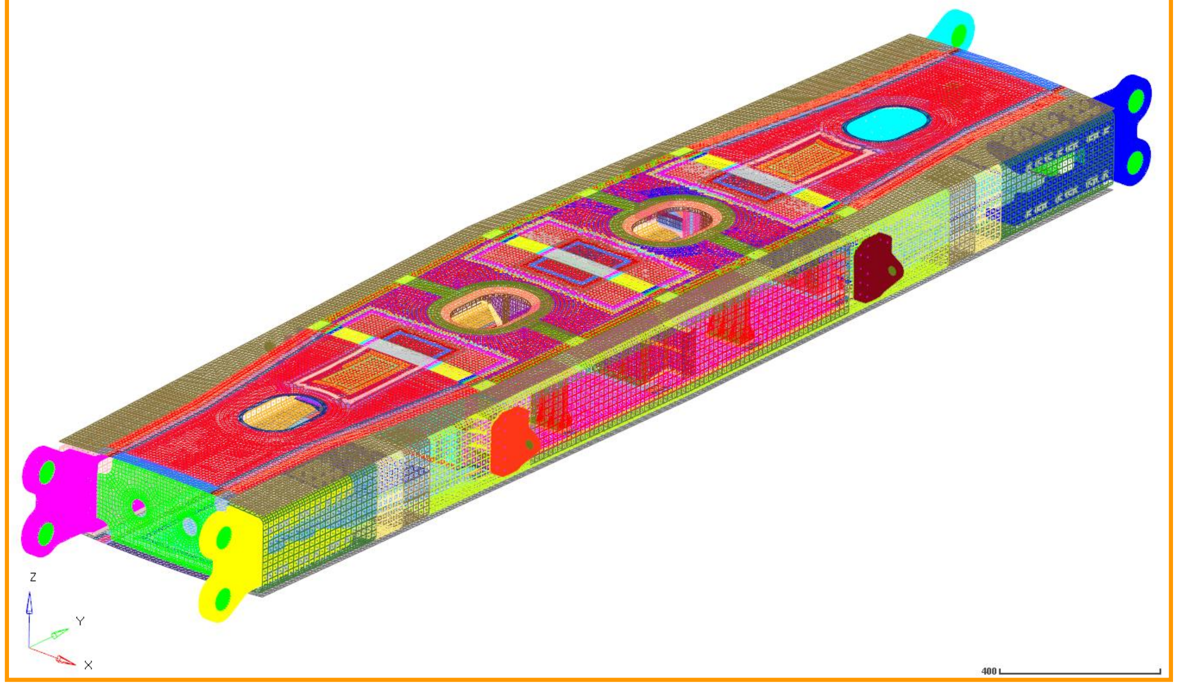
- Simple and fast methods to size the structure of the Demonstrator for Margin of Safety = 0
- Verify methods at component level test
  - Match strains
  - Predict failure modes
  - Predict failure load

Approach:

- Linear FEM model that reflect test article stiffness, predict load path, composite parts ply by ply strains, metallic parts stress and fastener forces
- Size composite parts using First Ply Failure and Max Strain Criterion
- Size metallic parts using von Mises criterion
- Size fastener connections, lugs and pins using hand calculations and forces extracted from FEM model

FEM Model of the test article

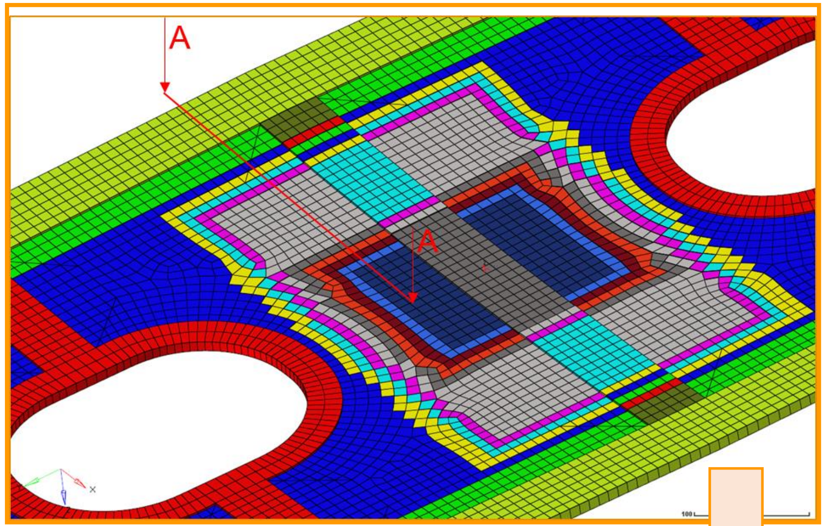
- Model prepared in HyperWorks environment (452 000 nodes, 317 elements)
- Linear analysis performed using Nastran 2016 solver (static and buckling analysis)
    - calculation time ≈ 5 min for static and ≈ 15 min for buckling
- Two critical load cases taken into account - Bend Up and Bend Down (@Ultimate Load)
    - Both load cases include Environmental Overload Factor equal 1.25 (based on OHC RTD/ETW for QI layup)
    - Overdesigned metallic parts (ribs, fittings, fasteners)
    - Overdesigned structure stiffness (buckling)

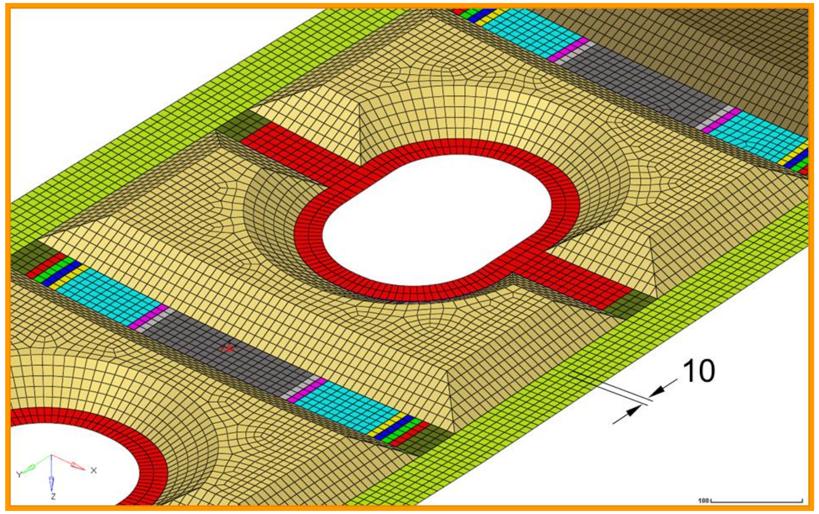


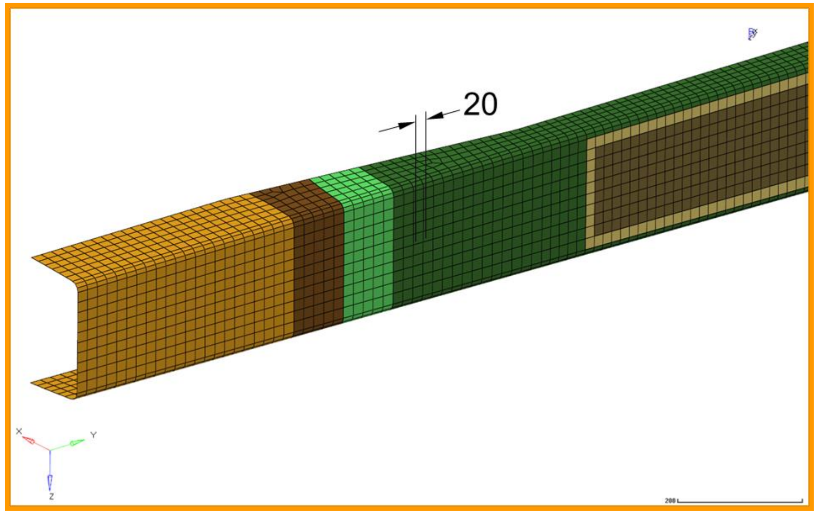
Stress Analysis

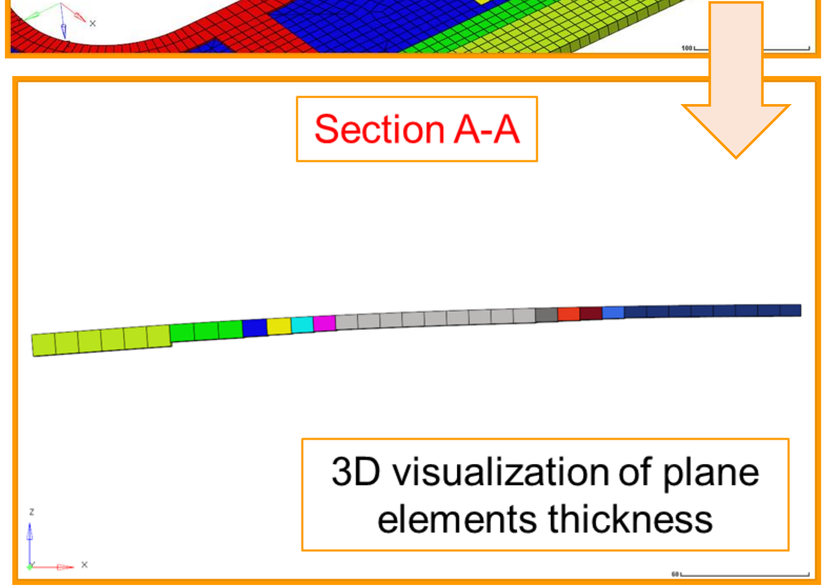
Composite Parts FEM models:

- Composite parts meshed on the tool surfaces using plane elements
- Honeycomb core modeld using 3D elements (1 element per thickness)
- Offsets defined to maintain continuity of composite plies across sections





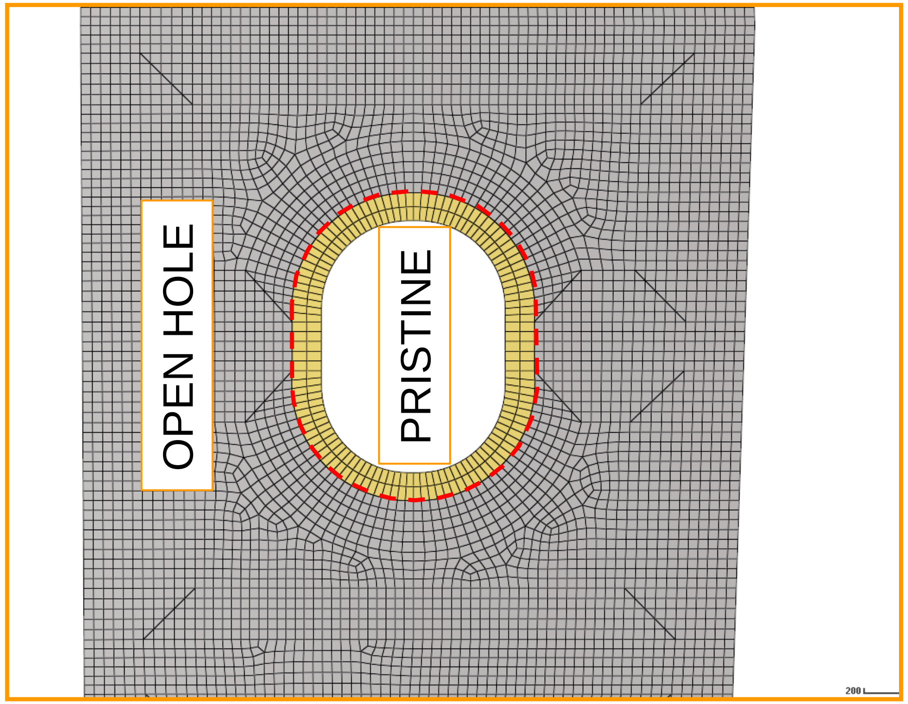


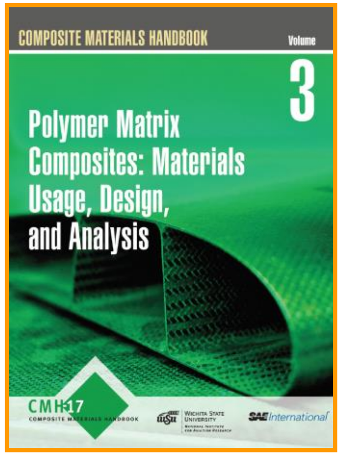


Stress Analysis

Composite Parts sizing:

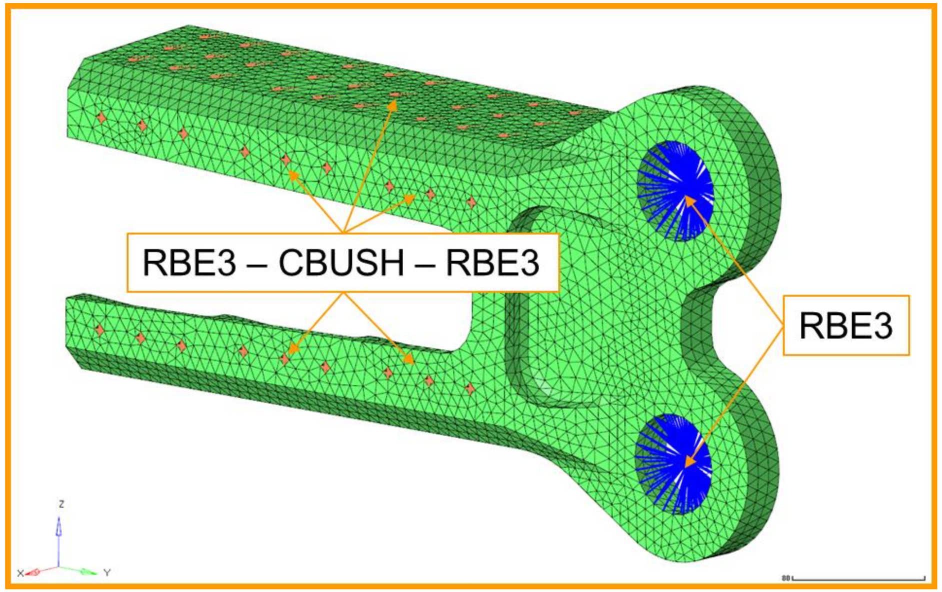
- Fulfill strength and stiffness requirements for Ultimate Load
  - Strength requirement – positive MoS based on First Ply Failure and Max Strain criterion
  - Stiffness requirement – no buckling allowed
- Ply stiffnesses (E1, E2, G12) → Pristine, Mean & RTA
- Design Values used for far field strain areas (grey zone):
  - Category 1 Damage knockdown based on 0,25 in Open Hole
  - Material variability knockdown based on B-Basis requirement
  - No Environmental Knockdown – already included in Overload Factor
- Design Values used for strain gradient areas (yellow zone):
  - Pristine conditions
  - Material variability knockdown based on B-Basis requirement
  - No Environmental Knockdown – already included in Overload Factor
- In order to eliminate matrix related failure modes Design Values were modified based on progressive failure analysis (Last Ply Failure) of characteristic layups tested for tension at coupon level





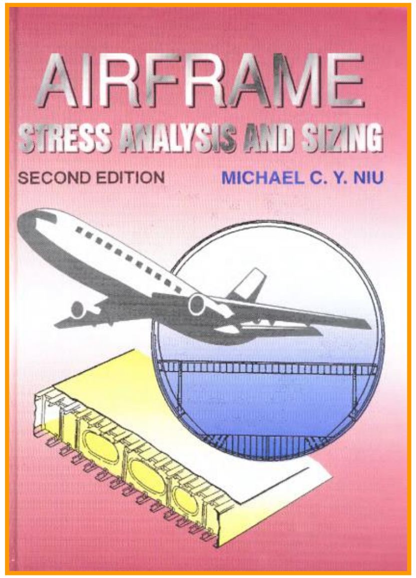
Metallic Parts FEM models:

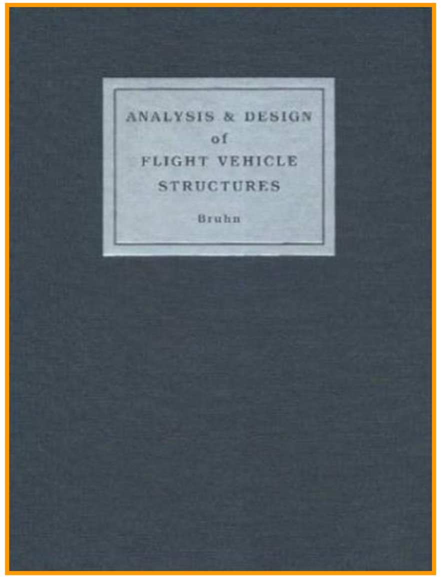
- All fitings modeled using 3D elements
- All ribs and frames modeled using plane elements

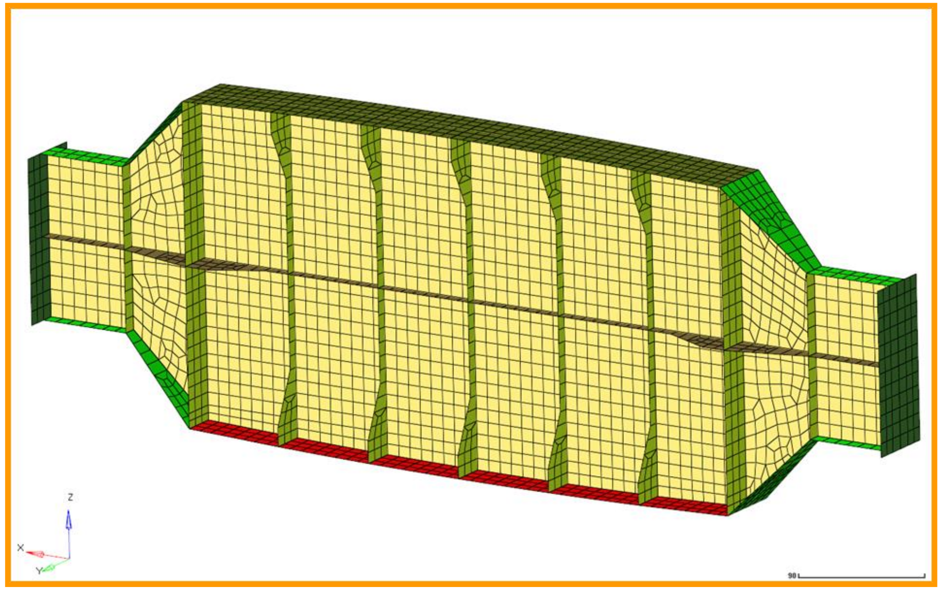


Metallic Parts sizing:

- Parts sized according to von Mises criterion
- Details like lugs or pins sized using hand calculations







Stress Analysis

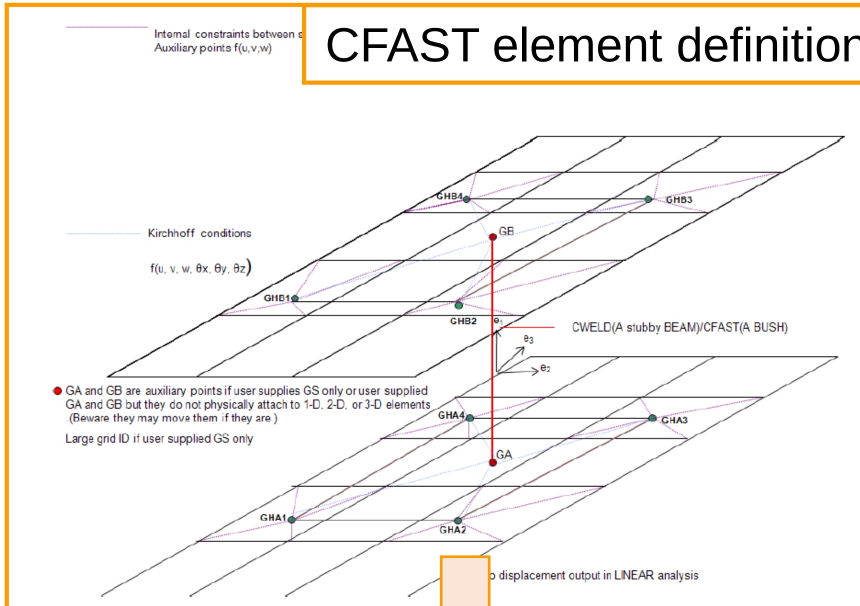
Connection FEM models:

- Efficient and accurate method needed to model 1500 fasteners
- CFAST elements → extremely efficient method for modeling flexible, user-defined connection between two shell elements (with user-defined longitudinal and rotational stiffness calculated according to e.g. Huth formula)
- HyperMesh Connectors tool used for modeling

Connection sizing:

- Sized using fastener forces obtained from FEM Model for:
  - Composite bearing
  - Composite pull through
  - Fastener shear and tension
  - Metallic parts bearing

CFAST element definition



Fastener Stiffness Huth Formula

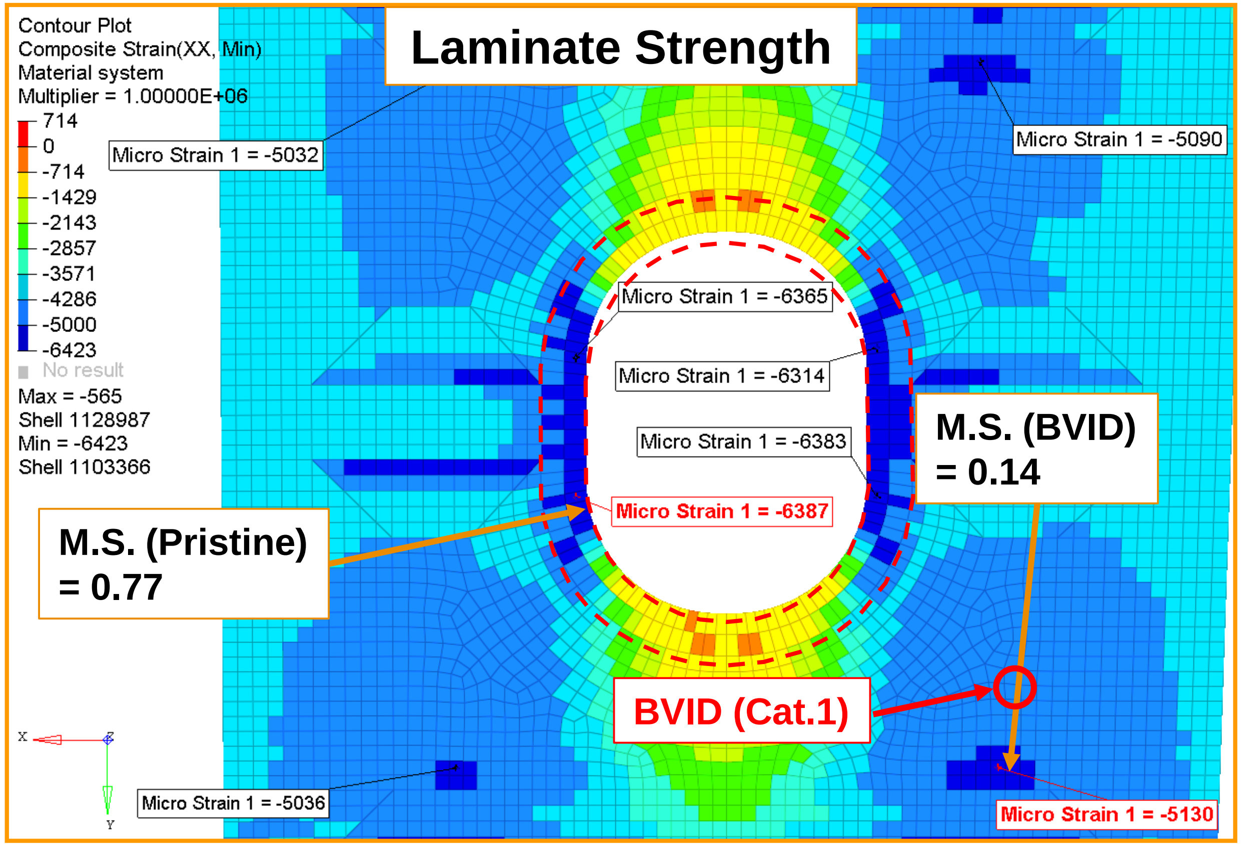
$$f = \left(\frac{t_1 + t_2}{2d}\right)^a \frac{b}{n} \left(\frac{1}{t_1 E_1} + \frac{1}{n t_2 E_2} + \frac{1}{2 t_1 E_f} + \frac{1}{2 n t_2 E_f}\right)$$

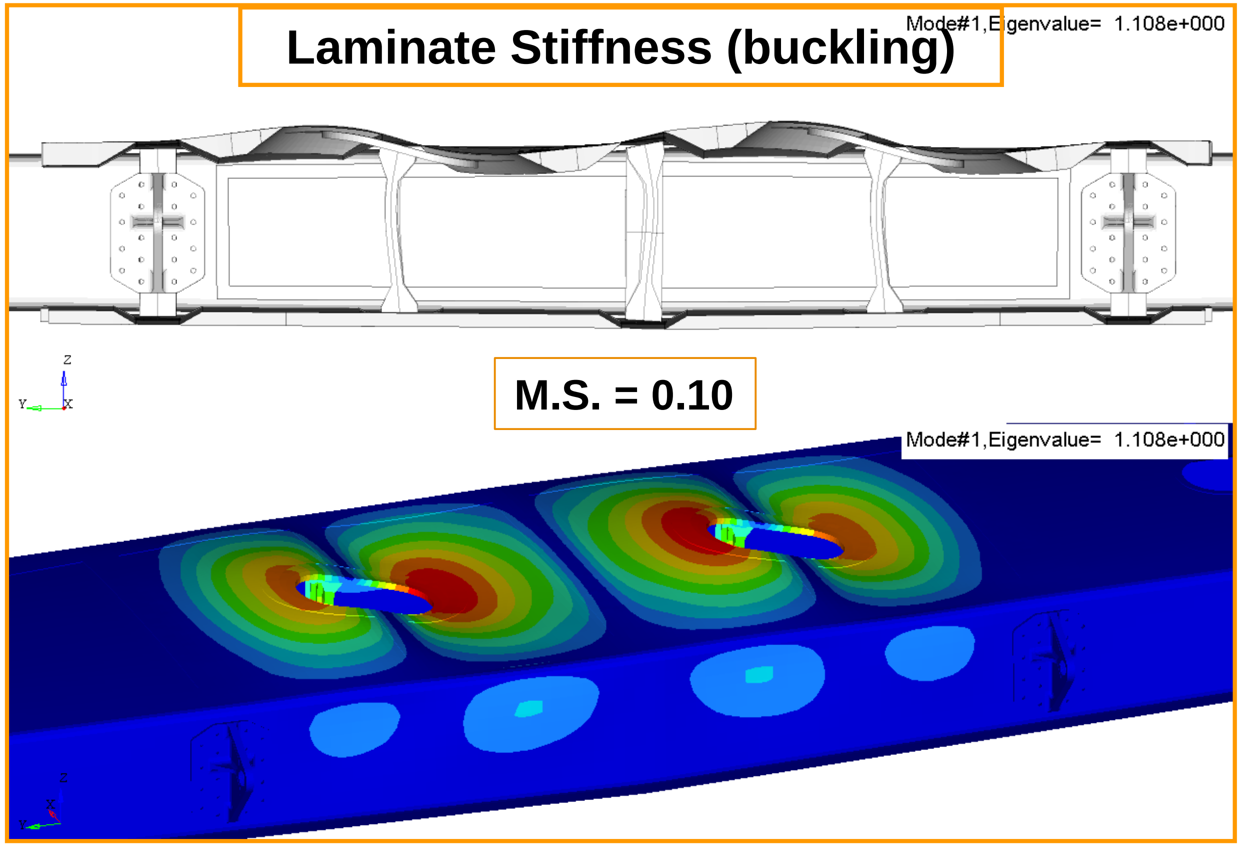
where a, b and n are parameters defining the joint type as seen in Table 2.1.

Single shear	$n = 1$
Double shear	$n = 2$
Bolted metallic joints	$a = 2/3,\ b = 3.0$
Riveted metallic joints	$a = 2/5,\ b = 2.2$
Bolted graphite/epoxy joints	$a = 2/3,\ b = 4.2$

FEM model predictions:

- Critical part of the test article – upper skin panel
- Critical failure mode – upper skin panel buckling
- Margin of Safety for critical failure mode = +10%

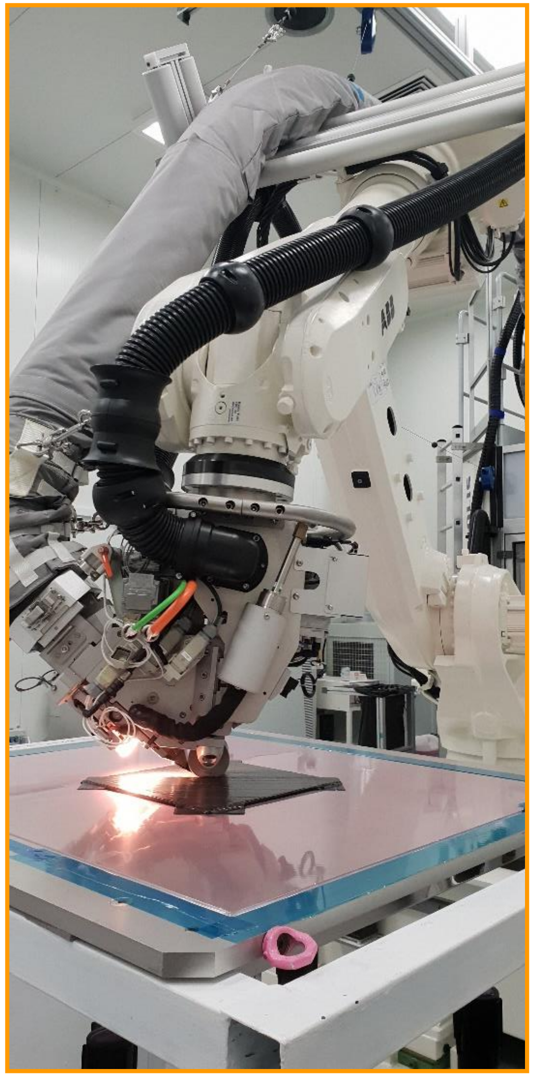




TECHNOLOGIES DEVELOPMENT & MANUFACTURING

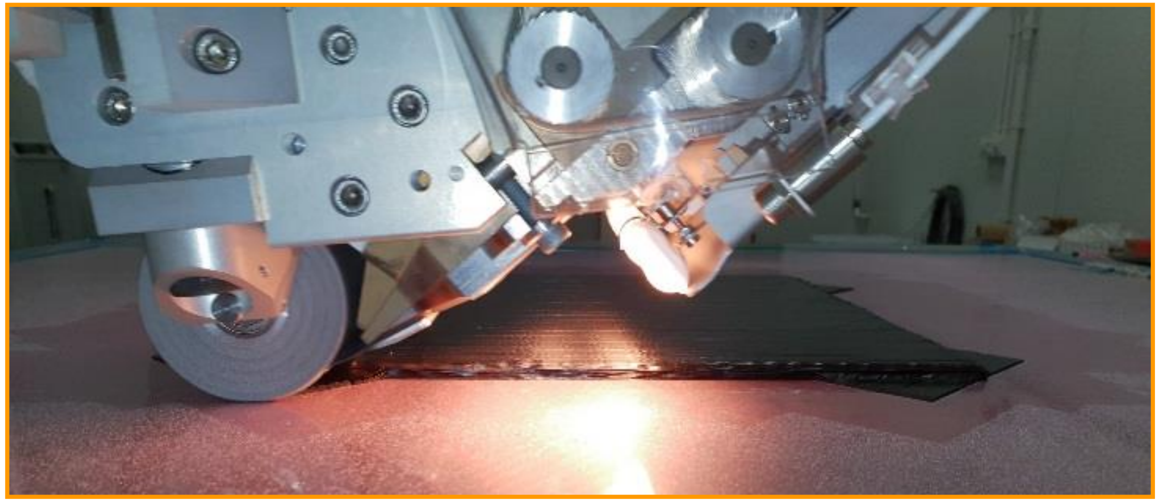
Technology development

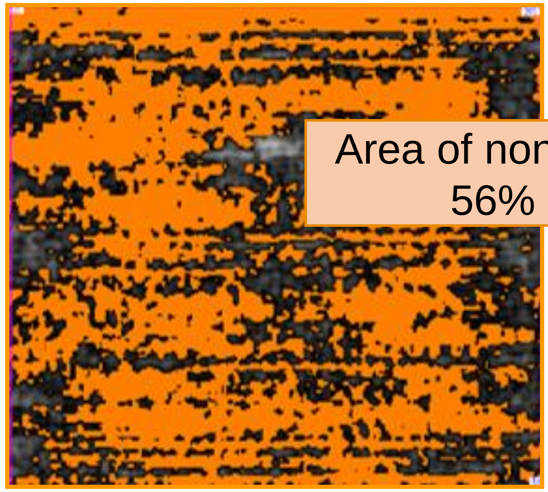
Automated Fiber Placement



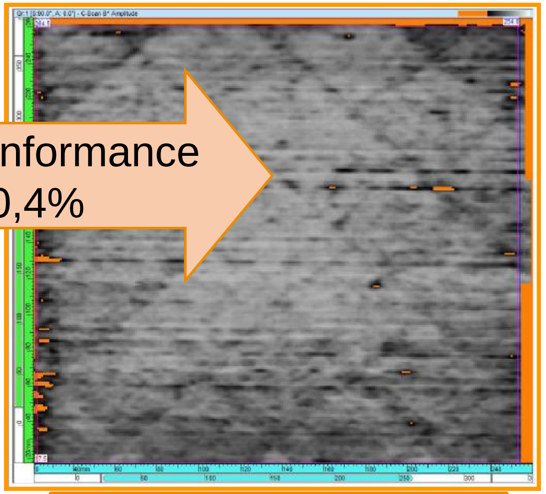
Parameters optimization:

- Layup speed
- Compaction force
- Heating power
- Head movements
- Gaps b/w tapes correction
- More than 40 Trial panels produced





Area of non conformance
56% → 0,4%



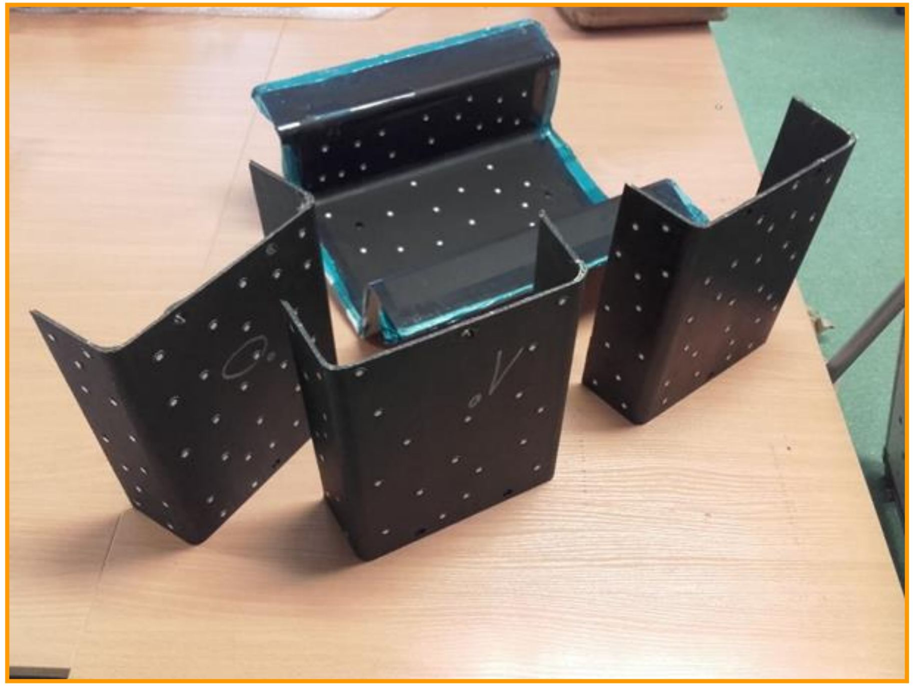
1st Trial

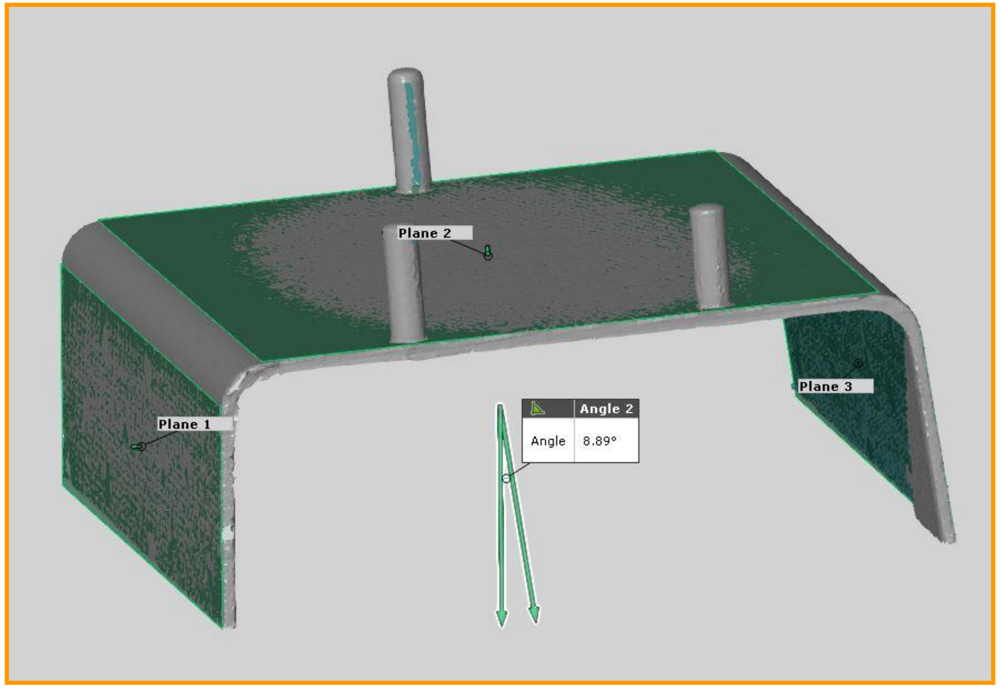
Optimized process

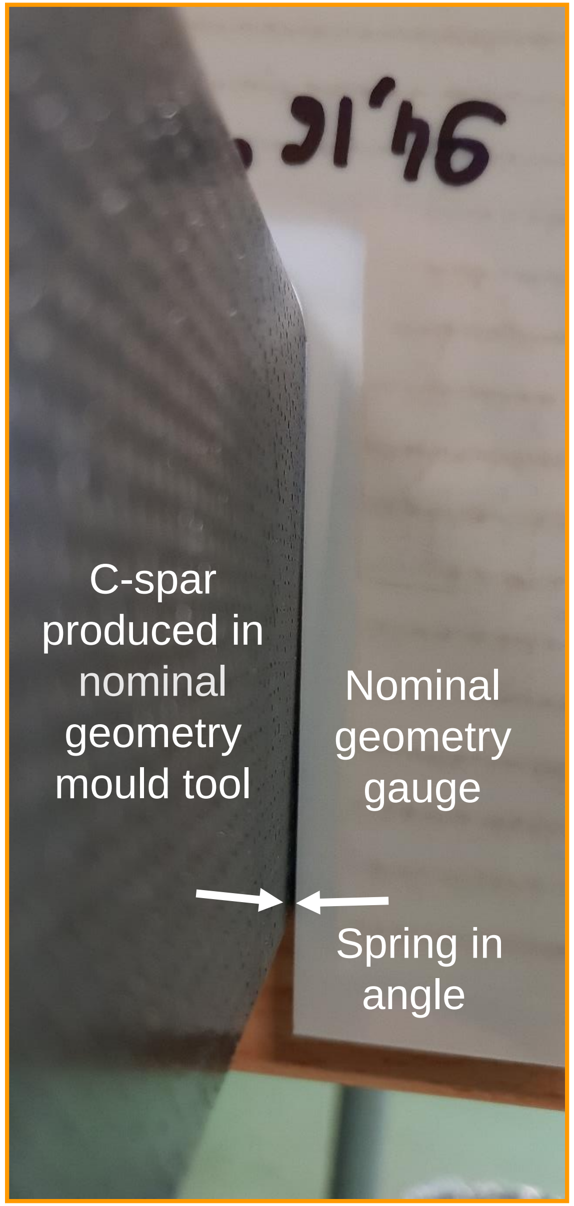
Technology development

Spring-in effect

- Trade study performed to minimize/eliminate shim usage - series of master models, mold tools and parts with different nominal angle between flanges produced.
- 3D scanning used to obtain angle values.







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Technology development

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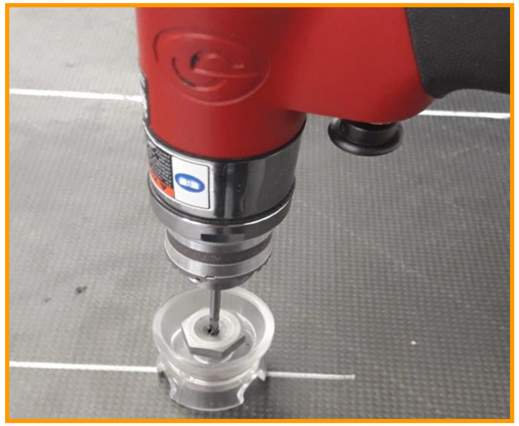
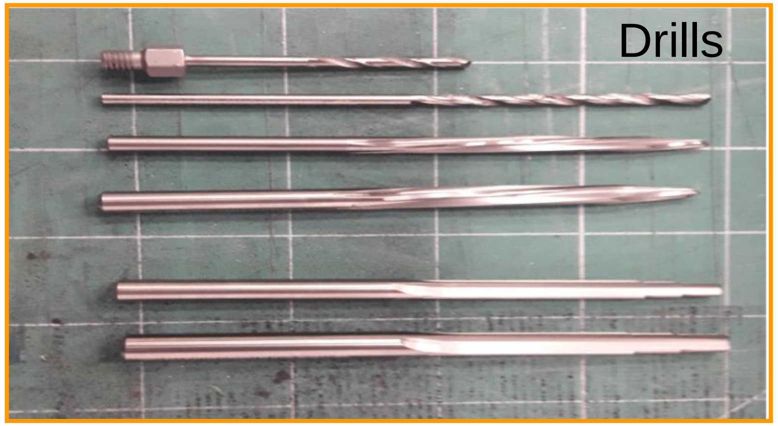
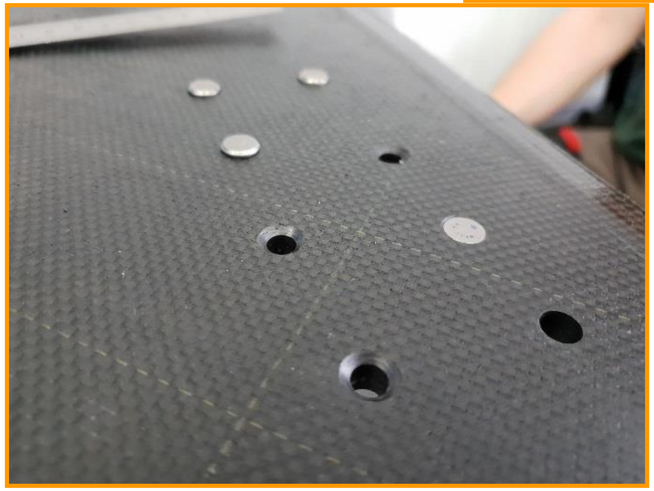
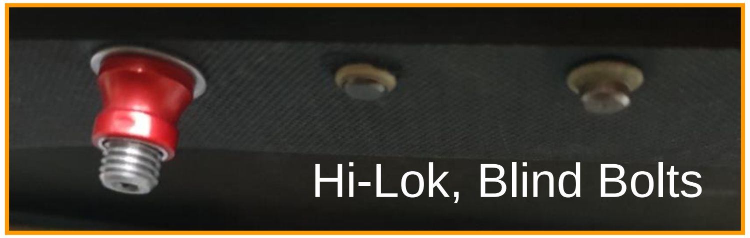
Drilling and fastener installation









- Optimized multi-stage drilling process → Drilling spec.
- Tools adaptation for Hi-lok installation

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Technology development

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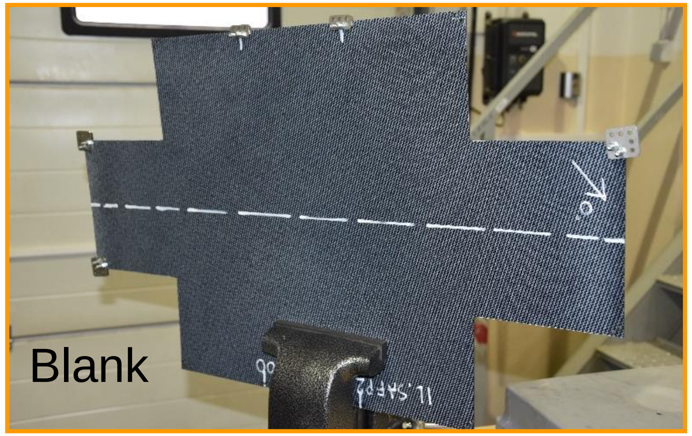
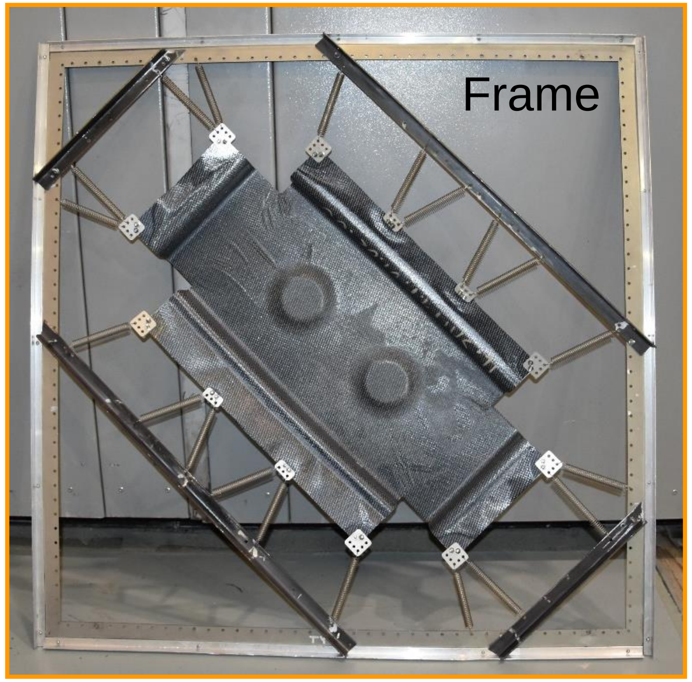
Thermoplastic rib trials

- Press parameters optimization
- Springs adjustment (stiffness, locations)
- Spring-in effect correction
- Tooling thermal expansion correction
- Wrinkles elimination





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FINAL ASSEMBLY

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Final assembly

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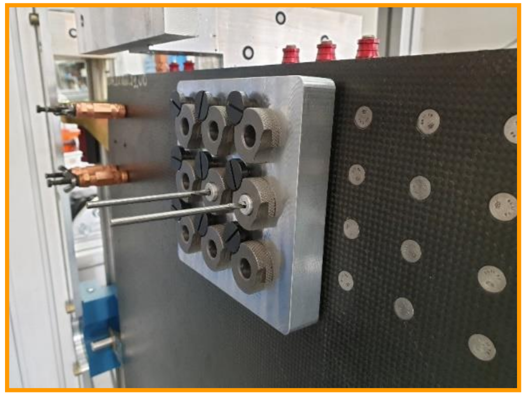
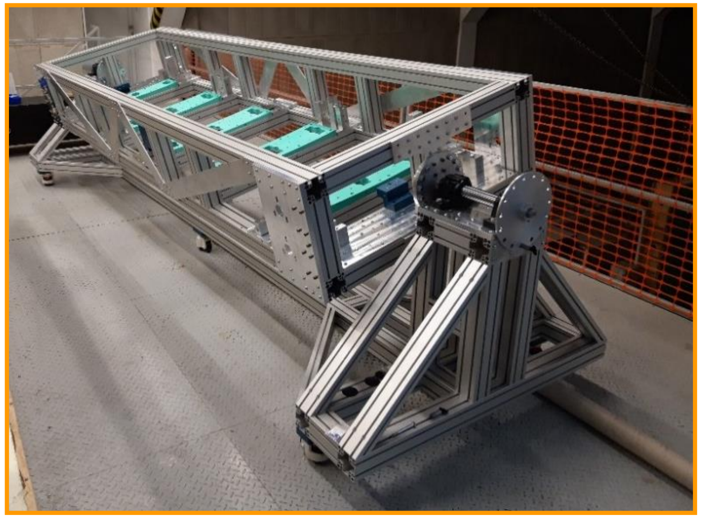
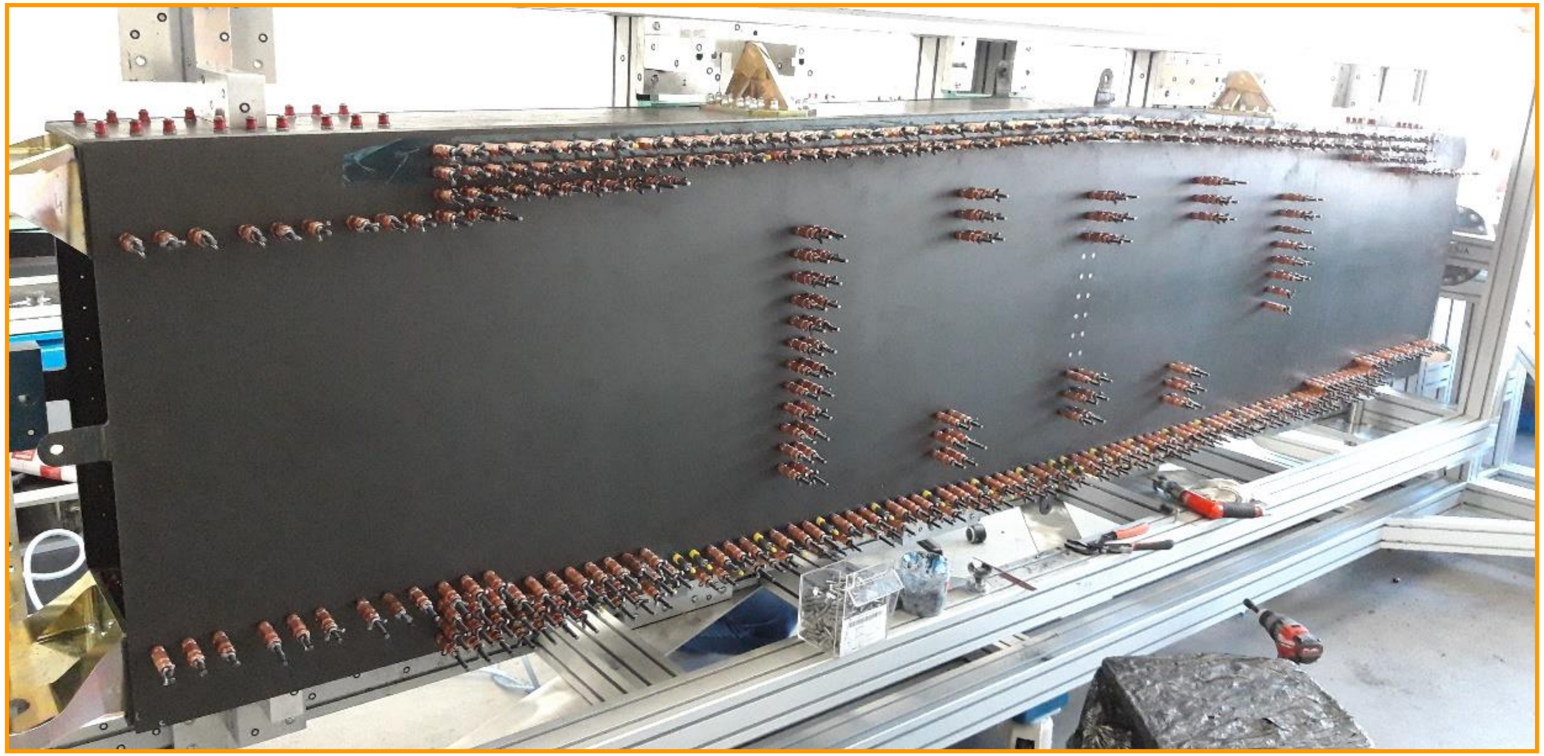
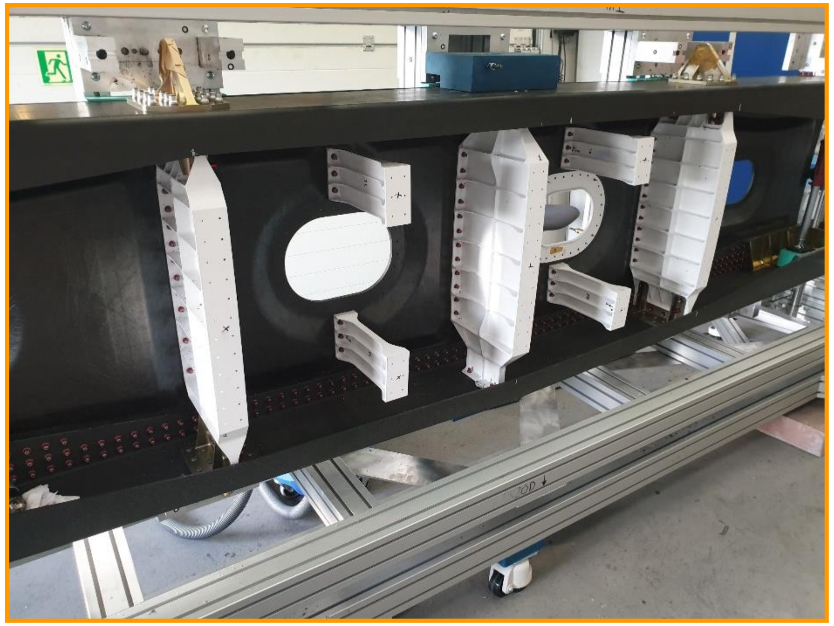
- Rotating & mobile assembly tool designed to allow access at every stage of assembly
- Critical position of interfaces
- Multi-stage drilling to ensure sufficient hole quality

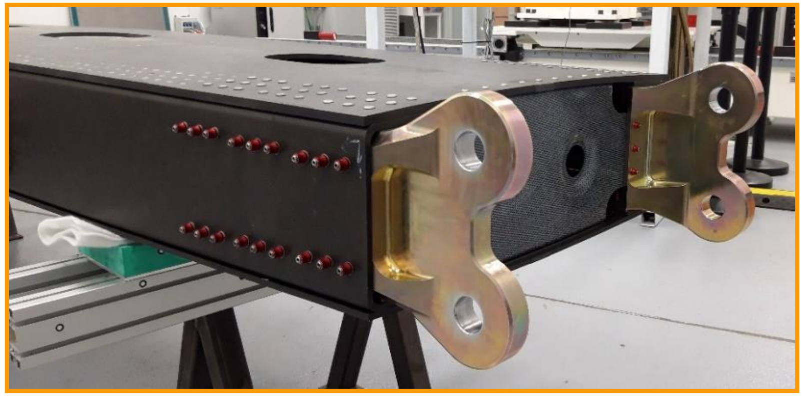


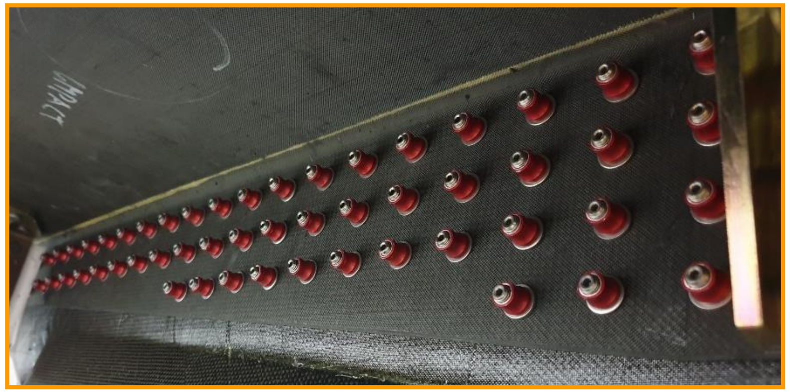


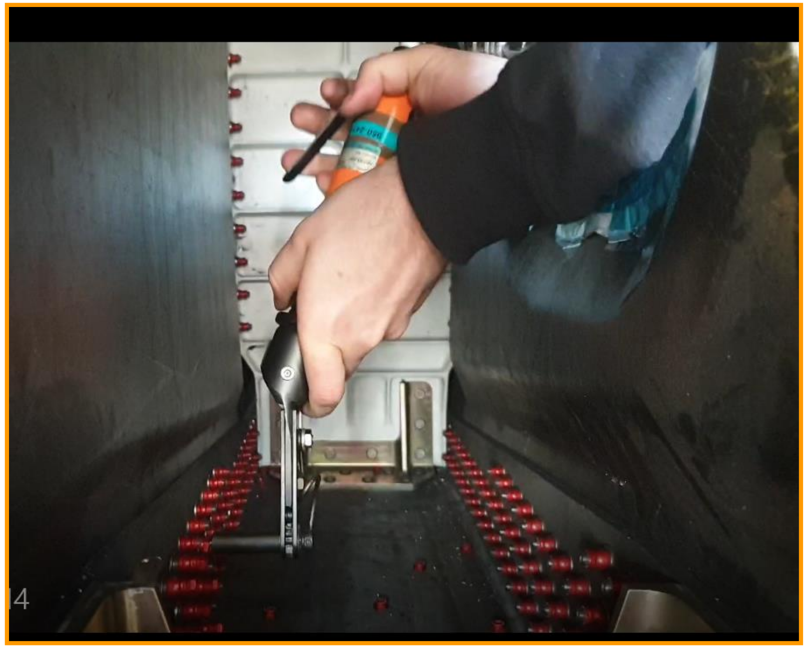


Final assembly

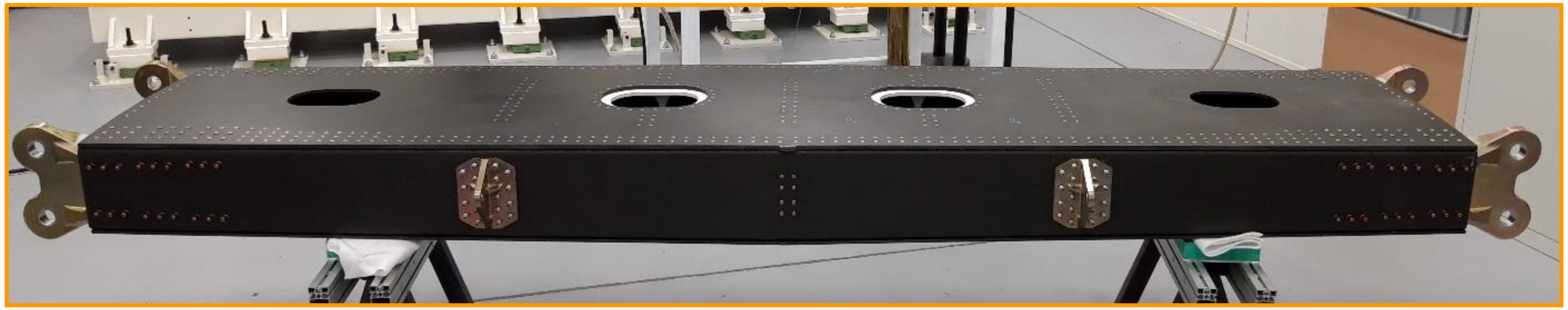








~1500 Hi-lok fasteners installed



QUALITY CONTROL

Quality Control Process

- Material Quality Control
- Integrated Quality Control Plan for each part family
- Composite parts manufacturing process records
- Process control of assembly

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L	C	PC	NDT
CHANGE NOTE			Y/N

CKT

Thermoset parts fabrication process

Part No.: .... Project/Stage: ....
Adhesive film Material: .... Adhesive film Batch No: ....
Skins No: ....

Fabrication of composite laminates shall be performed in accordance with Process Specification or with Composite Structures Manufacturing Division (CKTT) Instruction

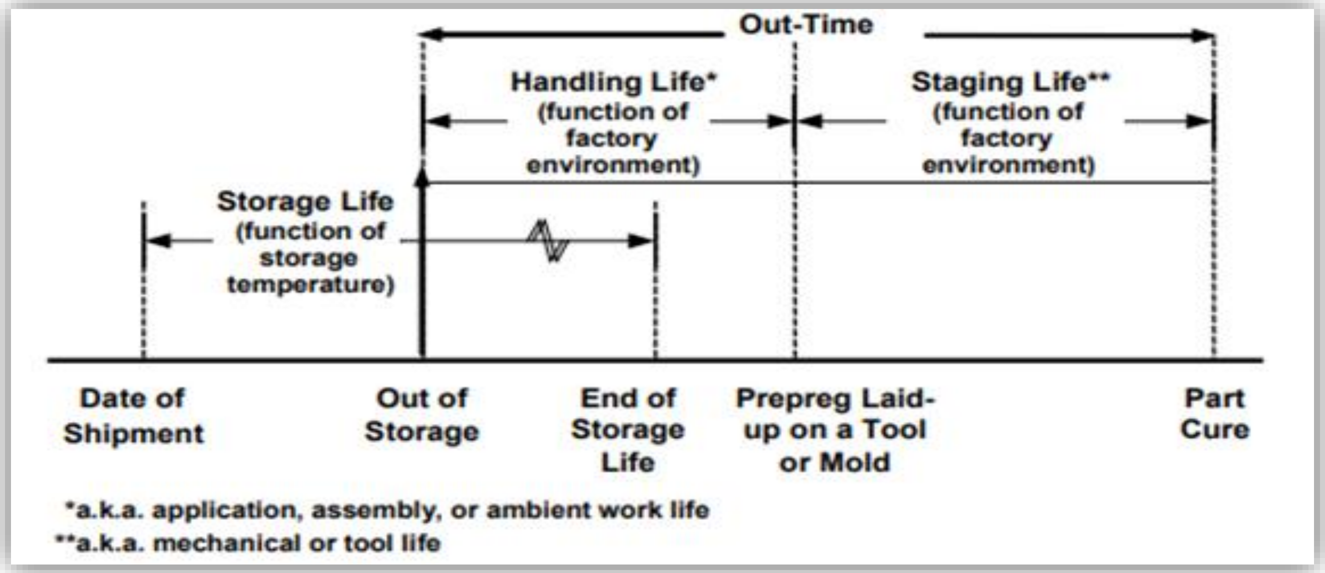
Operation Number	Operation	Technician / Date	Controller / Date	Comments	
1	**Surface preparation for bonding**			Comments:	Approved Conditionally Approved Not Approved
2	**Initial conditions check**			Temperature: ....°C Humidity: ....% Comments:	Approved Conditionally Approved Not Approved
3	**Inspection for honeycomb core**			Comments:	Approved Conditionally Approved Not Approved
4	**Inspection for adhesive film**			Comments:	Approved Conditionally Approved Not Approved

Page 1 of 5

Material Quality Control

Material storage

Example of storage requirements for UD slit tape (AFP)	
Storage temperature	-18°C
Storage requirements	Tightness of the material bag
Storage life in the freezer	12 months
Out time at 19÷24°C temperature and max. humidity 55%	440 hours



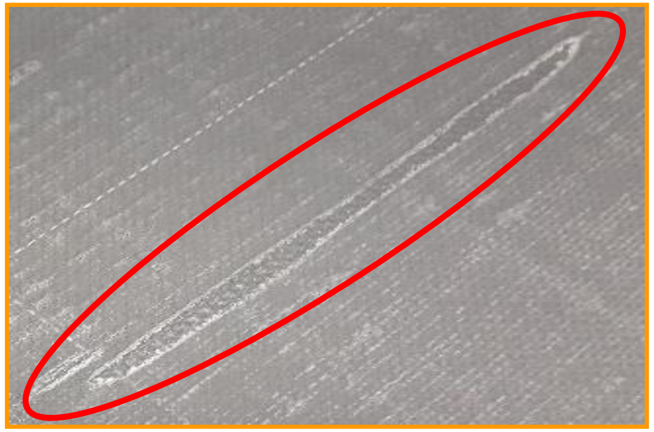
Material visual inspection

Visual inspection ensures that the material meets the quality requirements.
Inspection of the material is performed in two stages:
1. During cutting material
2. During laying the material

Type of defect	Acceptance criteria
Uneven tension fibers	Less than 6 mm for distance 300 mm
Interruption of fibers	Less than 1 tow per 0.1 m^2
Presence of foreign object	Not allowed
Fuzzball	fuzzball thickness less than 50 % of prepreg thickness
Wrinkles	No allowed
Lack of resin	No allowed

Fuzzball

Lack of resin



Material Quality Control

Physicochemical properties of prepreg

The matrix was developed on the basis of documents: DOT / FAA / AR-00/47

Test	Method	Sampling frequency	The number of samples	Acceptance criteria
The content of volatile components in the prepreg	ASTM D3530	The first and last roll from each batch	3 x 2	Max 2%
Resin content	ASTM D3529	The first and last roll from each batch	3 x 2	32÷40%
Amount of resin outflow	ASTM D3531	The first and last roll from each batch	3 x 2	15 max
Tack & drape	ILOT spec.	Each rolls	3	At least medium
Gel time	ASTM D3532	Optional	3	
Area weight	ASTM D3776	Each rolls	3	+/- 8 g/m2

Mechanical properties of material

Acceptance criteria for a new batch of material:

Test	**Method**	**Number of samples**	**Acceptance criteria for mechanical properties**
0 Tensile Strength	ASTM D3039	6	Value calculated based on NCAMP HYTEQ
Compression Strength	ASTM D6641	6	Value calculated based on NCAMP HYTEQ
Short beam shear	ASTM D2344	6	Value calculated based on NCAMP HYTEQ
DMA	ASTM D7028	3	+/- 3 sigma

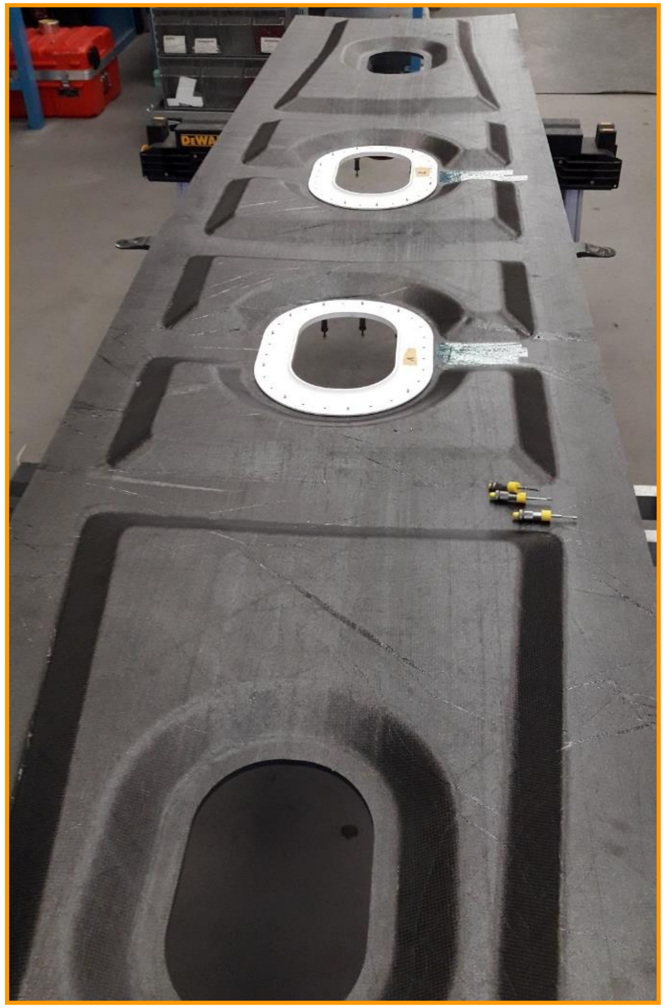
Integrated Quality Control Plan

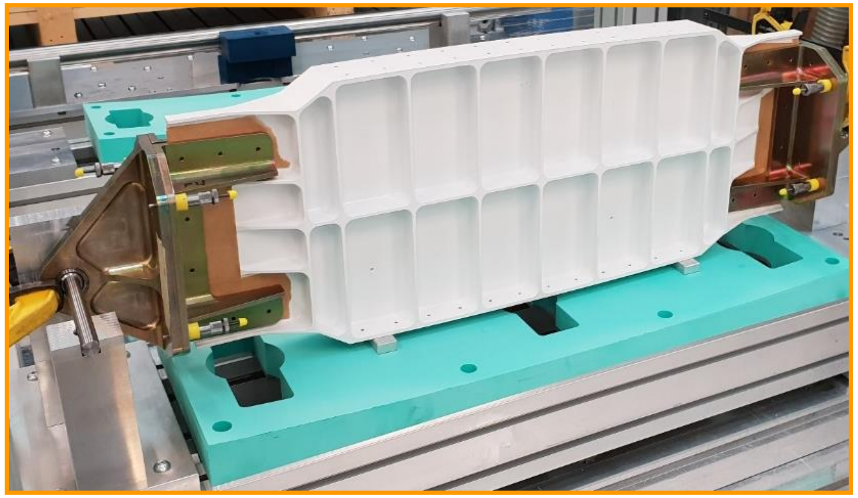
Quality control plan is defined for each part family:

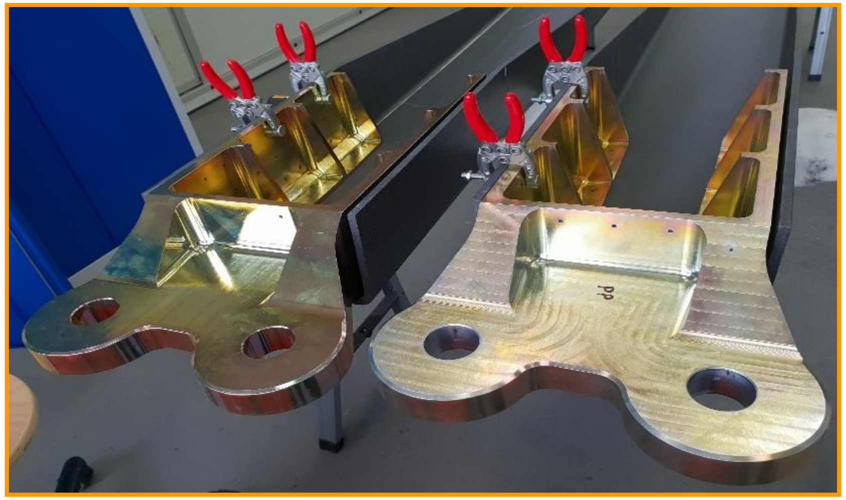
- Sandwich panels (wing covers)
- Solid laminate parts (C – Spars)
- Thermoplastic ribs
- Metallic parts
- Assembly

Quality control plan defines:

- All quality checks operations
- Process control specimens
- Method of control
- Defect types
- Acceptance criteria







Non conformances require engineering disposition.

Defined quality checks operations are considered in Production Process Record

QC for solid laminate parts

Operations controlled	Control method	Type of nonconformity	Acceptance criteria
Prepreg inspection	Visual		Material type in accordance with the process specification and drawings, acceptance check of material according to material specification
Layup Inspection	Visual		Number of layers and direction of fibers according to engineering drawing
Tooling Inspection	Visual		Control of parts and tool numbers. Control of the application of the mold release agents, the tool tightness check.
Inspection during laying material	Visual	Gaps	Gaps≤ 1 mm
		Fiber orientation	Orientation deviation ≤ 5°
		Dry fibers	Not more than one tow with a maximum length of 100 mm per 1 m2 of layer
Control of the production Process recording	Document control	Laying / curing parameters	According with the process specification
		Preparation of the oven curing element	Checking the correct positioning of the product in the oven, connection of the control and recording thermocouples, starting the recording of the curing cycle.
Visual inspection of the cured element	Visual	Wrinkles	Length ≤20 mm, The minimum distance between two defects 180 mm
NDT testing of the laminate after curing	Ultrasonic	Porosity	Max. 2% by volume
		Delamination, Voids, Foreign object, Blister	Surface of a single defect ≤150 mm2.
Verification of edge trimming quality	Ultrasonic	Delamination	Not allowed
	Visual	Fraying	Up to 5 mm for a single outer layer, Minimum distance between defects 100 mm
Verification of the quality of holes	Ultrasonic	Delamination around holes	Not allowed
	Visual	Chip-out or composite material	Maximum allowable depth of 0,2 mm, maximum 20% of the bore or countersink surface
Geometry verification	3D scan	Dimensional deviations	Acording to the engineering drawing

QC for honeycomb, film adhesive and cured skin surface preparation

Operations controlled	Control method	Type of nonconformity	Acceptance criteria
Core Inspection	Visual		Material type inspection in accordance with engineering drawing and material specification
		Damage to the cells	Not allowed
		Dirty, greasy	Unacceptable, control of the core milling process in terms of the possibility of contamination (glove transfer, cleanness of cutting tools, lack of oils and lubricants in the vicinity of the process)
	Measurement	Dimensional deviations	According to engineering drawing
	Visual	Moisture	Not allowed; (Verification of the production process record of the core, core should be dried at 80 °C for 2 hours and hermetically packed, check the bag tightness visually)
Cured skin surface preparation	Visual	Moisture	Not allowed; (Verification of the production process record, the laminate should be dried at 80 ° C for 2 hours after NDT testing.
	Visual	Dirty, greasy	Not allowed. Remove the peel ply in the clean room immediately before applying the film adhesive. In the case of removal of the delamination outside the clean room or deviations from the requirements, the surfaces of the laminate should be wiped with abrasive paper of 320-400 grid, vacuum the dust, then degrease the surfaces with acetone
Adhesive film Inspection	Visual	Material inspection	Material type control (including thickness) according engineering drawing. Checking the expiration date and out time. Material acceptance according material specification

Manufacturing process records

Manufacturing process record contains all critical production stages of composite elements.

Controller checks critical operations during the production process.

Recording of the production process includes:

- Inspection for completeness of plies kit
- Tooling Inspection
- Temperature and Humidity Condition Check
- Prepreg Plies Collation
- Count of foil and backing paper
- Leak Check
- Curing Parameters
- Honeycomb Core inspection
- Quality Control (Visual control, NDT)
- Part geometry 3D scanning

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CHANGE NOTE			Y/N

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Institute of Aviation – Composite Structures Manufacturing Division

Fabrication of Carbon Fiber Reinforced Epoxy Composite Test Laminates Process

Product Nane. .... Product No. ....
Document No (Drawing No.)..Project: ....
Roll No:. .... Batch No:..Kit No:..

Operation Number	Operation	Technican / Date	Controller / Date	Comments
1	Inspection for completeness kit Inspection Prepreg Material *Inspection in Accordance with Composite Structures Manufacturing Division (CKTT) Process Specification (points 2.4.4;2.3.; 2.7.10 and Ply Sequence Report for Test Plate)*			
2	Base plate/Tool Inspection *Inspection in Accordance with Composite Structures Manufacturing Division (CKTT) Process Specification (point 2.6.1;2.7.23.III)*			
3	Temperature and Humidity Condition Check Initial Temperature: °C Initial Humidity: % Final Temperature: °C Final Humidity: % *Inspection in Accordance with Composite Structures Manufacturing Division (CKTT) Process Specification (point 2.5.2.1)*			

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Operation Number	Operation	Technican / Date	Controller / Date	Comments	
4	Prepreg Plies Collation **(Attach Ply Sequence Record)**			Card Number: Comments:	Done Not Done
5	Count foil and backing paper			Comments:	Approved Not Approved
6	**Leak Check (Acceptable Leakage Rate Less Than 0.02 bar in 15 min)**	Cleanroom	Cleanroom	Comments:	Approved Not Approved
	Inspection in Accordance with Composite Structures Manufacturing Division (CKTT) Process Specification (point 2.7.30;2.6.2)	Oven/Autoclave	Oven/Autoclave	Comments:	Approved Not Approved

Materials	**Vacuum Bag**	CYTEC Vacfilm 800G (Green)	CYTEC Vacfilm 450V (Violet)	CYTEC Stretch-Vac 3000 (Pink)	CYTEC VacPack HS8171 (Green)
	Sealant Tape	CYTEC LTS90B (Black)	CYTEC UCS180 (Cream)	CYTEC SM 5142 (Yellow)	AIRTECH GS-213 (White)
Vacuum Valves Quantity			**Number Vacuum Gauge**	CLEANROOM	
				OVEN/AUTOCLAVE	
Initial Vacuum Level [bar]	CLEANROOM				
	OVEN/AUTOCLAVE				

Process Control Specimens

Example of process control specimens for upper wing cover

1st Stage cure

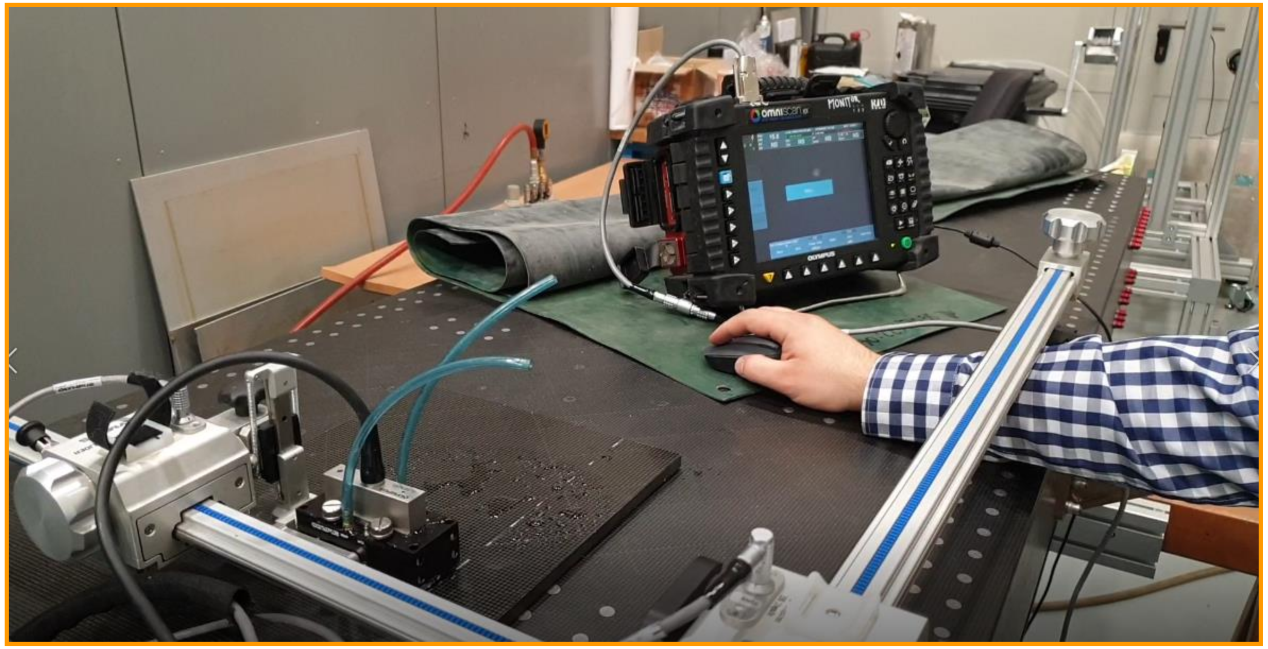
Part	Test	Specimens location	Method	Acceptance criteria
OUTER SKIN (of WING COVER)	Short beam shear	Test panel, part tool	ASTM D2344	Value calculated based on NCAMP HYTEC
	DMA	Test panel, part tool	ASTM D7028	+/- 3 sigma

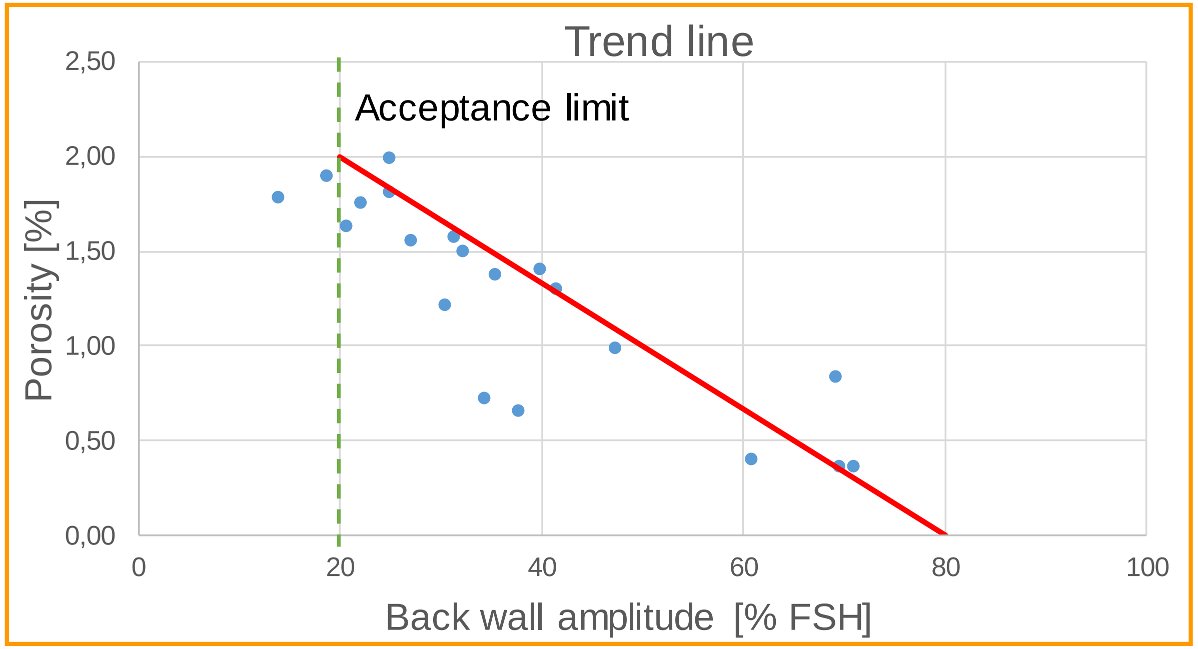
2nd Stage cure

Part	Test	Specimens location	Method	Acceptance criteria
WING COVER	Short beam shear	Test panel, part tool	ASTM D2344	Value calculated based on NCAMP HYTEC
	DMA	Test panel, part tool	ASTM D7028	+/- 3 sigma
	Flatwise tension	Test panel, part tool		Core failure
	Microscopic examination	Part (access hole cut out)	-	Max. 2% porosity
	Ply count	Part (access hole cut out)	-	According drawing

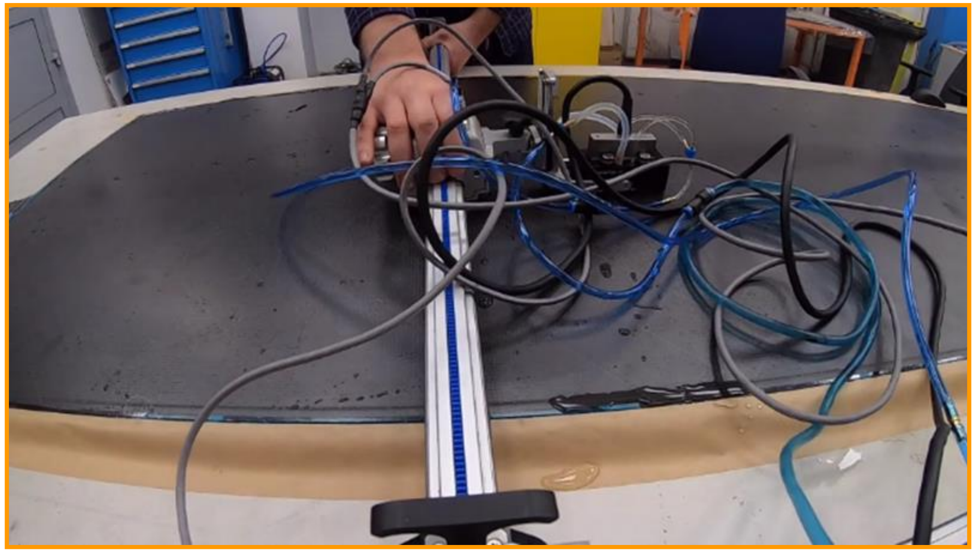
NDI calibration for porosity measurement

- Correlation of ultrasonic results with tomography (CT)
- Determining the optimal settings of the measuring apparatus
- Calibration on reference standard
- Consideration of peel ply on part and reference standard

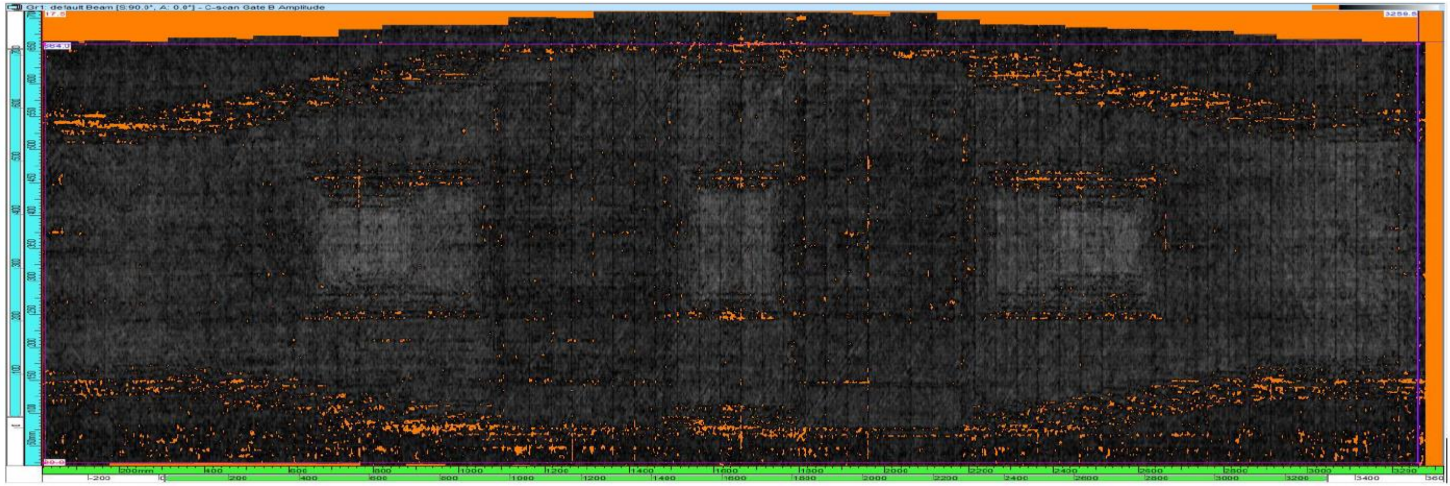




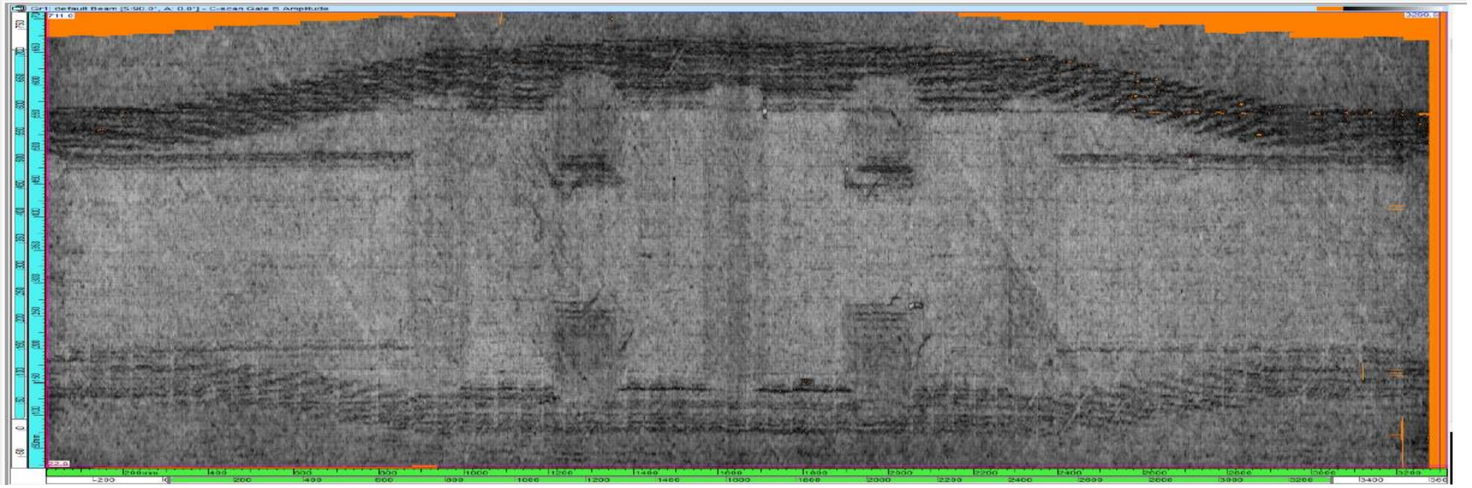
Wing covers outer skins NDI results



Upper Wing Cover – Outer Skin - **Porosity over 2% by volume on 3,21% area**
The estimated maximum porosity is 2-2,5%

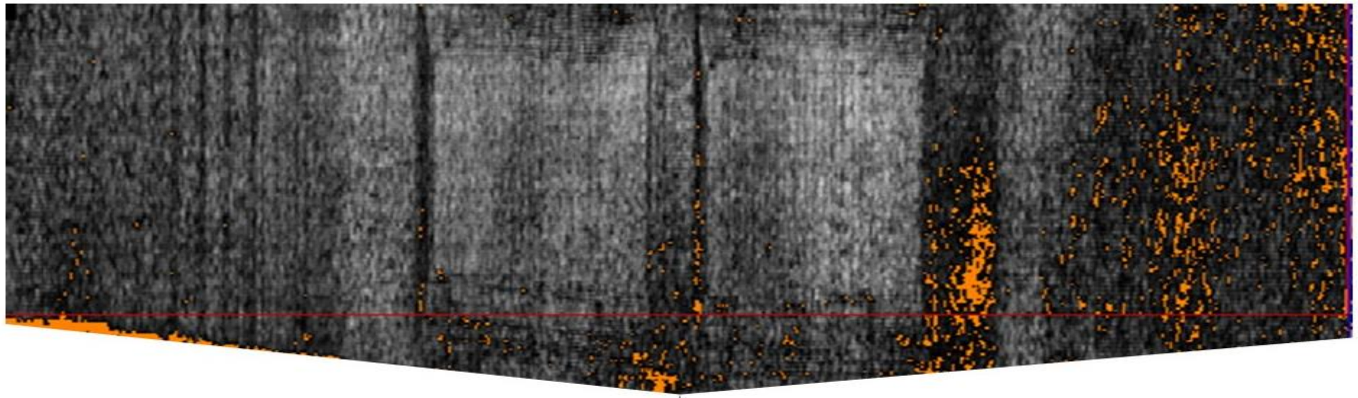


Lower Wing Cover – Outer Skin - **Porosity over 2% by volume on 0,07% area**
The estimated maximum porosity is 2-2,5%



C-Spar NDI results

Front C -Spar- **Porosity over 2% by volume on 10% area**
The estimated maximum porosity is ~2.5%



Rear C -Spar- **Porosity over 2% by volume on 22% area**
The estimated maximum porosity is ~2.5%

BONDED REPAIR

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Cat. 2 Damage location and size

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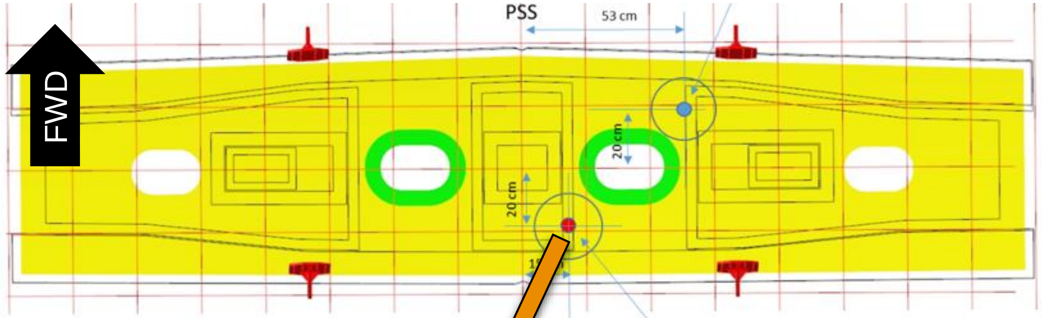
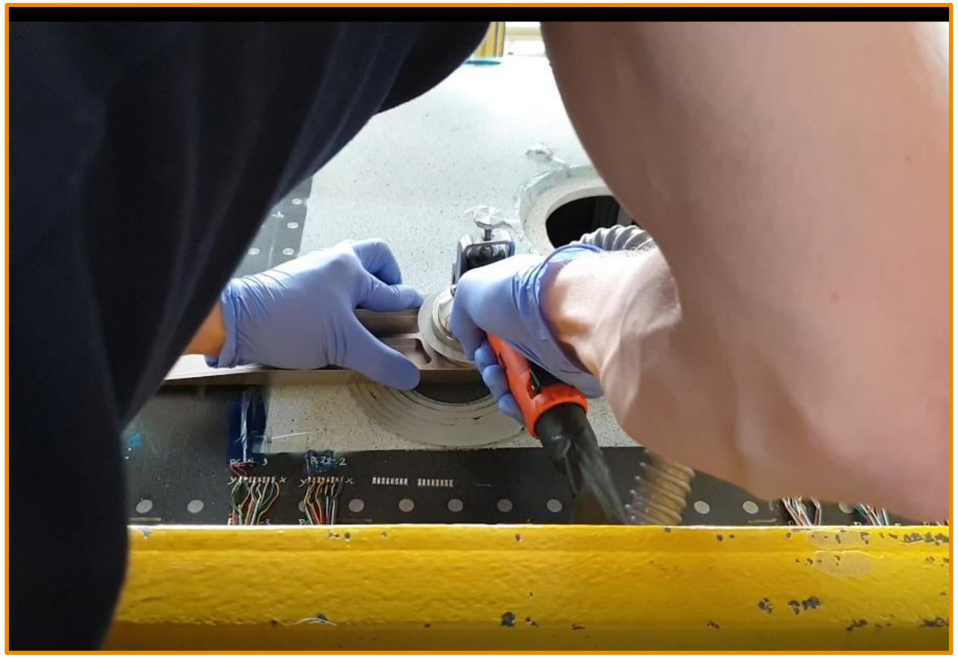


Top view

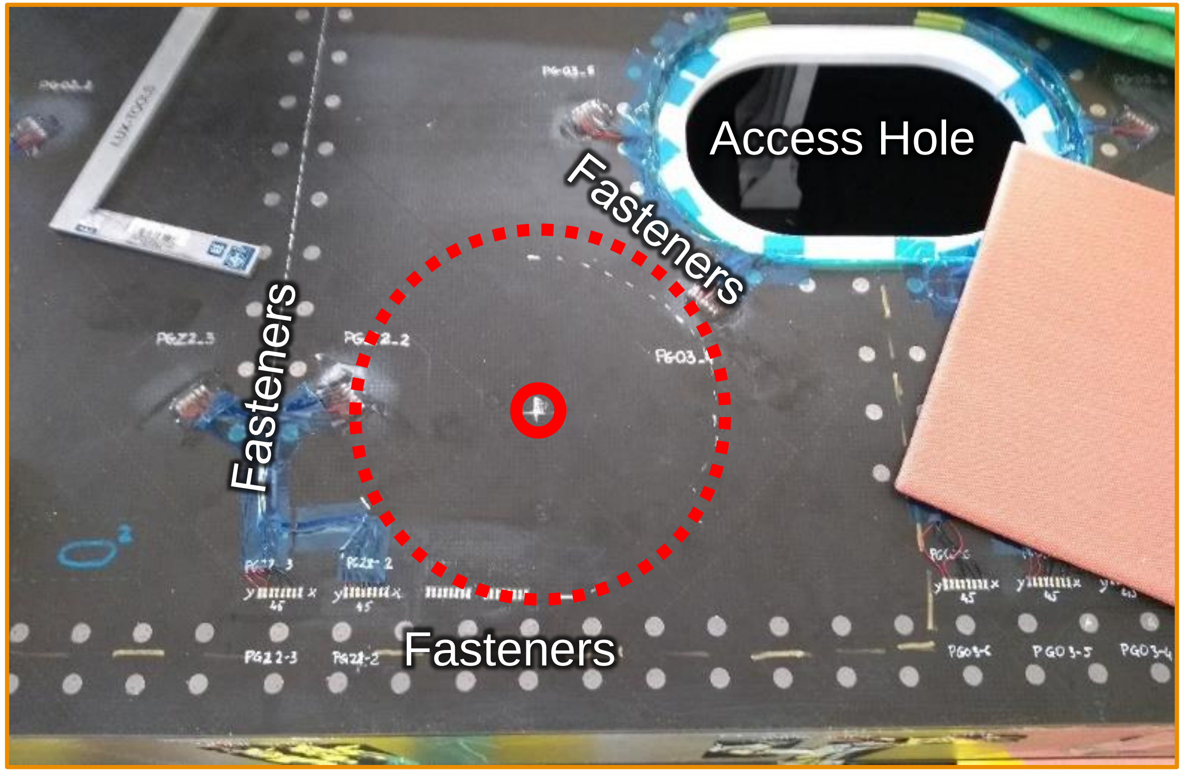


Artificially introduced damage by cylindrical pocket milling.
12 layers removed (out of 52 layers in outer skin)

Damage repair method selection

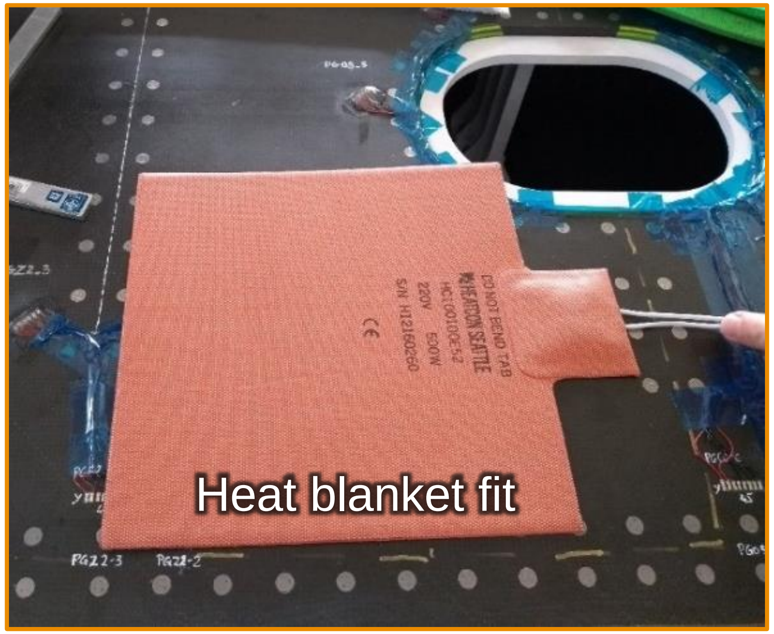
Adhesive and cure cycle:

- **Paste adhesive cured at 60°C = risk of air traps**
- **Film adhesive cured at 179°C = risk of heat sink and uneven temperature distribution**
- **Film adhesive cured at 121°C = optimal and feasible selection**

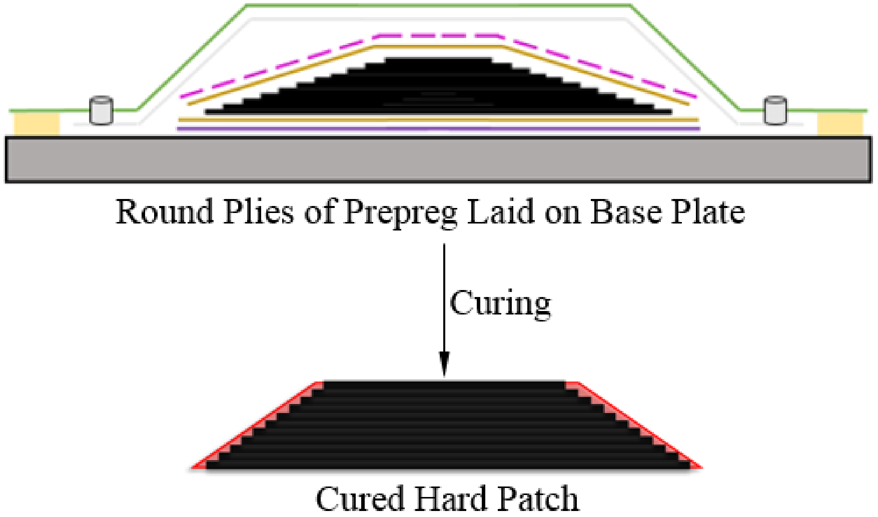


Repair patch type:

- **Soft patch not feasible due to:**
  - Limited space for heat blanket and vacuum bag (fasteners, access hole)
  - Risk of pressure leaks during cure cycle = bad quality repair with potential high porosity
- **Hard patch = controlled porosity level, less severe consequences in case of pressure leaks**



Damage repair - Hard Patch preparation



- **Diameter of plies reduced by 2mm in order to facilitate fit**
- **Layup starting from the biggest to smallest ply**
- **Curing cycle identical with the one used on Wing covers**

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Damage repair – process steps

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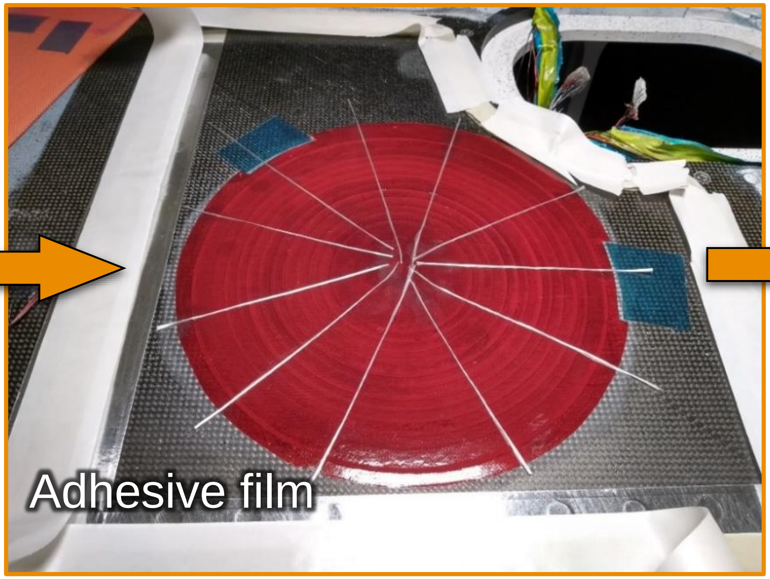
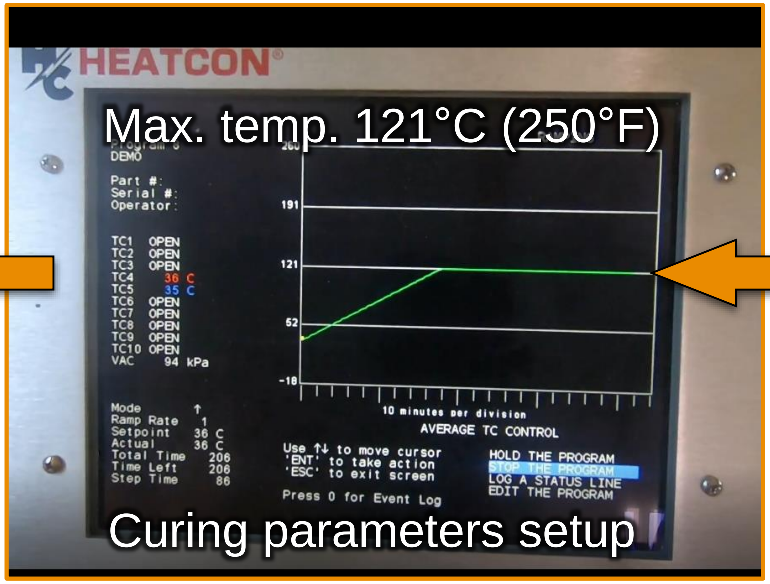




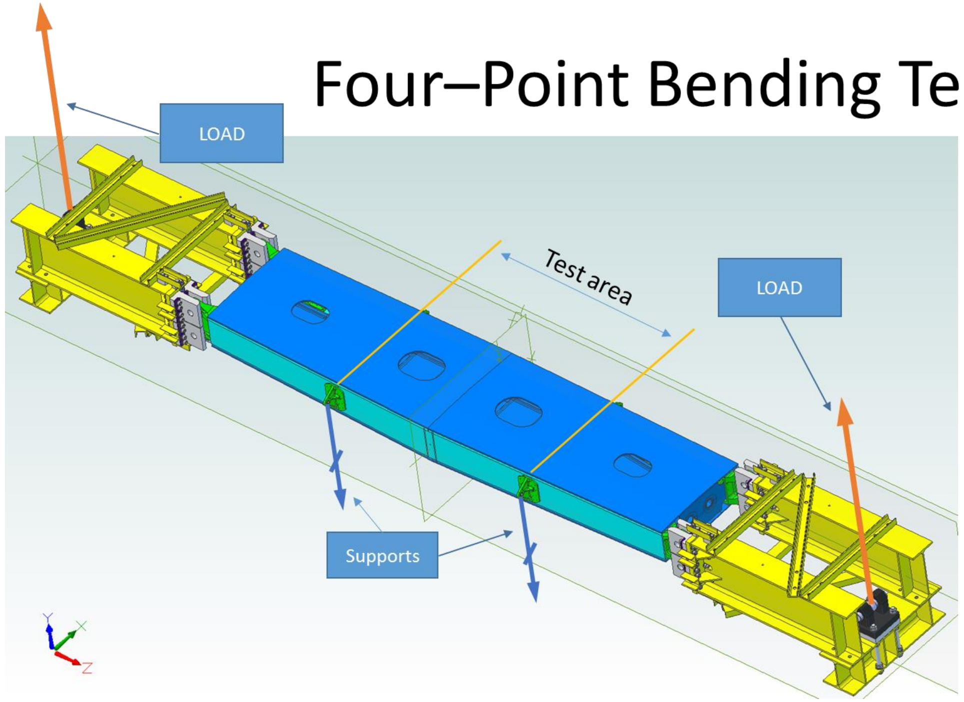
STATIC AND FATIGUE TESTS

Durability and Damage Tolerance tests

Main objectives:

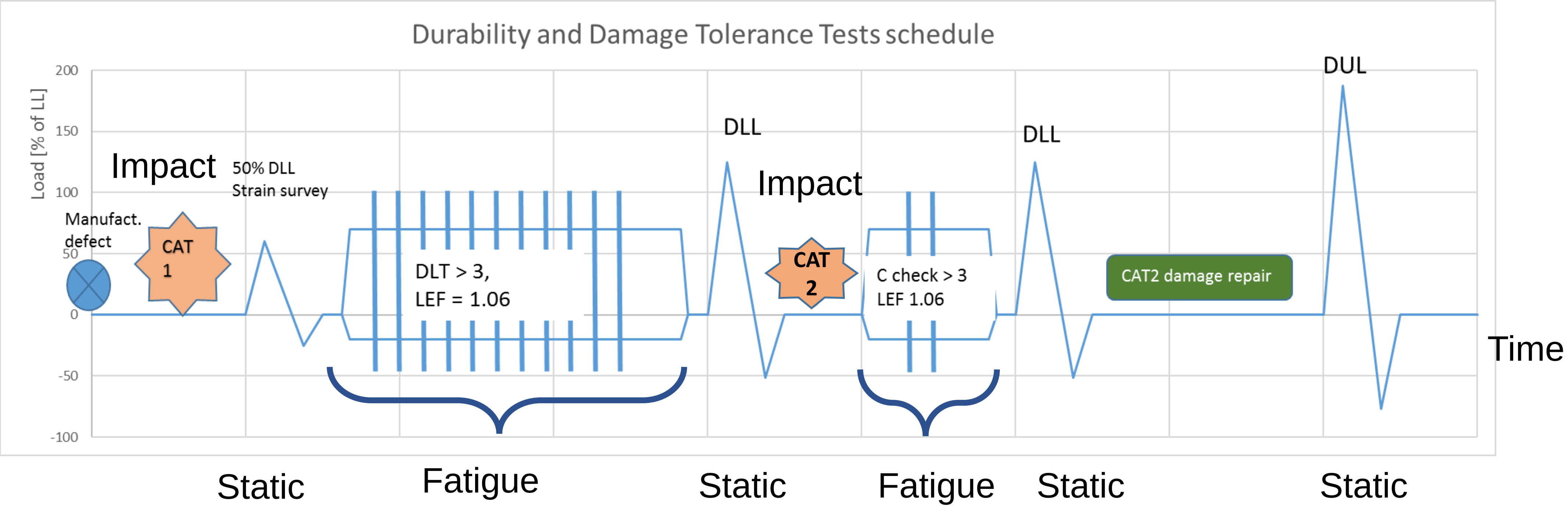
1) Verify analysis methods: stress and buckling load prediction
2) Assess material properties:
    - Compression Strength After Impact of thick laminates
    - Fatigue of the damaged laminates

Four–Point Bending Test



Durability and Damage Tolerance tests

Test Campaign



Nomenclature:

- LL – Limit Load. Max load existing in the flight spectrum
- DLL – Design Limit Load = k_{temp} * LL = 1.25 * LL
- DUL – Design Ultimate Load = sf * DLL = 1.5 * 1.25 * LL = 1.875 LL

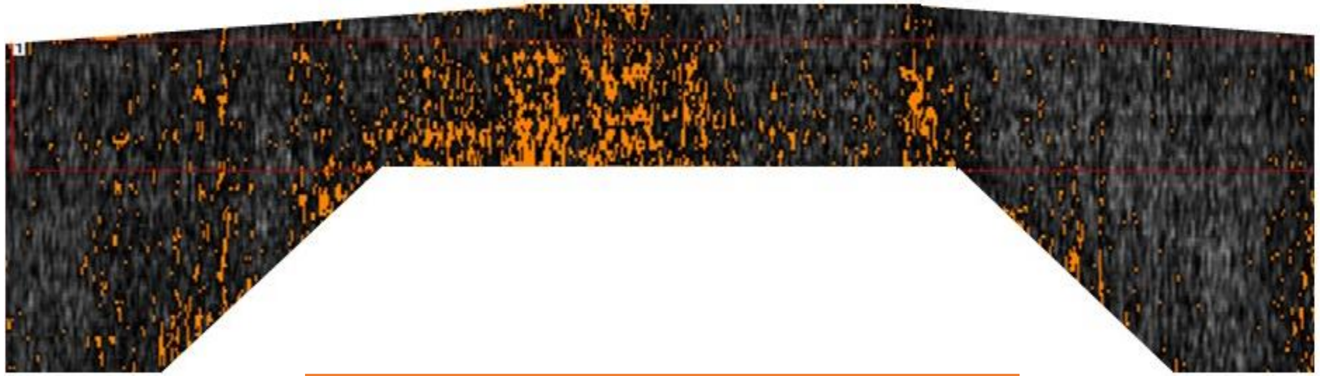
Temperature knockdowns applied to the static loads only

Damage threat assessment

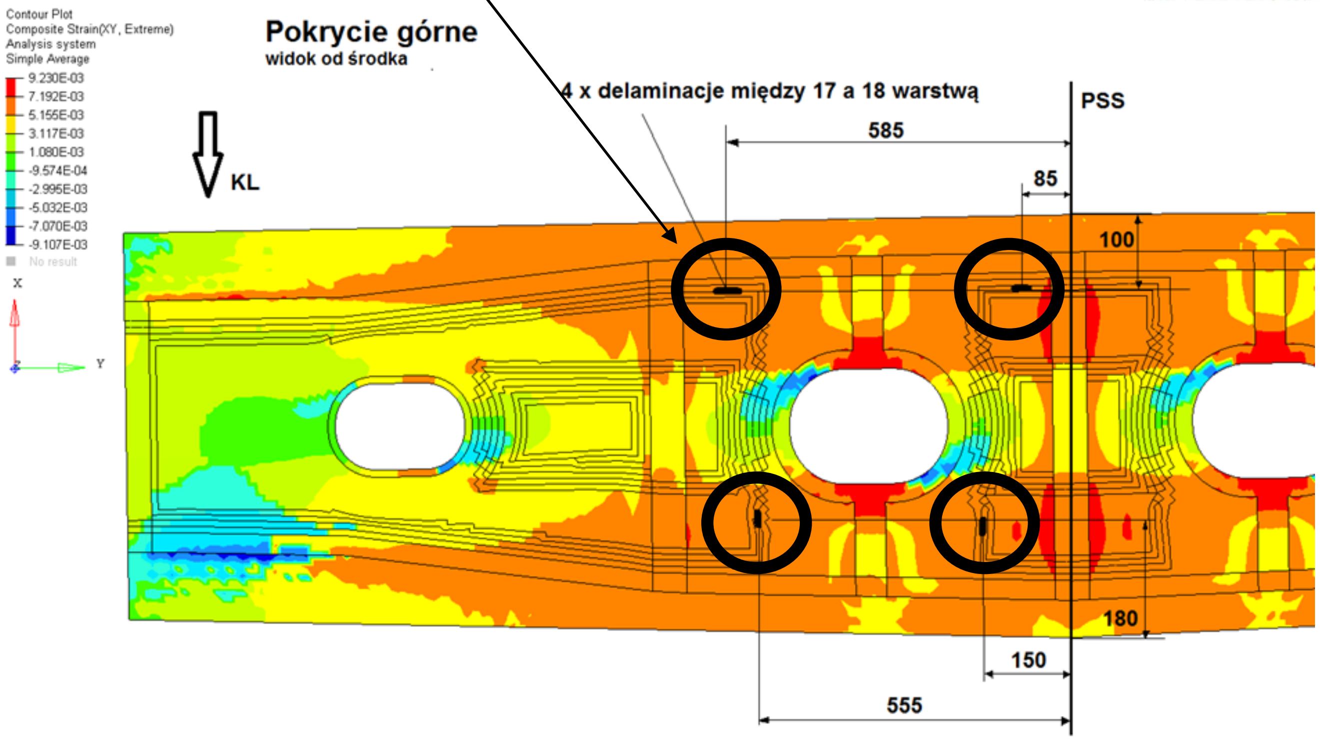
Manufacturing Defects

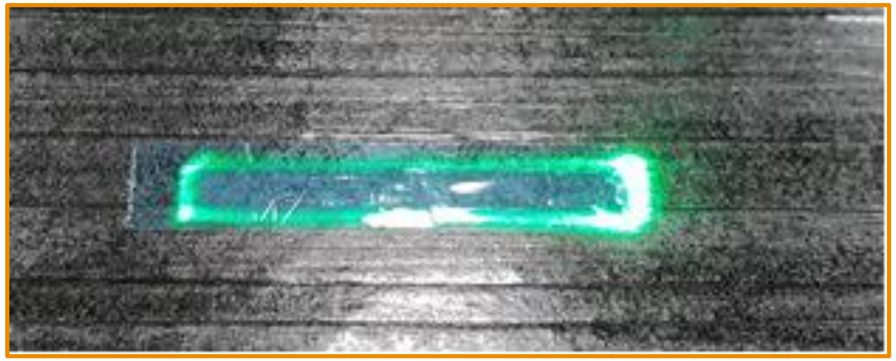
Defects:

- **Porosity**
- **Intended delamination (5 x 30 mm)**
  - 4 locations @ upper skin
  - 4 locations @ lower skin



Porosity defects on C-Spars





Teflon tape to simulate delamination

Damage threat assessment

CAT1 and CAT2 damage

CAT1 damage:

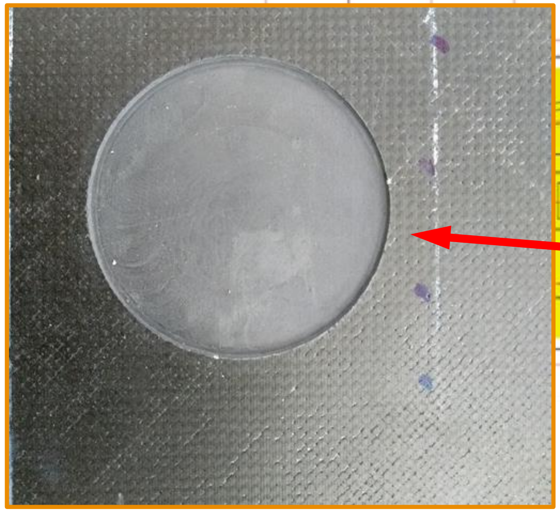
- Upper skin : Toolbox drop – Ek = 135J, impactor diam 1”
- Lower skin : Runway debris impact – Ek = 82J, impactor diam 1.5”

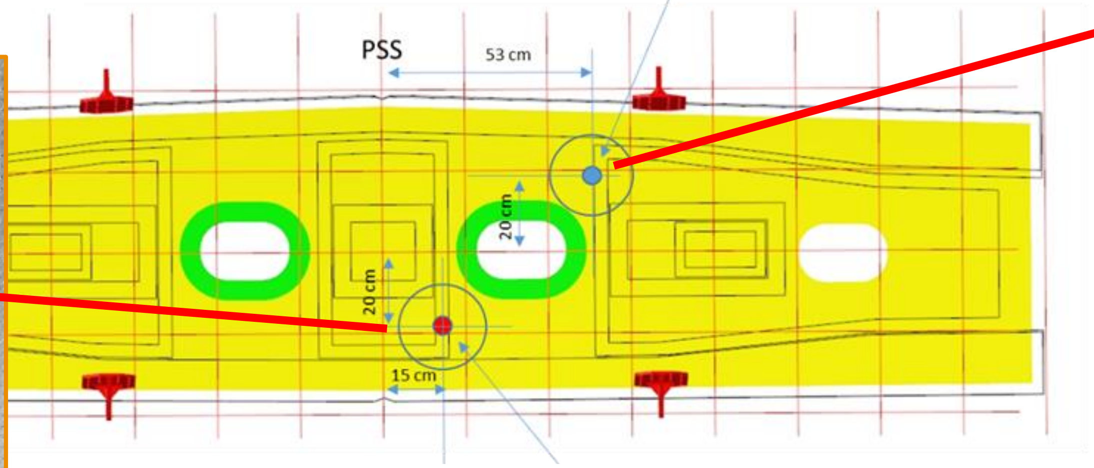
CAT2 damage

- locally removed 25% of the skin - machined pocket

KL Upper skin

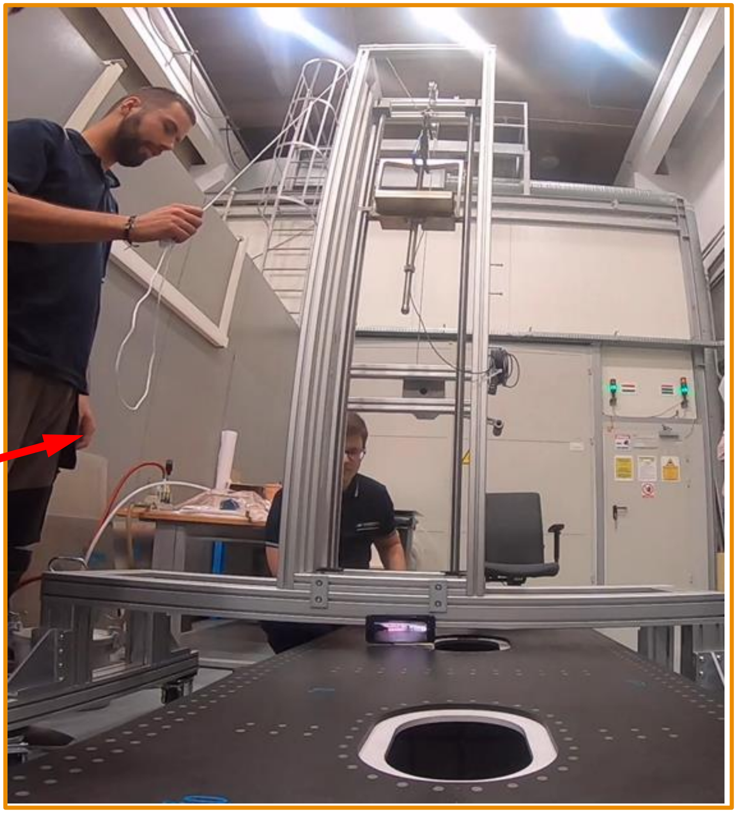
CAT1, Ek = 135J, diam 1”





CAT2, diam = 76,5mm (3”)
/ 1,75mm (0,07”) depth

nm



Gravity Assisted Drop Tower

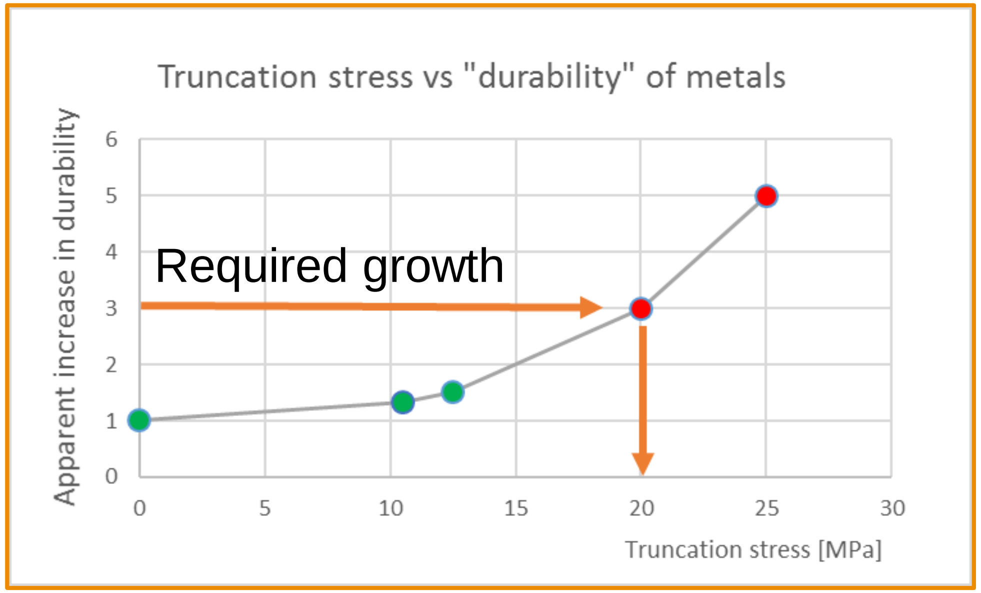
Fatigue loads definition

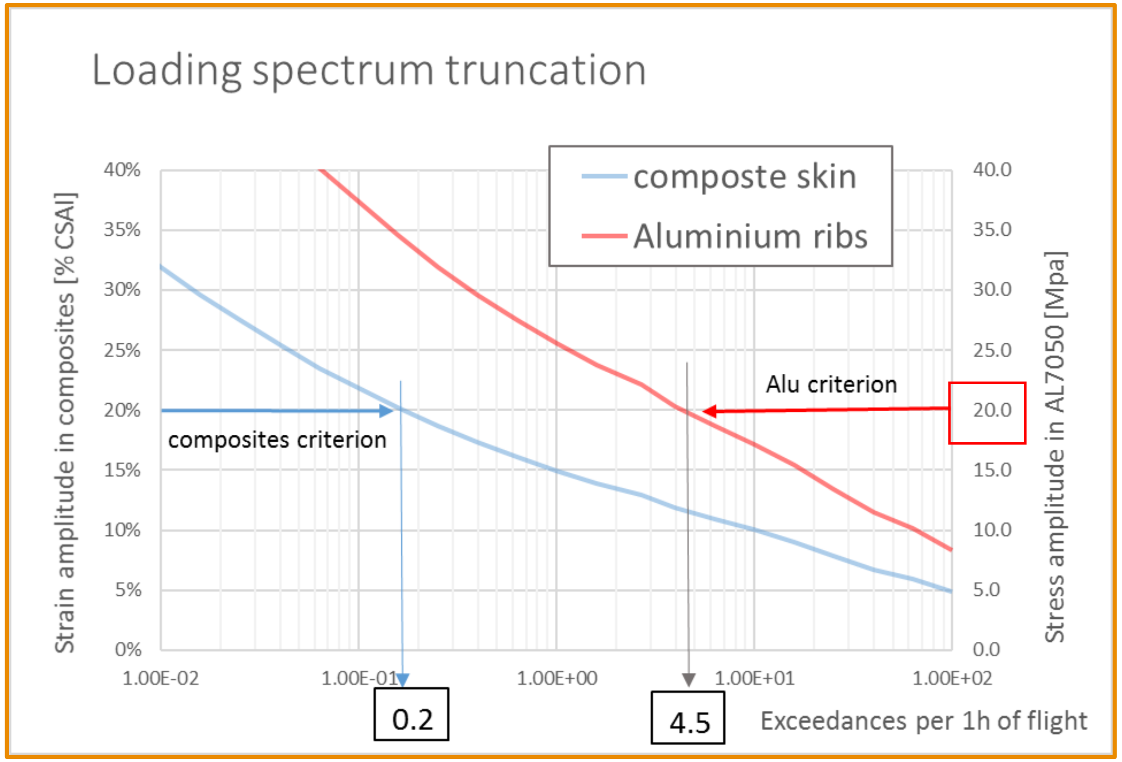
Wing demonstrator is a Hybrid structure (metal and composite materials)

Fatigue test duration due to material scatter
- metal elements 3 x DLT
- composite elements 13 x DLT (NAVY LEF data)

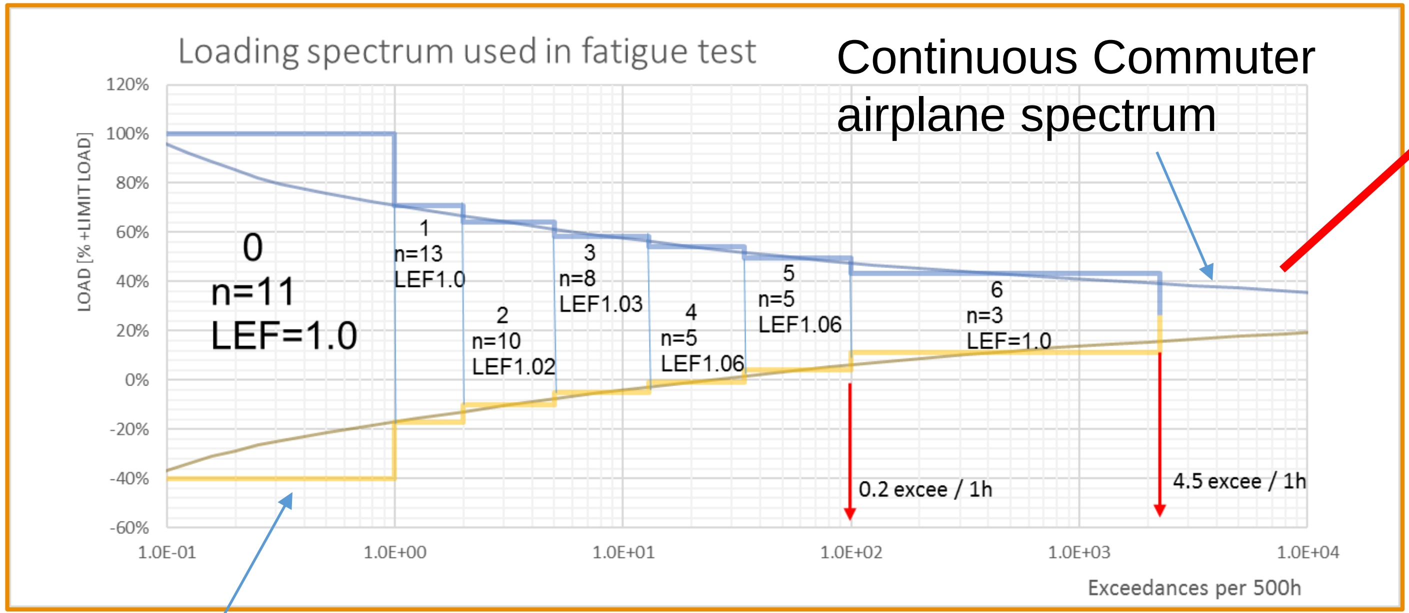
Major task : How to increase metal's life by 3 times?
Solution : Loading spectrum truncation level method.

Old masters:
„Omission of any higher stress range affects the fatigue crack propagation significantly."

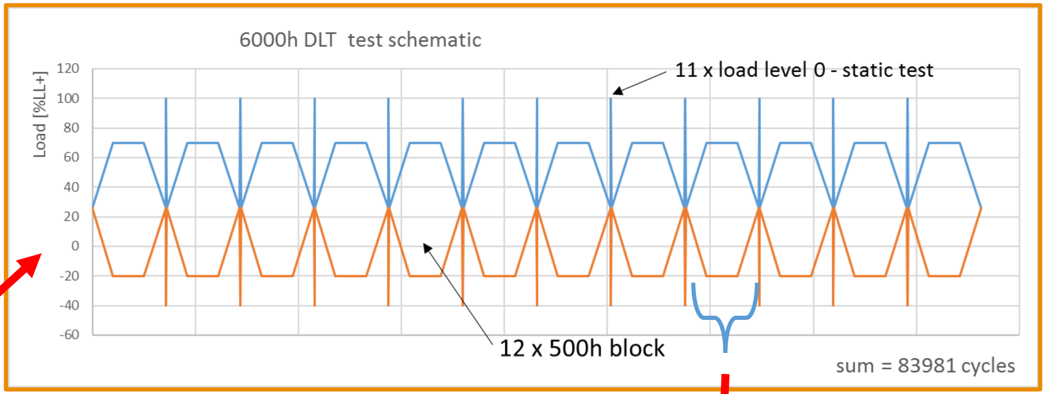


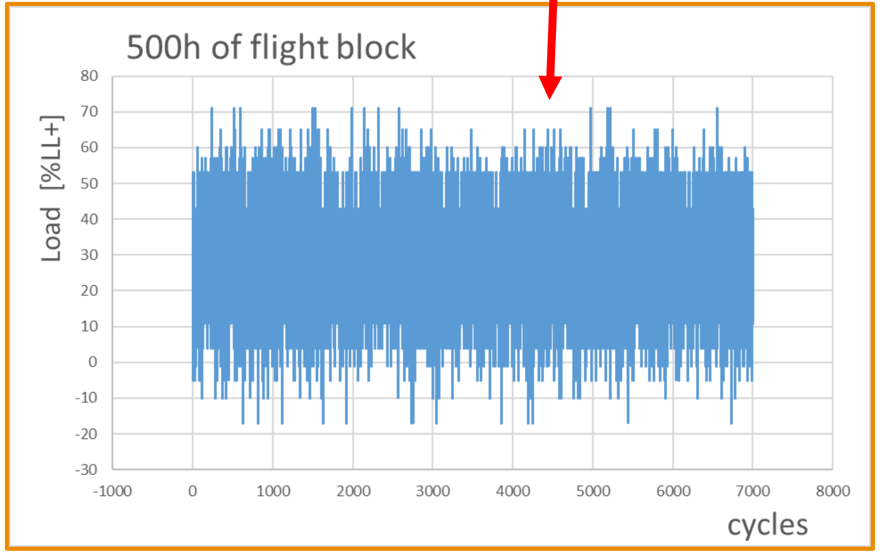


Loading spectrum



7 levels discrete spectrum





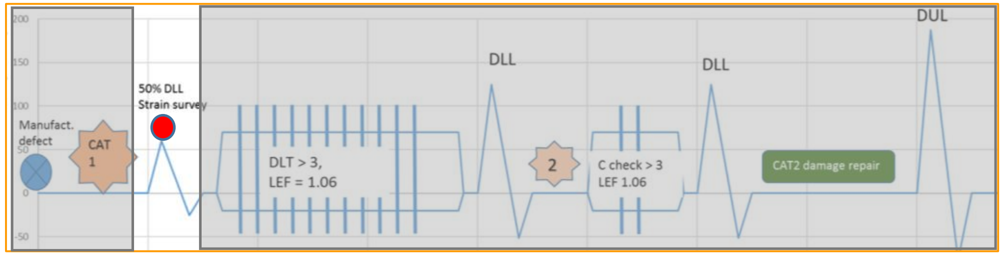
Random distribution of cycles

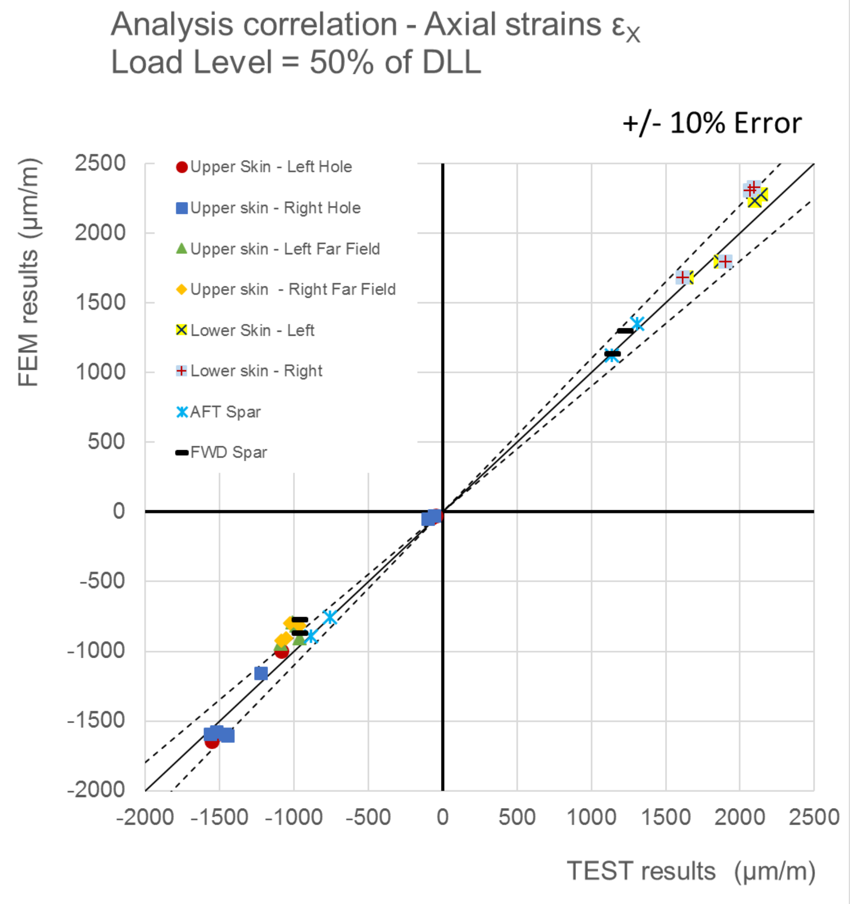
Multi LEF approach : each load level driven by different n and LEF

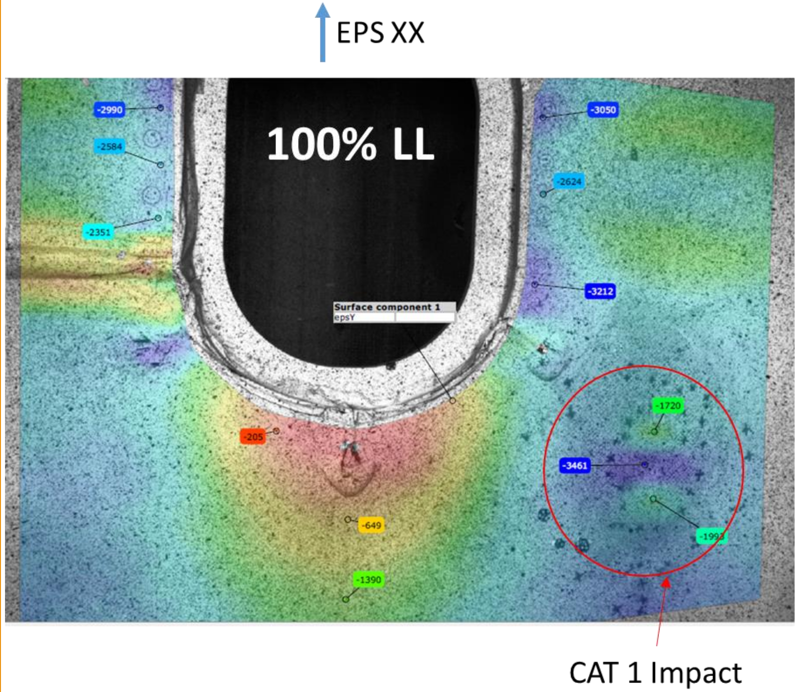
Stress surveys – 50% and 100% of LL

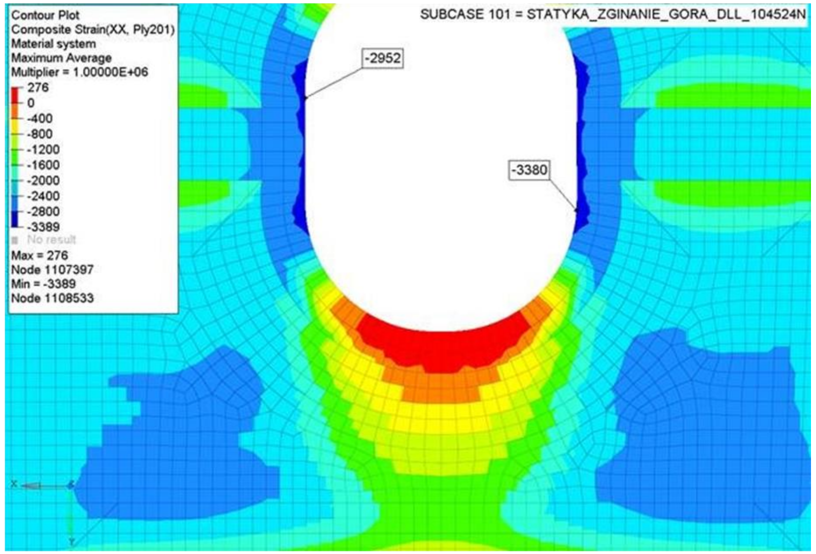
Instrumentation:

- 150 strain gauges
- 4 deflection meters
- Digital Image Correlation



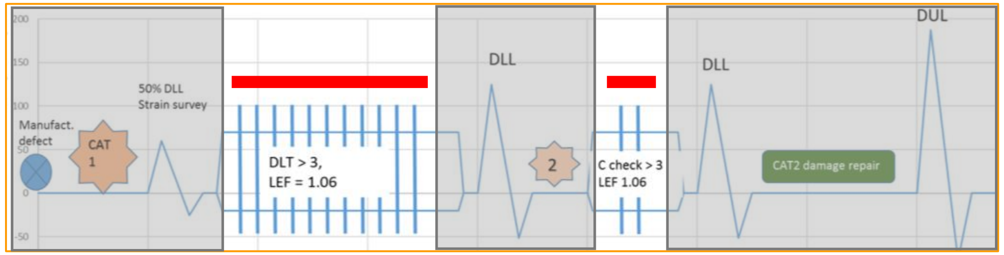


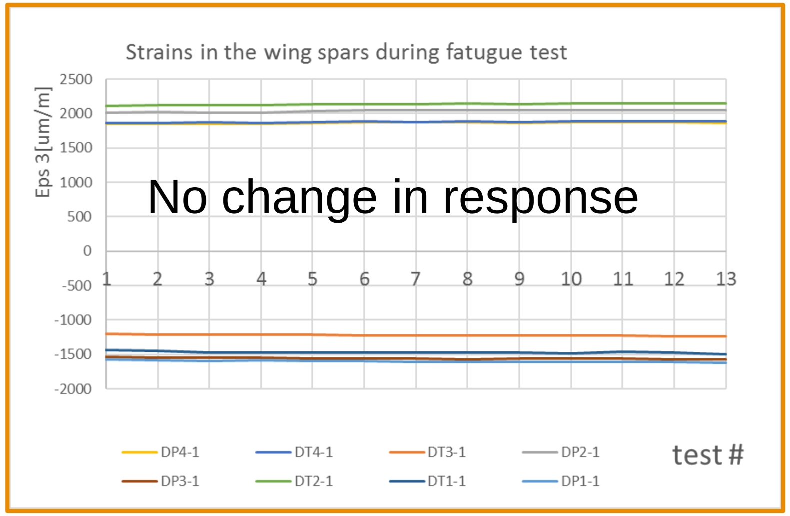


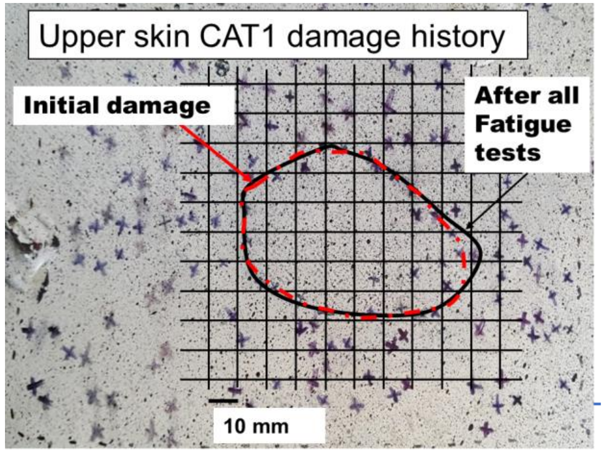


- **Good Stress and deformation predictions**
- **Different stress distribution @ impact area**

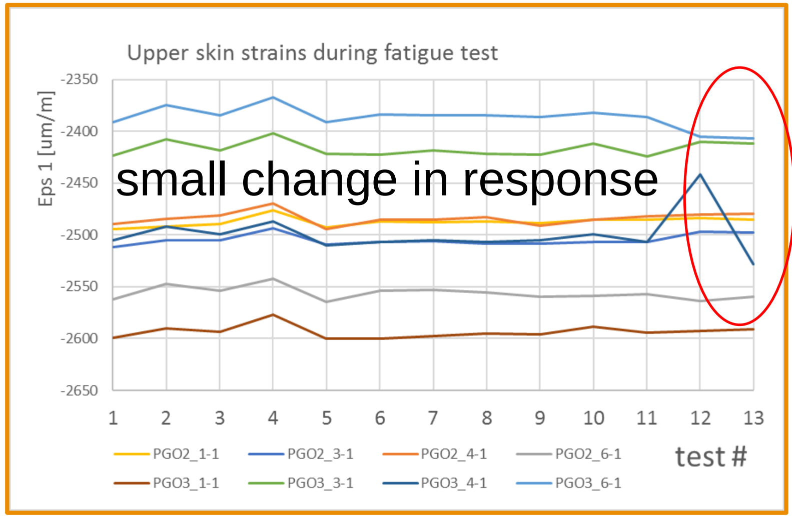
Fatigue test runs



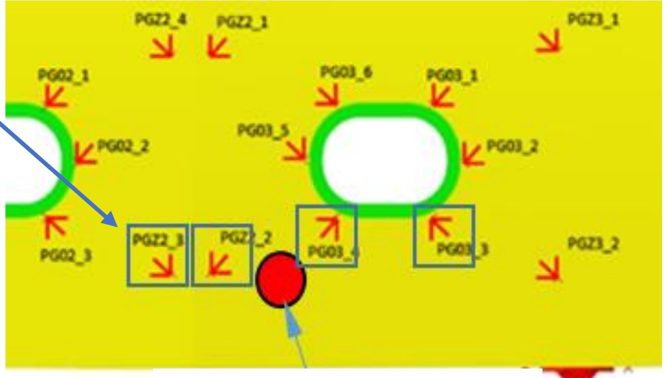




- **None of the damages showed propagation**
- **All damages are local – no global load redistribution**



Very limited number of strain gauges records CAT2 damage



CAT2 Damage

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100%DLL of Static tests

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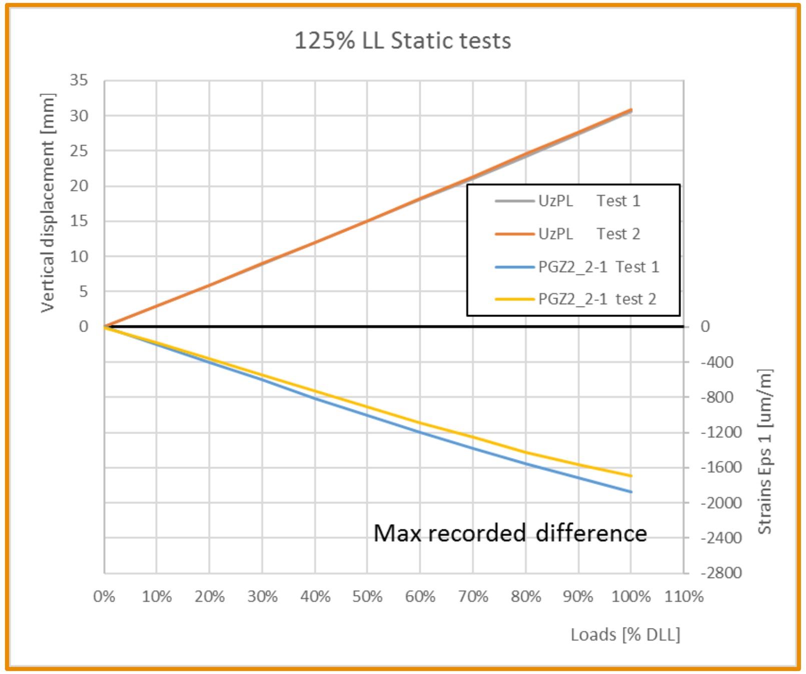
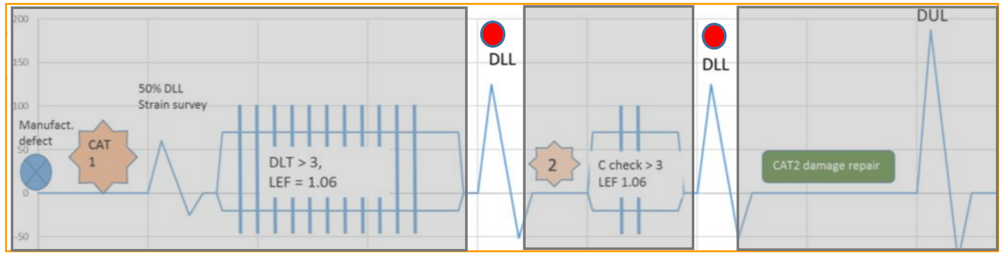
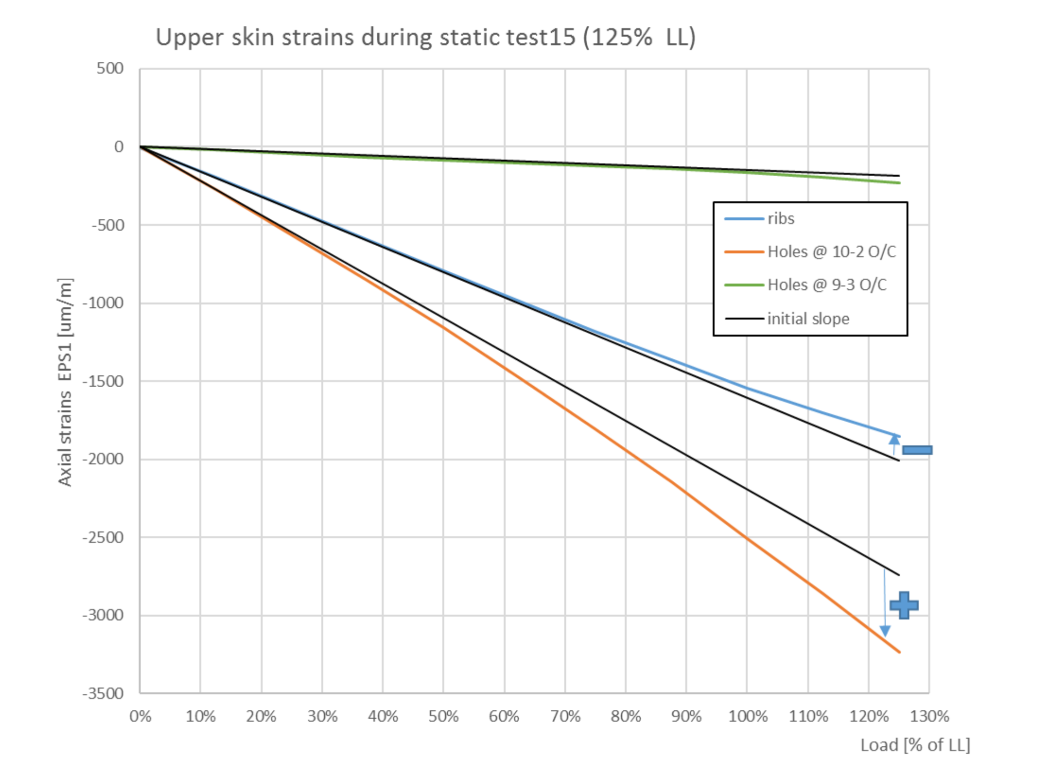
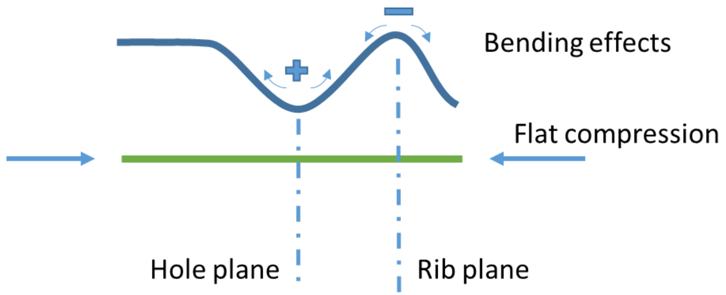


- **No difference between Test 1 and 2** (before and after CAT2 damage)
- **CAT2 damage shows no progress**





Upper skin shows NL behavior due to skin double curvature



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warsaw, since 1926

150%DLL of Static test

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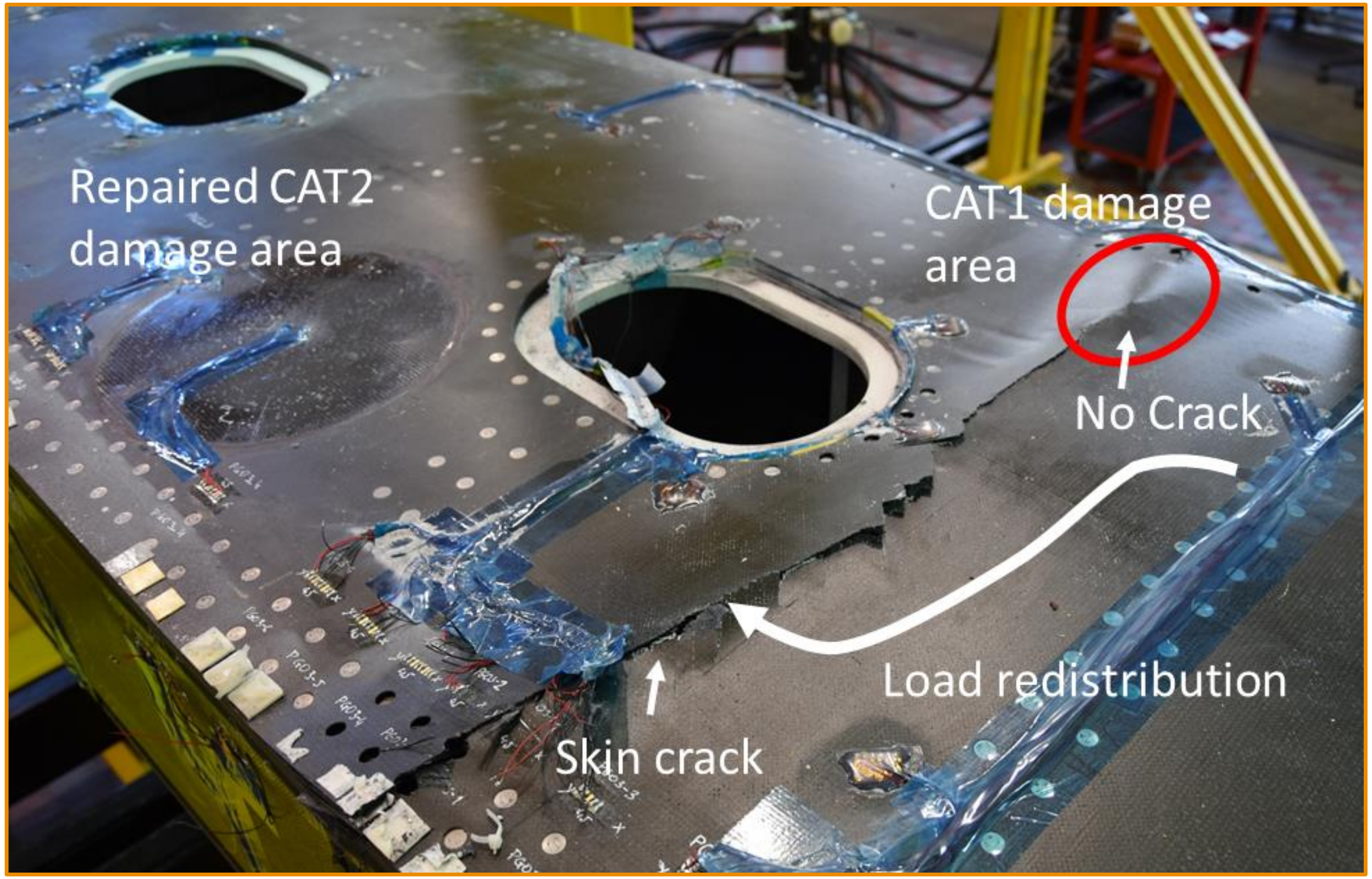
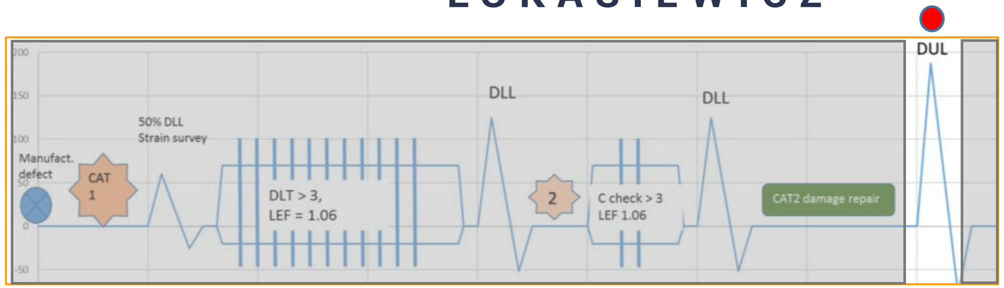
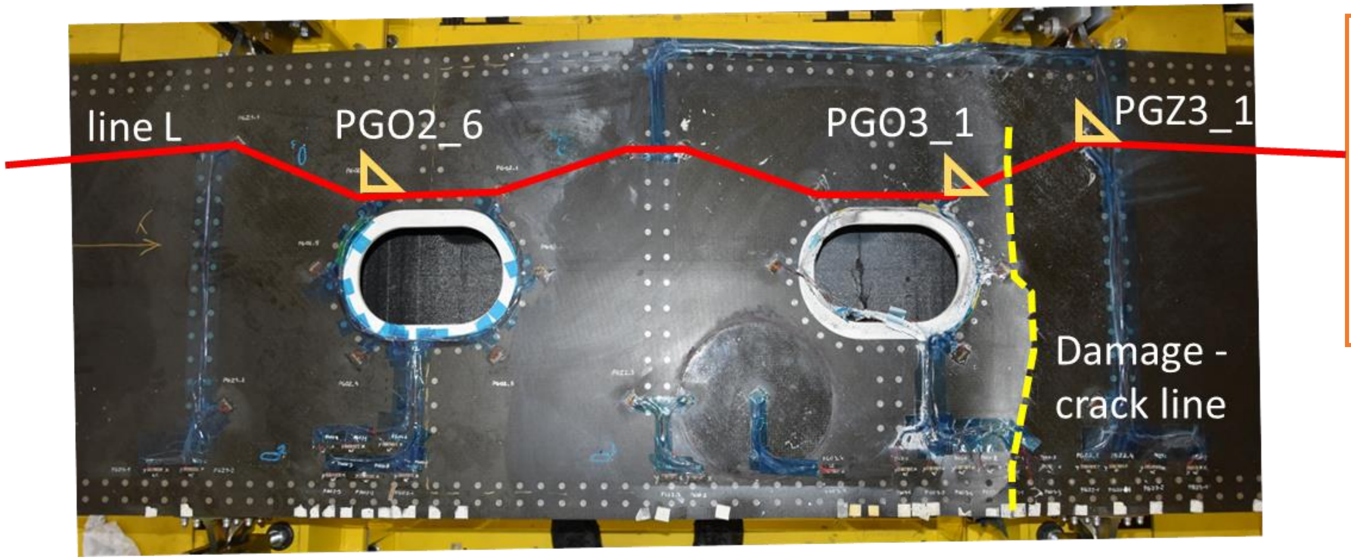




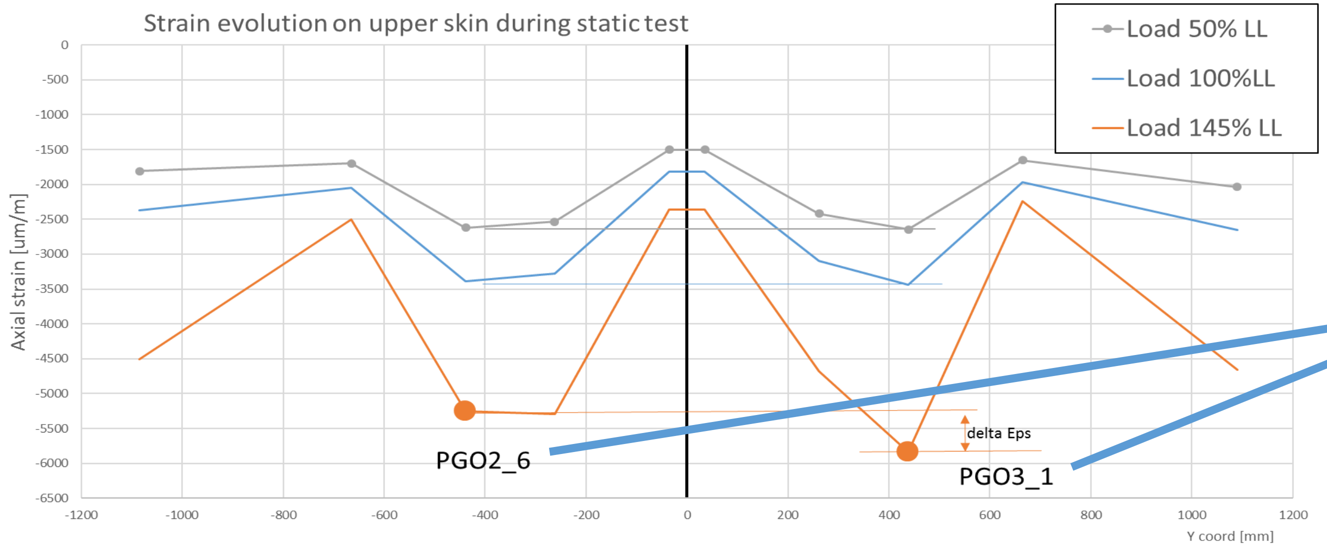
- **Structure failed @ 145% of DLL due to upper skin buckling initiated by Cat. 1 damage.**
- **Repaired Cat. 2 untouched**

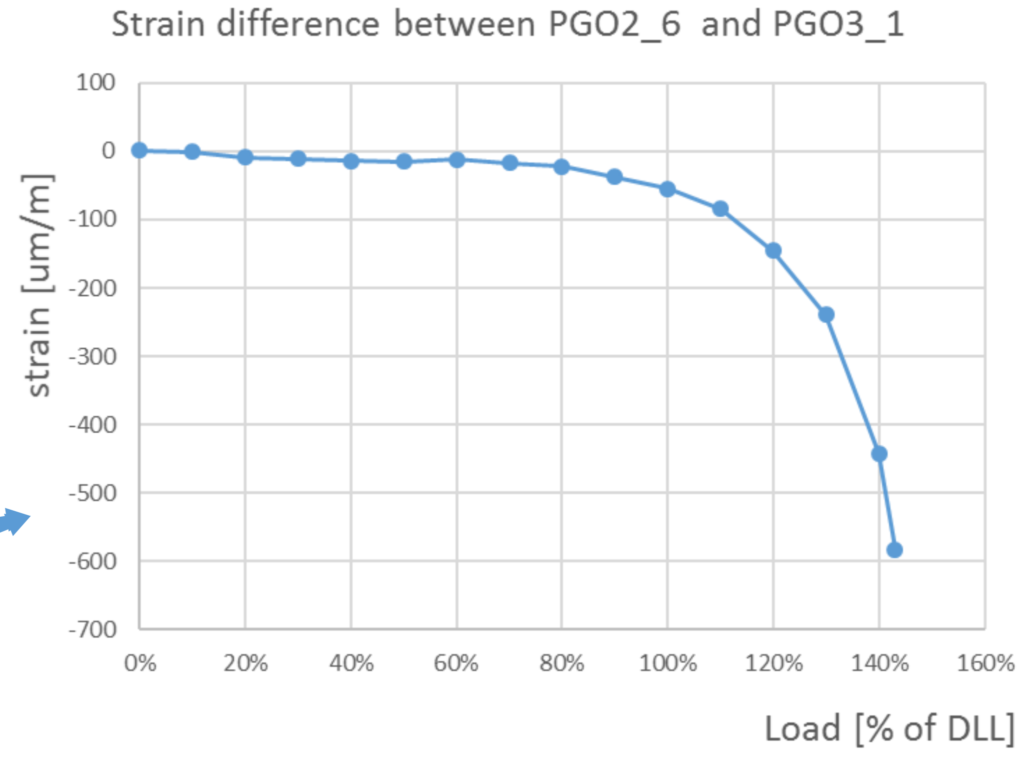
150%DLL of Static test



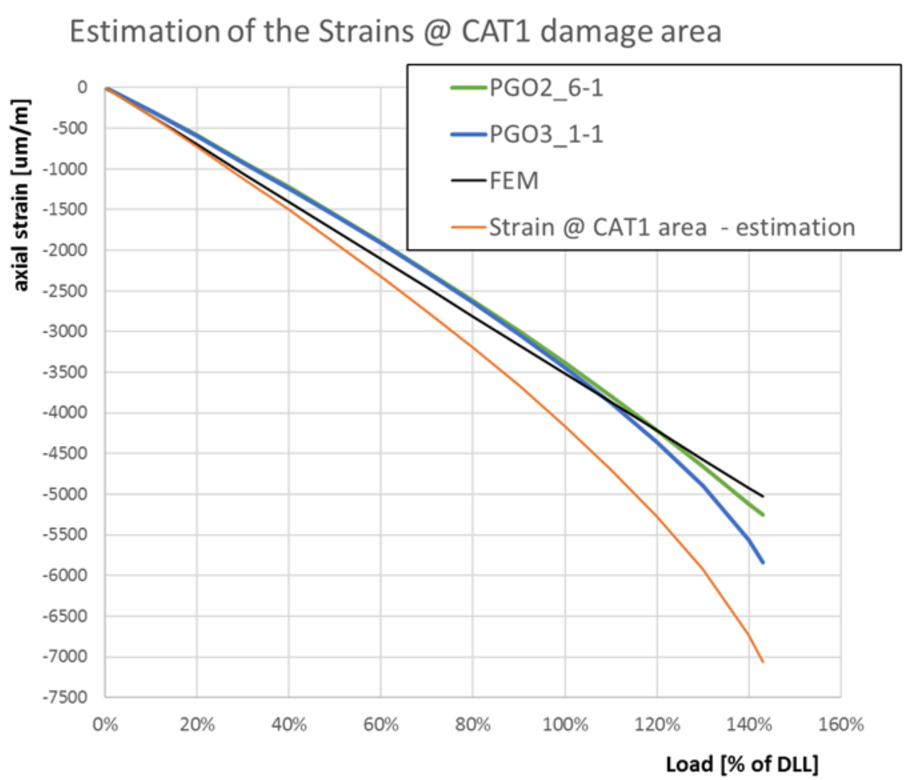
- Crossing 80% of loads, right side of the skin shows higher strains.
- Differences are Non Linear in the nature

Conclusion : Buckling of the right side





Conclusions – discussion



Design values – discussion

- **CSAI recorded during test ε_{1C} = -7000 µm/m**
- **Material tests on coupon level (QI layup thkc 2.9 mm) indicated RTA average properties:**
  - **Pristine material: ε_{1C} = -11330 µm/m**
  - **OHC: ε_{1C} = -5857 µm/m**

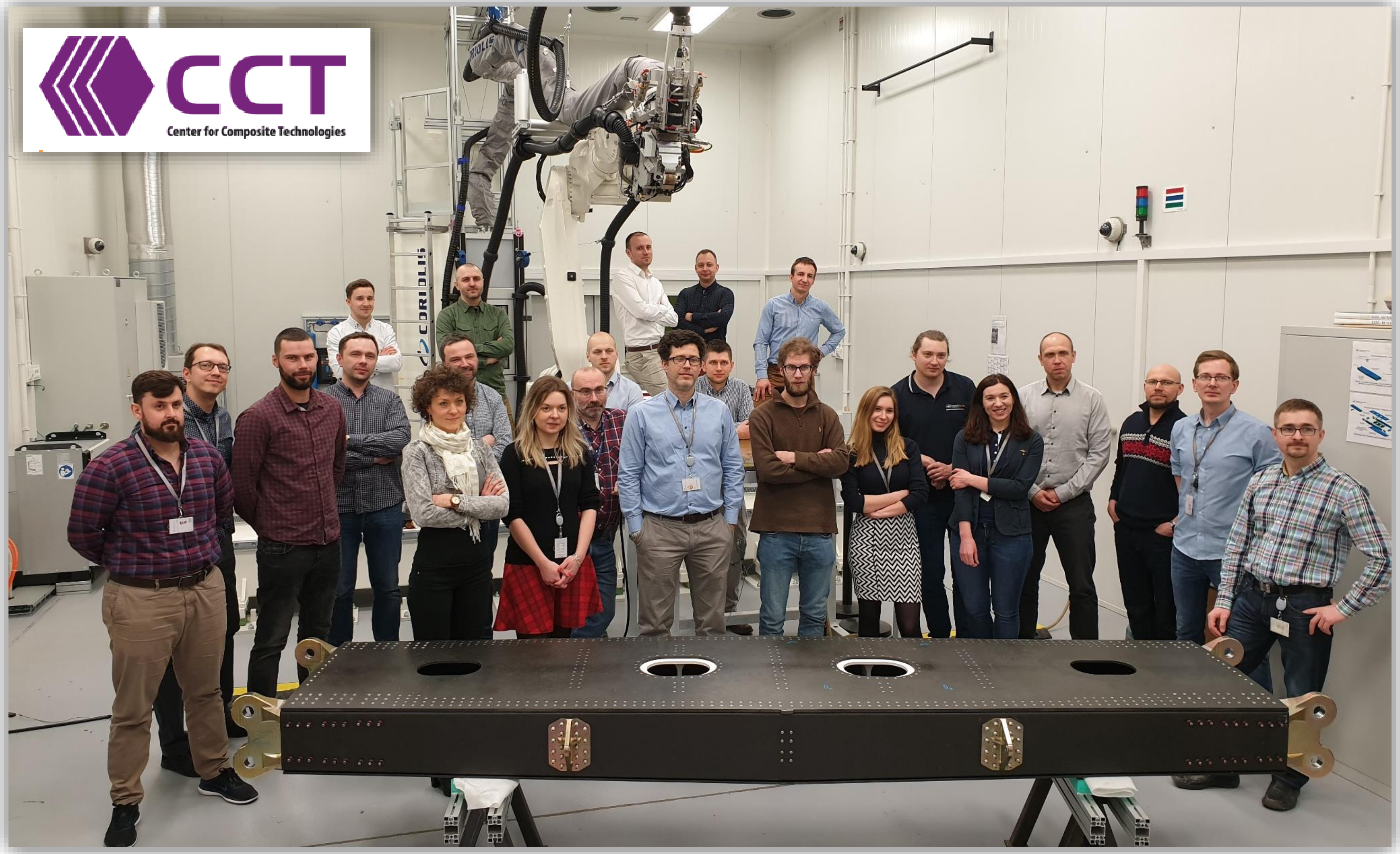
Conclusions – Action Items

- For thick laminates Design Values can be increased.
- Stiffness of the material (E modulus) should be reduced to account impact damage.
- Analysis should be done including NL solver to account large deflection effects.

Summary

- Combination of AFP+OoA is cost effective technology for ILX-34 9-seater Aircraft.
- Implemented OHC industry standard resulted in oversized structure, BVID could be a better approach.
- Strain surveys confirmed good quality of FEM model, non-linear analysis could show better failure predictions.
- Reliable quality control process (based on correlation of Ultrasonic scan and CT) implemented which identifies and quantifies the level of porosity.
- Hard patch bonded repair sustained all static tests with no sign of failure.
- Introduced method of testing hybrid structure allowed to successfully run fatigue tests without metallic parts failure.

CCT IPT



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Questions?