Joining Sub-Platform

Industrial Challenges in Joining

FoF.2015.12: Industrial technologies for advanced joining and assembly processes of multi-materials

ComMUnion PROJECT (GA680567)

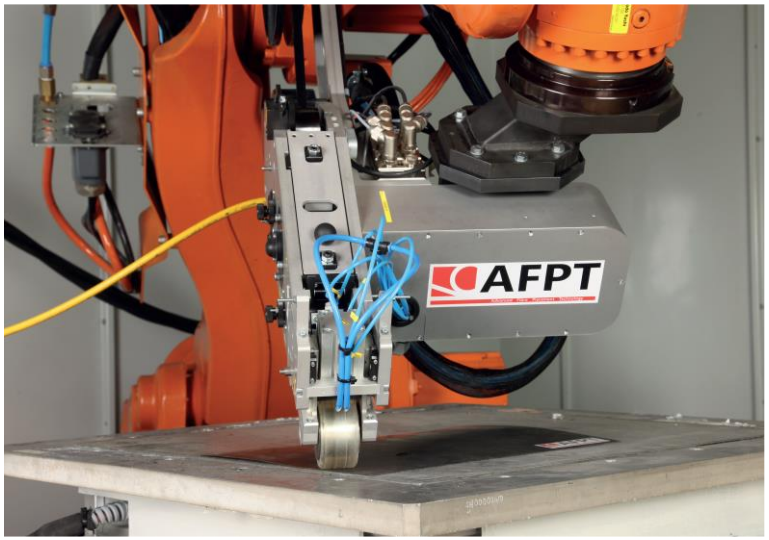
Dr. Pilar Rey Rodriguez

16th November 2017

NET-SHAPE JOINING TECHNOLOGY TO MANUFACTURE 3D MULTI-MATERIALS COMPONENTS BASED ON METAL ALLOYS AND THERMOPLASTIC COMPOSITES

ComMUnion addresses *Industrial technologies for advanced joining and assembly processes for multi-materials*

- Aims to enable the **productive** & **cost effective manufacturing** of multi-material components.
- Thermoplastic tapes + Metallic counterpart (i.e. Steel and Titanium)
- Comprises the development of a novel ***fully automated*** and ***flexible system*** able to perform successfully the **dissimilar joint**.

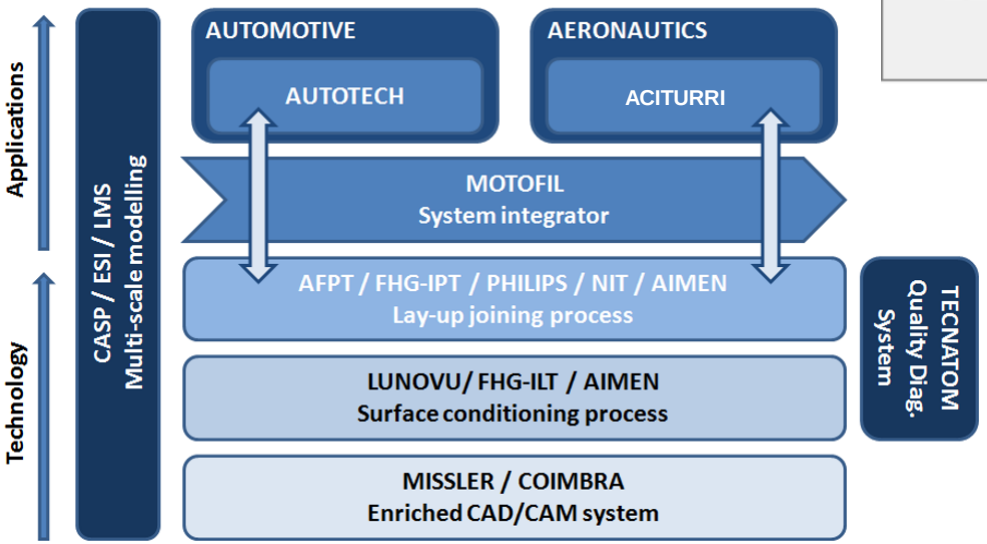


Proof of concept under **different scenarios**; study cases from different industries

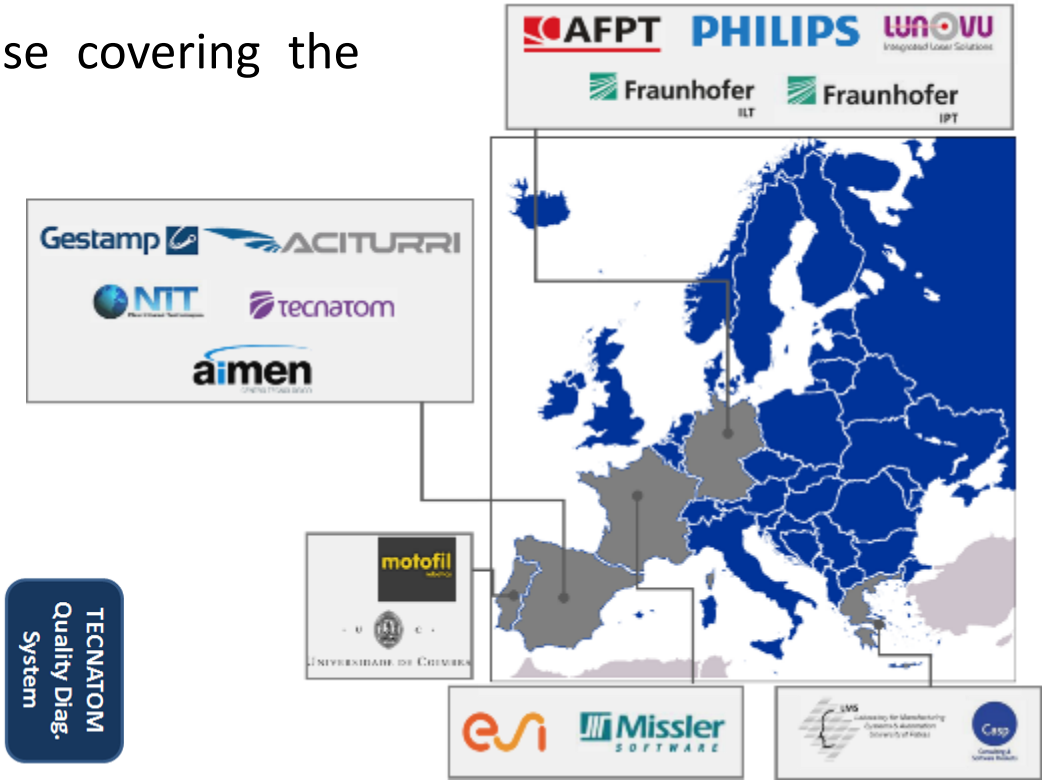
Preserve EU leadership in the most advanced State- of- the- Art production technologies for composites

ComMunion CONSORTIUM

- 15 partners from 5 different EU countries
- Key and complementary expertise covering the value chain



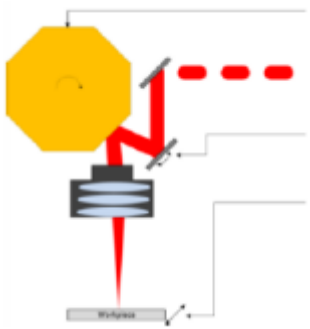
Role of each partner within the value chain targeted by ComMUnion

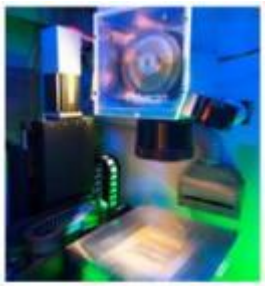


The approach & Current developments

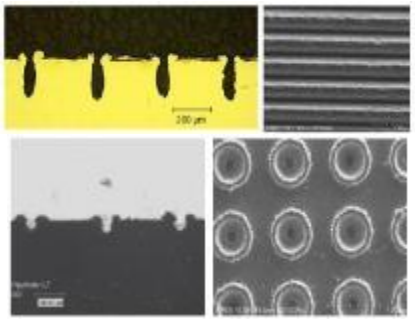
LASER TEXTURING & CLEANING OF SURFACES

- Elimination of undesired substances
- Creation of controlled structures on the metal surface for the anchorage of the TPCs.





Polygon scan laser
(SOURCE: FHG-ILT)



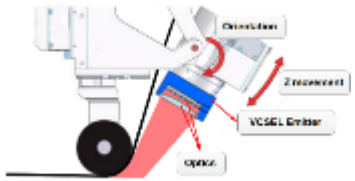
Texturized surfaces details
(SOURCE: FHG-ILT & AIMEN)

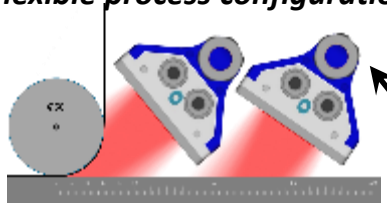
IMPROVED WETTABILITY
CONTACT AREA OPTIMIZATION

LASER ASSISTED SYSTEM FOR METAL-COMPOSITE JOINING OF COMPLEX SHAPES



Flexible process configurations



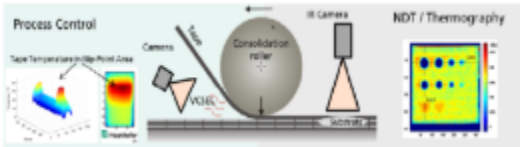


Tape angle 90°
VCSEL angle 40° / 56°

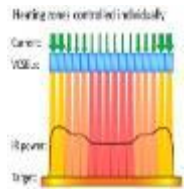
VCSEL heating system
(SOURCE: Philips)



Automatic tape laying
(SOURCE: FHG-IPT & AFPT)



Process control
(SOURCE: FHG-IPT & AIMEN)



Adjustable heating profile
(SOURCE: Philips)

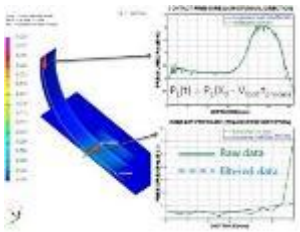
ACCURATE CONTROL OF HEATING DISTRIBUTION
ADJUSTMENT TO COMPLEX GEOMETRIES

The approach & Current developments

END- TO- END ENGINEERING

DECISION SUPPORT SYSTEM (DSS)

DESIGN AND MULTI-SCALE SIMULATION



SELF-ADAPTIVE SYSTEM

ENRICHED CAD/CAM
- geometry information
- laminate information
- process parameters



CAD/CAM robot planning system applied to tape-laying
(SOURCE: http://www.fibrechain.eu/publication/index.jsp)

REDUCED LEAD TIMES IN NEW PRODUCT DESIGN
OPTIMIZING THE SET-UP CONFIGURATION PROCESS

QUALITY DIAGNOSIS SYSTEM

DUAL STAGE NTD's
QUALITY DIAGNOSIS SYSTEM
- Speckle pattern technology for surface condition monitoring
- Active thermography for in-line inspection

PROCESS

KNOWLEDGE BASE SYSTEM

SELF-ADAPTIVE SYSTEM

ENRICHED CAD/CAM SYSTEM

IDENTIFICATION OF OUT OF RANGE STRUCTURES

PREVENTING DEFECTS PROPAGATION THROUGH THE DIFFERENT STAGES

EXISTING TECHNOLOGIES

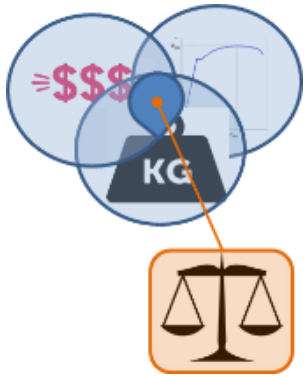
MULTI-MATERIAL COMPONENTS	• TS composites currently being used	• Introduction of TP composites within multi-material design • Faster manufacturing process & OoA (cost, bottle neck…)
DISSIMILAR JOINT	• Composite manufacturing & joint process; different fabrication stages	• One step process • Disassembly functionality
POLYGON BASED SCAN HEAD	• Galvanometric scanner; rates <10m/s • Polygon scanner prototype for ultra-fast structuring with 1 axis; rates >100m/s	• Polygon based scan head for rates >10m/s and <60m/s with second deflection axis
ENRICHED CAD/CAM	• Robot paths generated off-line; just geometric information	• Robot paths generated off-line from CAD will contain geometrical information and process parameters.
LASER-ASSISTED HEATING SYSTEM	• Diode laser up to 40-60mm • Fixed Top-hat profile.	• VCSEL up to 125mm width • Flexible heating profiles
TEMPERATURE DISTRIBUTION MEASUREMENT	• Multi-point Temperature measurement • 60 Hz temperature imaging	• Spatially resolved measurement of Temperature distribution. • 10kHz temperature imaging
CLOSED-LOOP CONTROL	• Image-based process control under 50Hz	• Image-based control at 2kHz of control rate
SURFACE MONITORING	• Optical techniques limited to laboratory • Surface roughness characterization	• On-line NDT technique based on speckle technique. • Cognitive approach for cleaning & roughness measurement
JOINT QUALITY EVALUATION	• Automated UT inspection after joining process • Algorithms for automated defect recognition	• On-line NDT technique based on IR • Automated defect recognition for a layer-by-layer correction
PROCESS DIAGNOSIS	• Commercial systems limited to OK/NOK results based on statistical thresholds	• Process diagnosis (anomaly detection) that relates measured magnitudes to process parameters and quality
USABILITY	• Process changes require manual reconfiguration	• Data interoperability in the whole joining process. • From Simulation to product approach

Multi-material approach

- Composite materials appear to be one of the most promising candidates for reaching weight reduction, durability, design freedom but the most important barrier is the COST

MATERIAL	WEIGHT REDUCTION (%)	COST
Magnesium	60-75	1.5-2.5
CFRP	50-60	2-10
Aluminium	40-60	1.3-2
Titanium	40-55	1.5-10
GFRP	25-35	1-1.5
AHSS	15-25	1-1.5
HSS	10-15	1

BASIC PRINCIPLE: Combination of materials of different nature in a single structure, so that it has the ***optimum material for each purpose*** *allowing, ultimately, a higher performance/cost ratio than a bulk material leading to a* ***more efficient resources use****.*



But…. Dissimilar Composite-Metallic Joint is CRITICAL!!

Key points and barriers on multi-material joints

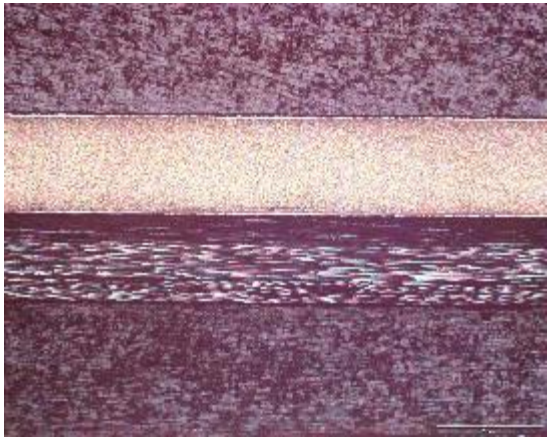
Quality control: large dispersión in results trough the manufacturing chain

SURFACE

Training: lack of specific skills

Is it a Problem?

Direct Dissimilar Joints



ADHEREND MATERIALS

APPLICATION

Nomenclature: misunderstanding in naming these joints: types of failure, type of "join"

Standarization: lack of tests, DT & NDT, dealing with these type of joints

MANUFACTURING PROCESSESES

S&M: lack of maturity on multi-scale and multi-material

DESIGN

OR…Is it a Challenge?

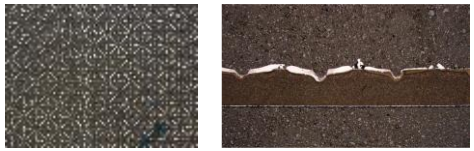
Multi-material approach in ComMunion related with JOINTS

1) Laser texturing

- Two line of works;

  1) High productivity rates

  2) Medium-low productivity rates





- Relation between the surface parameters and the joint mechanical performance
- Better behaviour with the higher productivity

2) Joint manufacturing

- MANUFACTURING; Initial trials with hot-press; then AFP will be used
- SYSTEM UNDER STUDY;

1) Metallic counterpart (Usibor/Ultraform/Titanium)**; 2) Composite** (CF-PA66, CF-PEEK); **3) Adhesive joint** (Adhesive (i.e. Epoxi), Direct joint)

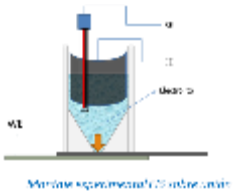




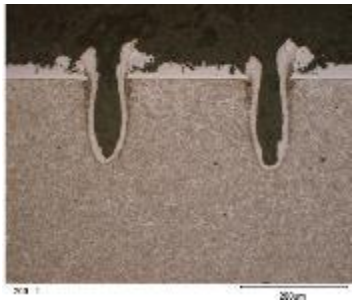
3) Joint characterization

- Mechanical: SLJ, DCB
- Durability, corrosion

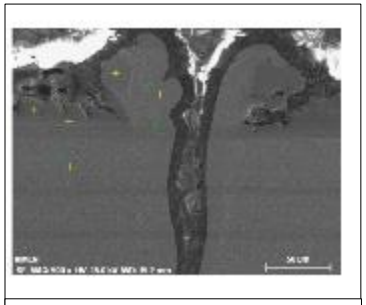




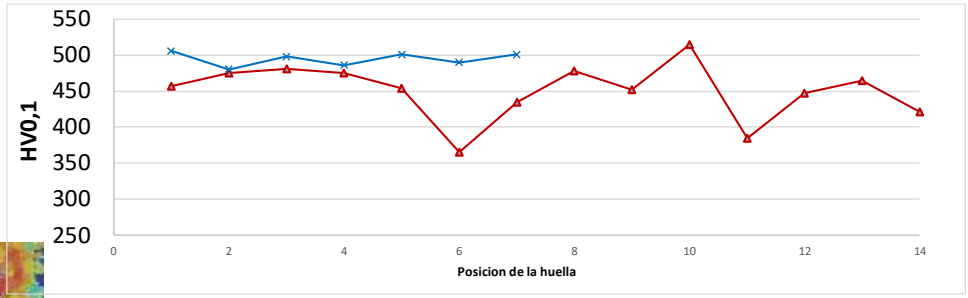
Joint Characterisation: Surface analysis

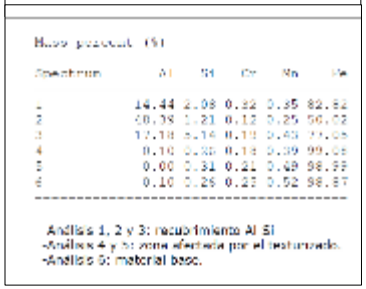


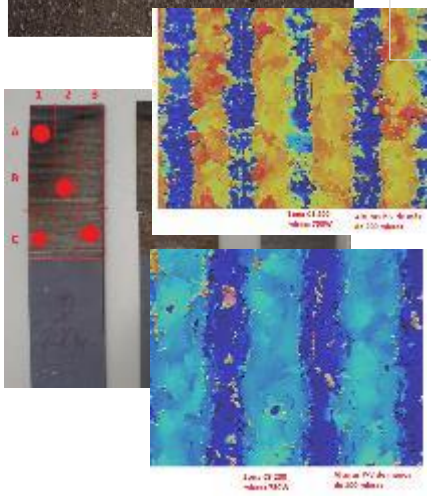
- Metallic coatings or oxides
- Microhardness
- Roughness parameters
- Chemical analysis

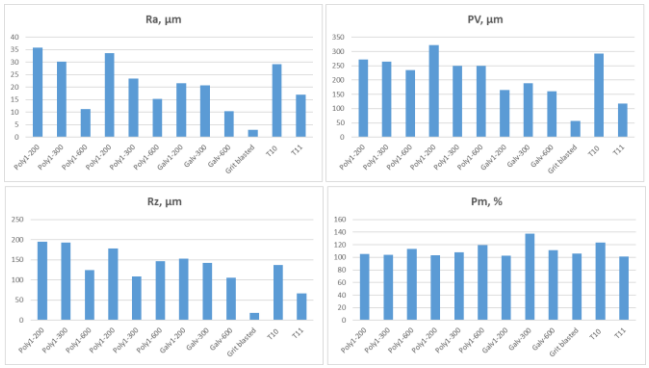


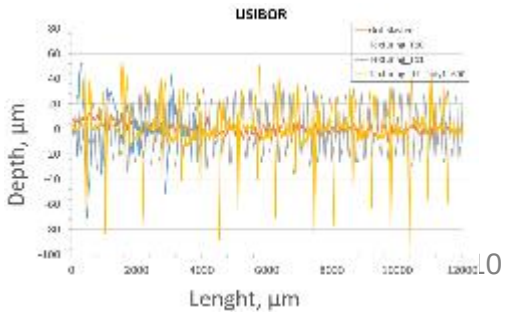






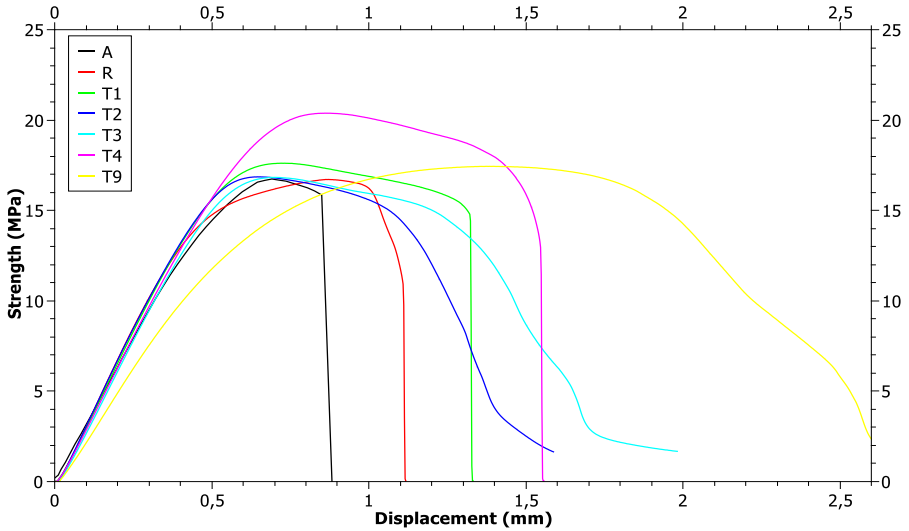


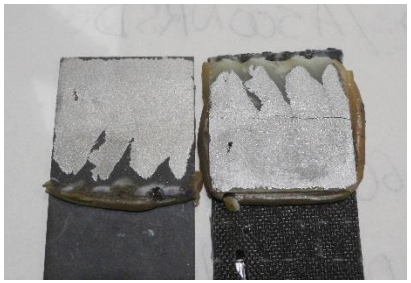


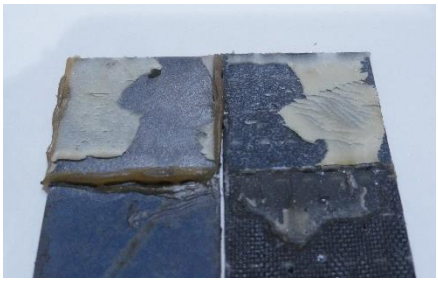


Joint Characterisation: Effect of the texturing and Joint manufacturing

Adhesive joint: USIBOR/AlSi+ Epoxy adhesive+Composite (CF-Epoxy): **CHEMICAL INTERACTION**

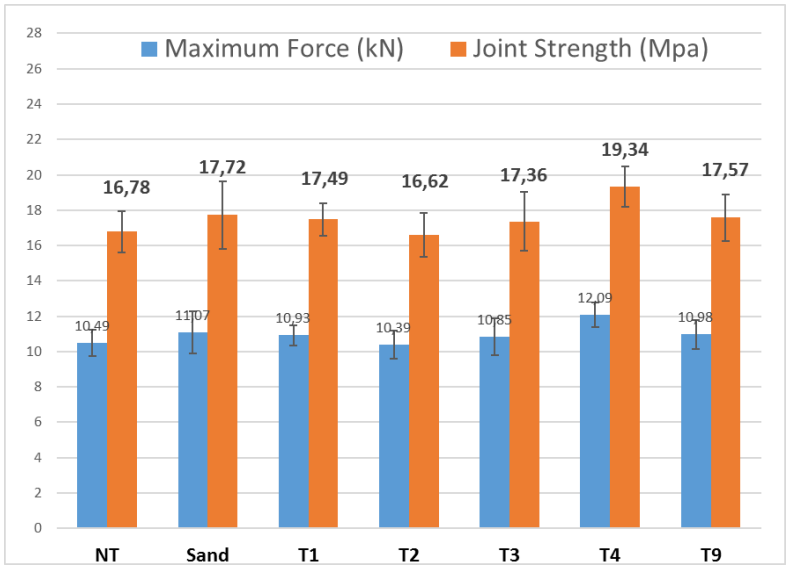


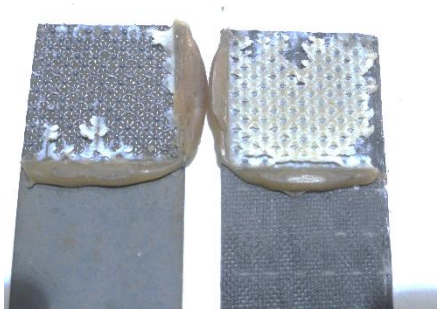




NT: coating substrate failure

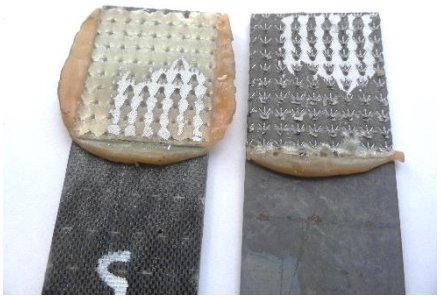
S: adhesive failure





T2: CSF (15%)+ Adhesive failure (85%)

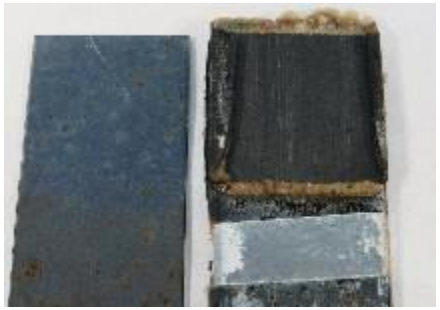
T4: CSF (45%)+ Adhesive failure (55%)



Joint Characterisation: Effect of the texturing and Joint manufacturing

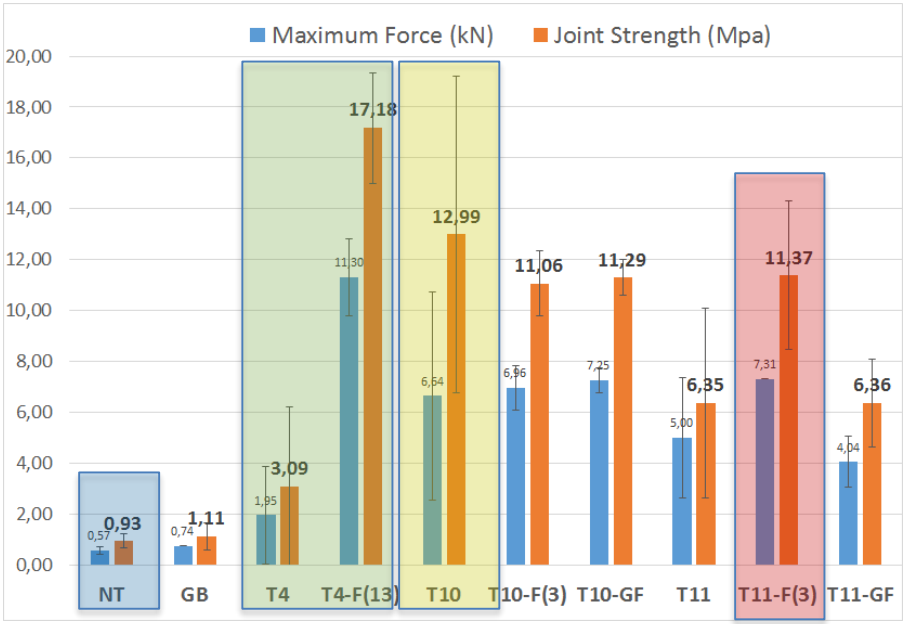
Direct joint: USIBOR/AlSi+ CF-PA66:
Micro MECHANICAL INTERLOCKING





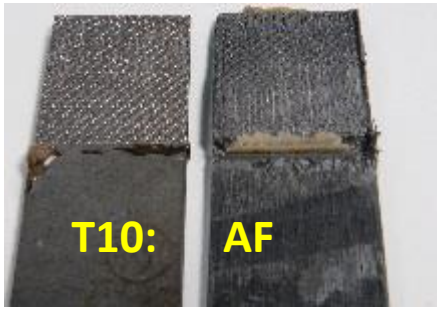
NT: AF

T4: AF





T4F: SCF



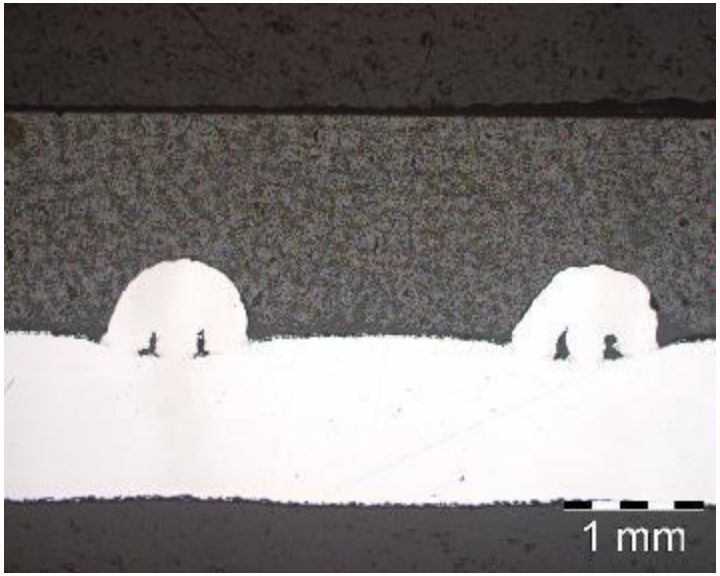
T10: AF

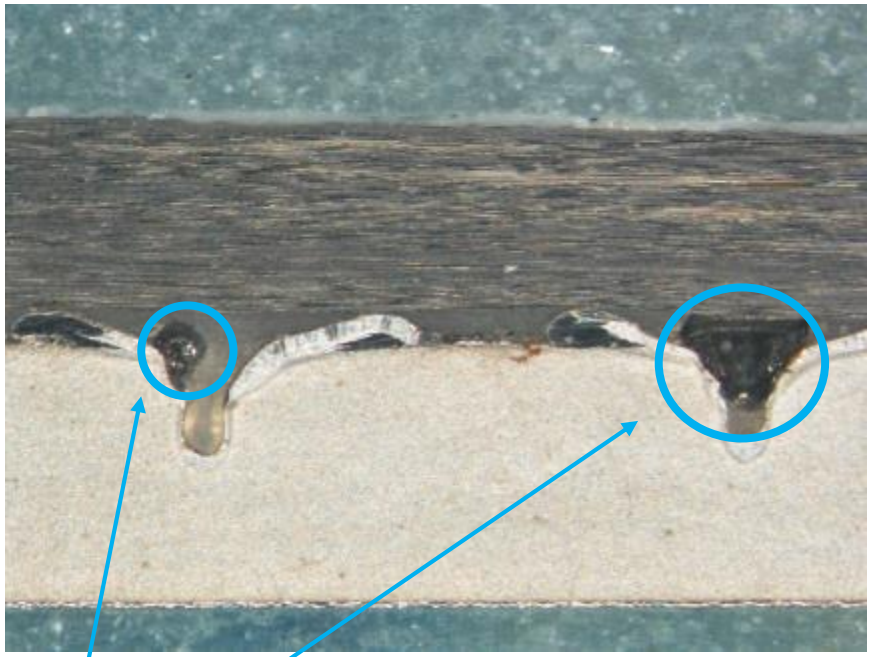


T11-3F: CF

Joint Characterisation: Microstructural analysis





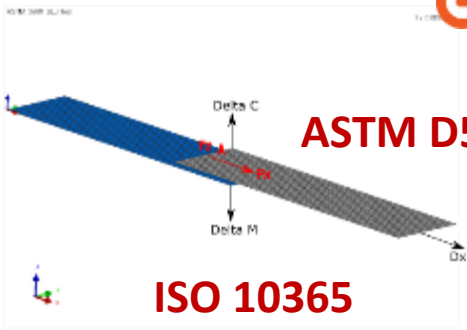


Voids



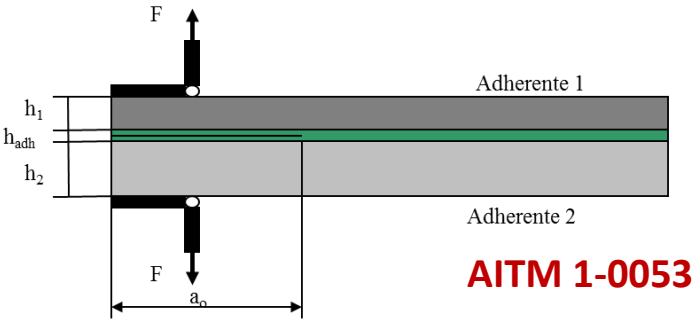
Mechanical tests optimization: SLJ and DCB

METAL	COMPOSITE	OVERLAP OUT OF PLANE DISPLACEMENT AT THE OVERLAP END OF THE TWO MATERIALS				INTERFACE FORCE		
Thickness / mm	Thickness / mm	Delta M / mm	Delta C / mm	Delta Diff / mm	Delta Total / mm	TIED Fx / kN	TIED Fz / kN	Fz/Fx
1	1,4	-0,415	0,25	0,165	0,665	-7,864	-0,207	0,026322482
1	1,6	-0,278	0,328	0,05	0,606	-8,75	-0,23	0,026285714
1	1,8	-0,18	0,389	0,209	0,569	-9,517	-0,249	0,026163707
1	2	-0,109	0,437	0,328	0,546	-10,185	-0,264	0,025920471



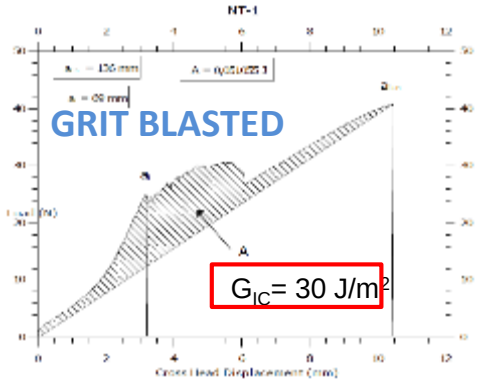
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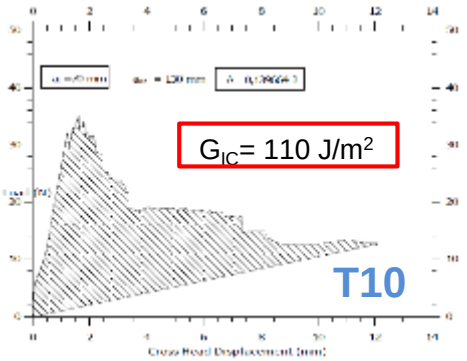
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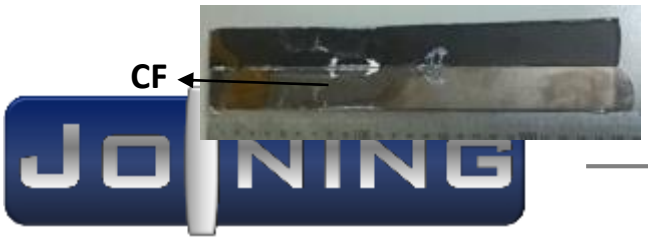


AITM 1-0053





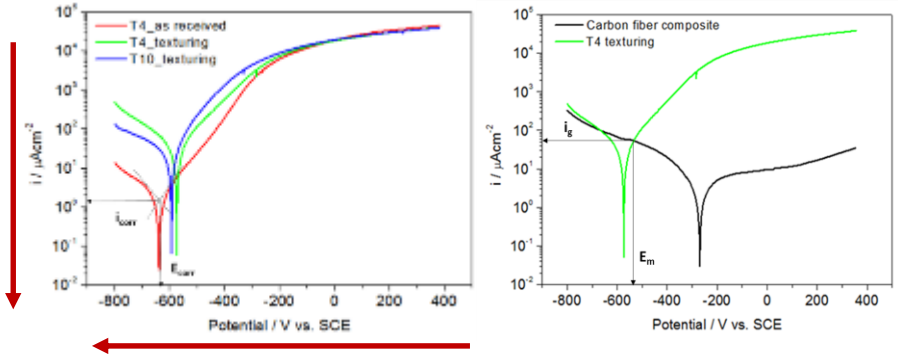






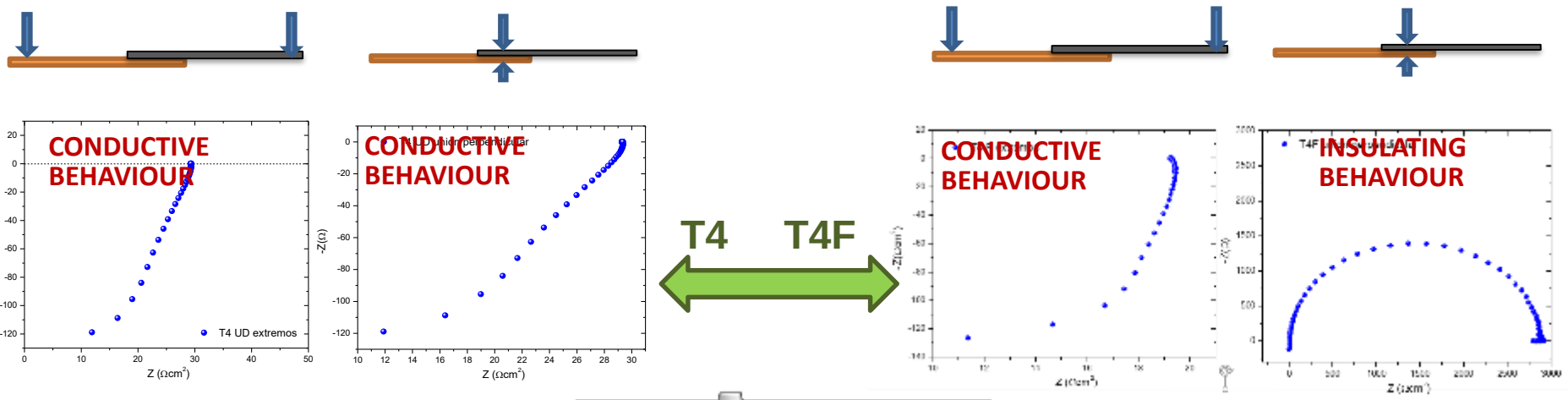
Joint Characterisation: corrosion analysis

- **GALVANIC COUPLING CHARACTERIZATION**: effect of the textures



Material	E_{corr} (mV)	i_{corr} (µA/cm²)
Ref.	-633.80	1.38
T4	-571.80	56.25
T10	-591.78	30.23
CF- PA66	-262.90	1.44

- **ELECTROCHEMICAL IMPEDANCY SPECTROSCOPY** (High frequency): effect of the interface & fibre directions



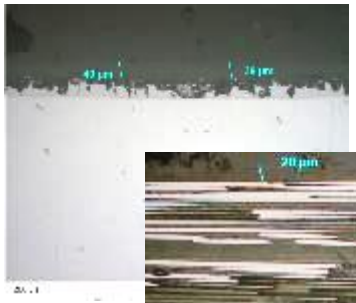
Joint Characterisation: corrosion analysis

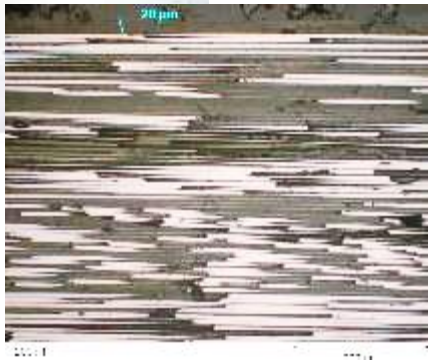
- **CATAPHORETIC PAINTING/ CATHODIC DIP PAINTING (CDP)/ E-COATING**

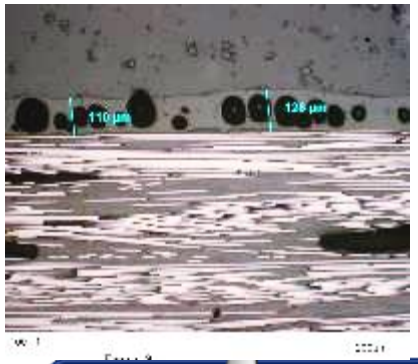
Main parameters (OEM depending)

- Bath T: 28 – 32 ºC
- t: evaluated
- Anode/Catode ratio: 1/4
- V: evaluated
- i: 2A
- Curing T; 180-200 ºC
- Curing t; 15-25 min

Material	Tª (28-32)	V, V	$t_{inmersion}$ seg	I, A	t_{curing}, min	T_{curing}, ºC	$t_{INITIAL}$, µm	t_{FINAL}, µm	t_{CATA}, µm
USIBOR	32	220	120	2	15	180	30	55	25
	32	220	240				27	56	29
	31	270	120				38	68	30
	31	270	240				38	70	32
	31	320	120				26	69	43
	31	320	240				27	67	40
JOINT	31	220	120	2	15	180	26	47	21
	31	220	240				25	45	20
	31	270	120				35	57	22
	31	270	240				34	60	26
	31	320	120				35	67	32
	31	320	240				35	69	34







Effect of curing conditions on SLJ tests and in the EIS analysis are on-going

Thank you for your attention

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