METAL MORPHOSIS

Optimization of joining processes for new automotive metal-composite hybrid parts

Materials and manufacturing processes of composites and hybrid components for joining by EMP technology

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Grant Agreement Nr: 609039
Collaborative Project - FP7-2013-NMP-ICT-FOF(RTD)

Co-funded by the European Union

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OBJECTIVES

Material definition for the different applications.

Optimized parts and inserts design for representative cases. Define manufacturing method.

Determine the influence of the joining method, and joining parameters an the properties of the part.

Establish the limits of the joining technology.

DESIGN AND MANUFACTURING OF COMPOSITE PIECES REQUIRED

Different type of materials were analyzed and taking into account the experience of each partner a selection was carried out.

COMPOSITE MATERIALS

MACHINING COMMERCIAL MATERIAL (CIDAUT)

- *PA6.6 GF30*
- *EP GC 22*
- *EP GC 203*

INJECTION MOULDING (CENTIMFE)

- *PA 6.6 GF30*
- *AKULON K224-PG8 40% 6 50% GF*

RTM & VACUUM BAGGING (IDEKO)

- *RESIN: EPOLAM 2020*
- *GLASS FIBER: SELCOM EBX600 ± 45º*
- *CARBON FIBER: SELCOM CBX600-24K ±45º*

METALLIC MATERIALS

ELECTROMAGNETIC JOINING (WELDING & RIVETING)

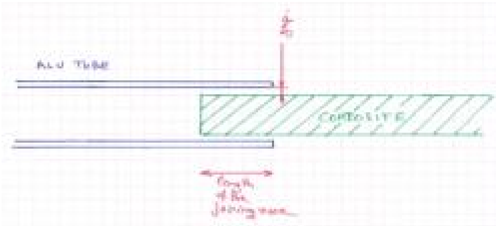
- *ALUMINIUM Al 6082 T6 Alloy (POYNTING)*

ELECTROMAGNETIC JOINING (CRIMPING)

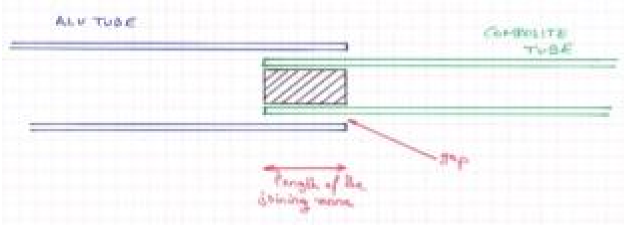
- *ALUMINIUM Al 6082 T6 Alloy (BWI)*

DESIGN AND MANUFACTURING OF COMPOSITE PIECES REQUIRED

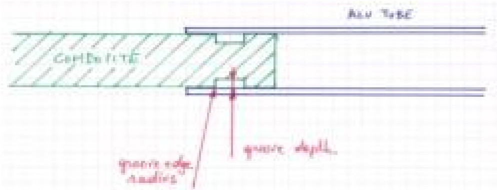
TUBULAR PARTS. CRIMPING



Concept 1



Concept 2



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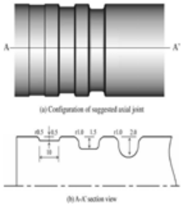

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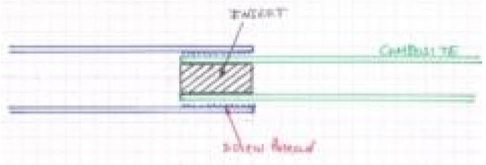

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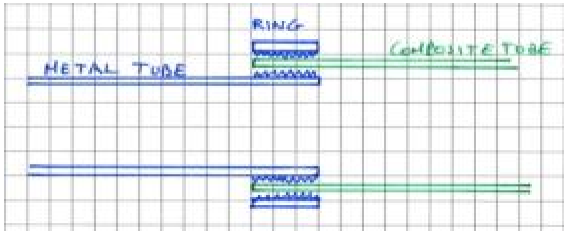
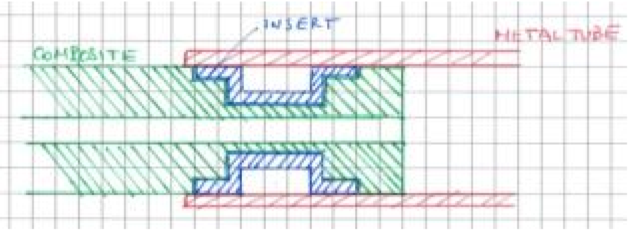


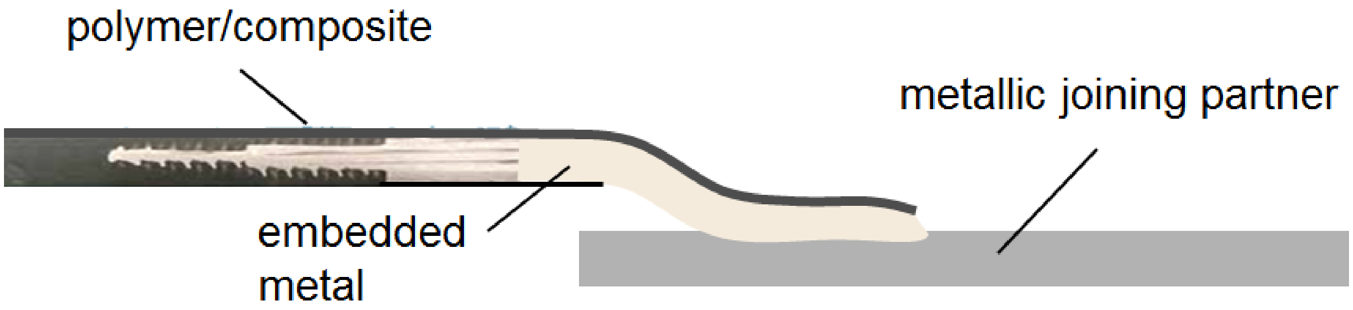
Concept 6



Concept 7

METAL MORPHOSIS

SHEET PARTS. WELDING AND RIVETING

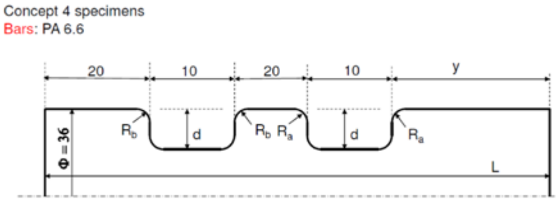


WELDING

RIVETING

DESIGN AND MANUFACTURING OF COMPOSITE PIECES REQUIRED

Tubular Work pieces (CIDAUT)



Machining commercial material:

PA6.6 (70)/Short Glass fibres (30) (PA6.6 GF30)

PA6.6 GF30 machined parts

Continuous glass fibre with epoxy (EP GC 22 & EP GC 203)

EP GC 22 & EP GC 203 machined parts

DESIGN AND MANUFACTURING OF COMPOSITE PIECES REQUIRED

Tubular Work pieces (IDEKO)

Continous glass and carbon fibre manufactured by RTM

Materials to manufacture

Mold X 3

Resin injection and curing process

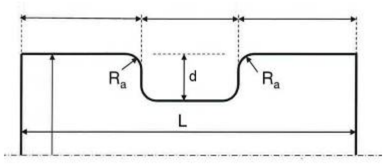
Materials:

- Glass Fibre   Selcom EBX600 ± 45º
- Carbon Fibre Selcom CBX600-24K ±45º
- Resin EPOLAM 2020

Finished composite pieces

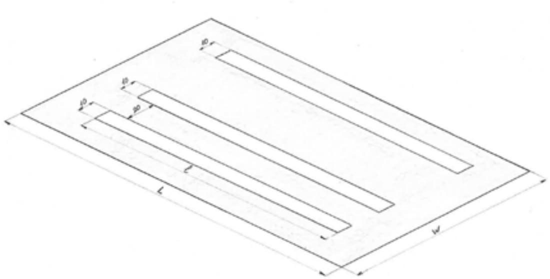
DESIGN AND MANUFACTURING OF COMPOSITE PIECES REQUIRED

Tubular Work pieces with grooves (IDEKO)



Groove geometry

Inserts



Fabric geometry

Molded piece

Finished pieces

DESIGN AND MANUFACTURING OF COMPOSITE PIECES REQUIRED

Tubular Work pieces with grooves (CENTIMFE)

PA6.6 /Short Glass fibres (30) (PA66GF30) & Akulon K224-PG 40GF & 50GF

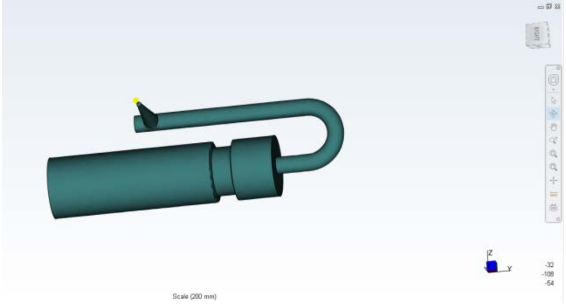
Methology followed for main steps:

- Parts design and material
- Part injection simulation
- Tool design
- Tool production
- Specimens production
- Specimens verification

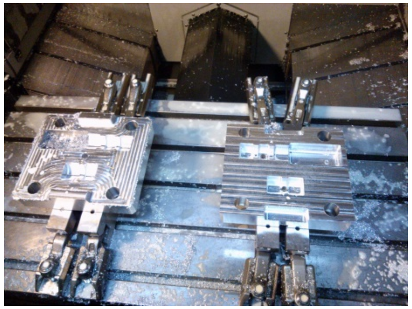
Different experiments:

- Changing injection gate
- Changing nozzle temperature
- Other changes in order to increase the injection pressure

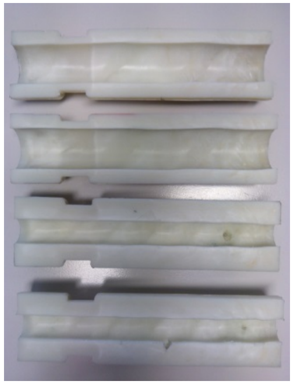
Injection modelling



Mould machining



Finished pieces



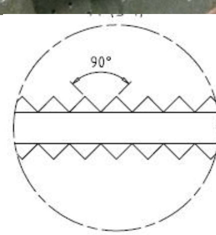
Sheet Work pieces for Electromagnetic Joining (EMJ) (IDEKO)

Manufacturing of the plates

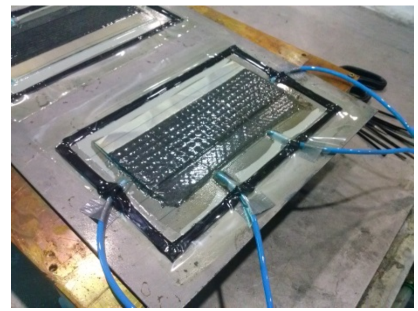
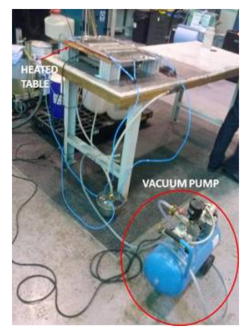
1. Machining of Aluminium plate with needles


2. Machining of Aluminium plate with pyramids





3. Vacuum bagging + heat

4. Finished plate

DESIGN AND MANUFACTURING OF COMPOSITE PIECES REQUIRED

Sheet Work pieces for Riveting (IDEKO)

Manufacturing of the plates

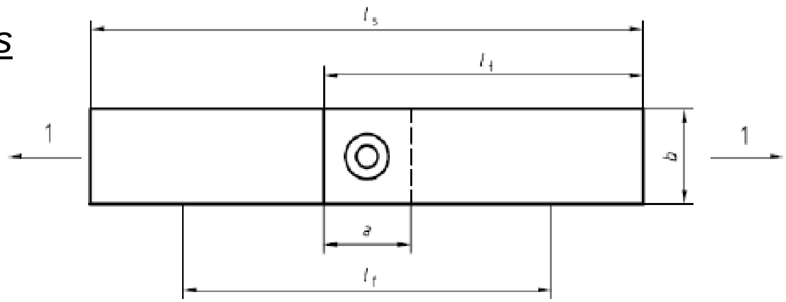


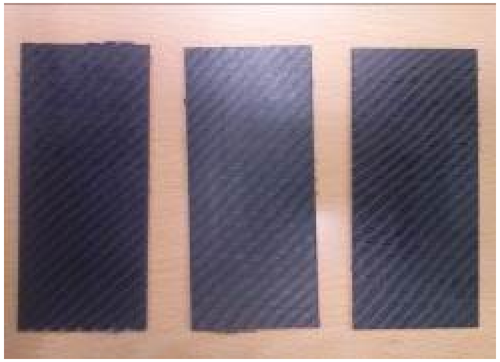
Figure 2: Specimen for shear test acc. to EN ISO 14273, [2]

Thickness t (mm)	Overlap a (mm)	Specimen width[a] b (mm)	Specimen length l_s (mm)	Free length between clamps l_f (mm)	Length of individual test coupons l_t (mm)
0,5 ≤ t ≤ 1,5	35	45 (30)	175	95	105
1,5 ≤ t ≤ 3	46	60 (30)	230	105	138
3 ≤ t ≤ 5	60	90 (55)	260	120	160

[a] Figures in parentheses will give approximately 10% reduction in strength and these widths may be used only by agreement between the manufacturer and the purchaser.

Table 1: Dimensions of shear test specimen acc. to EN ISO 14273 [2]

Vacuum bagging + heat



Cut to size

Typical damage in composite material during joining processes:

- Resin degradation
- Delamination (debounding in case of short fibres)
- Cracking

Inspection techniques:

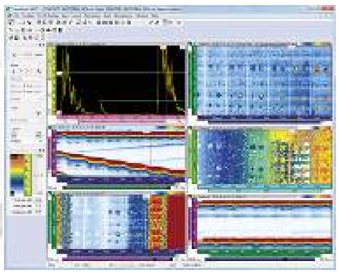
- Ultrasonic Inspection
- Active Thermography Inspection
- SEM
- Tensile tests

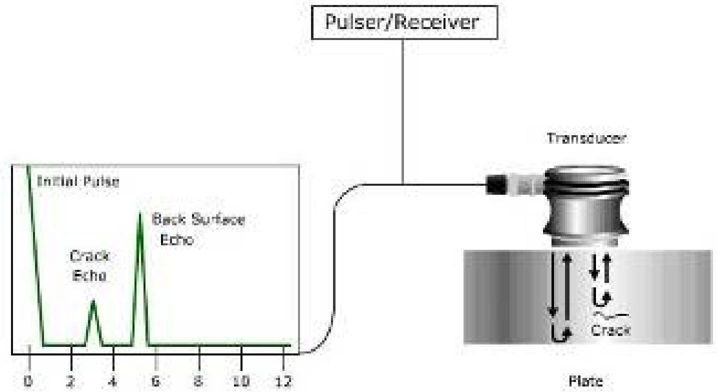
INFLUENCE OF HIGH SPEED JOINING PROCESS ON THE INTEGRITY OF COMPOSITE PARTS

Ultrasonic Inspection

Quality of the short fibre composite (PA 6.6 GF30) have been analysed.

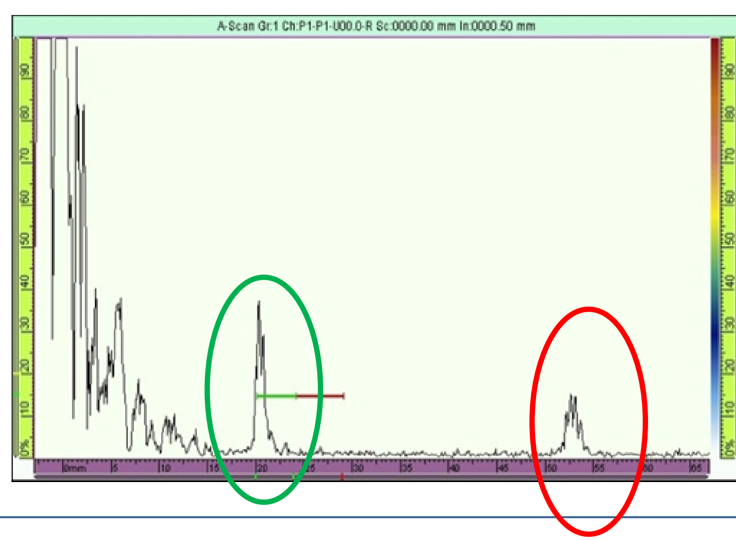
Experimental results obtained using OmniScan MX (Olympus) and results analysis with Tomoview software





Slot echo

Backwall echo

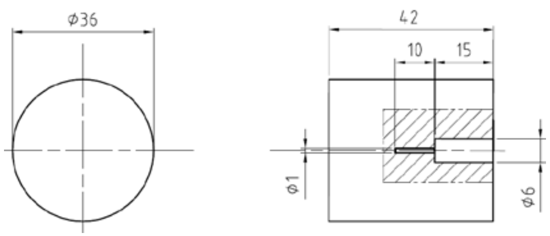


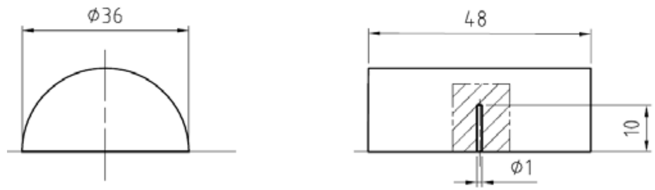
The results show that ultrasonic inspection is able to determine the presence of defects in PA 6.6 GF30

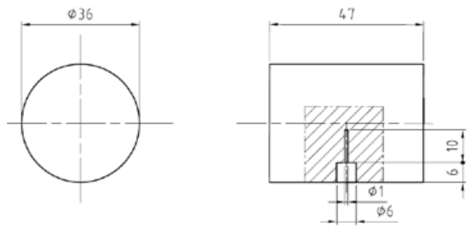
In order to determine the resolution of the system some reference block should be manufacture.

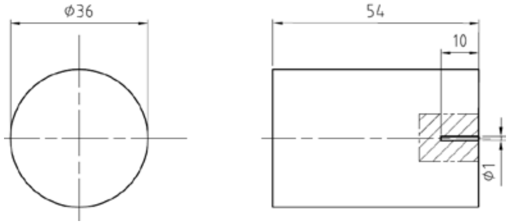
INFLUENCE OF HIGH SPEED JOINING PROCESS ON THE INTEGRITY OF COMPOSITE PARTS

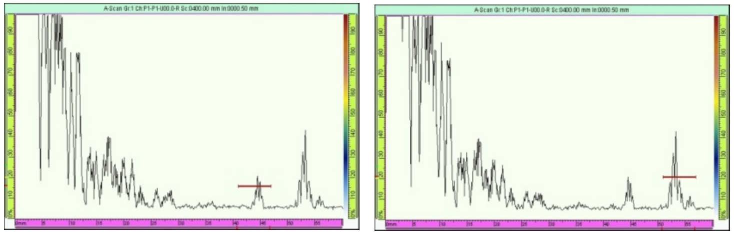
Ultrasonic Inspection











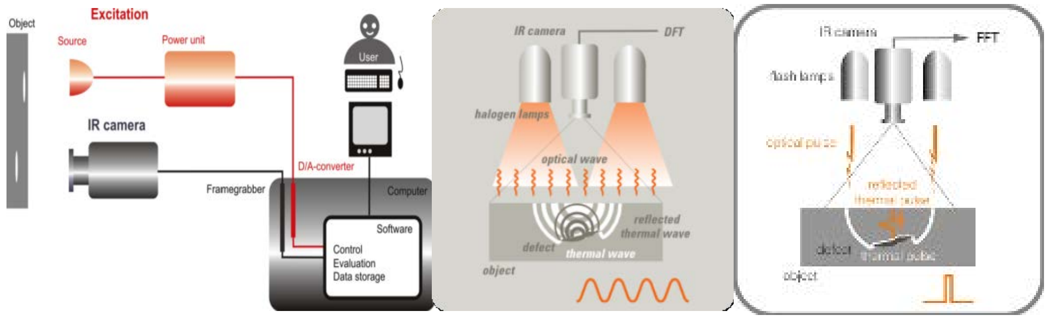
All reflectors with Ø = 1mm → Detected by Ultrasound Inspections

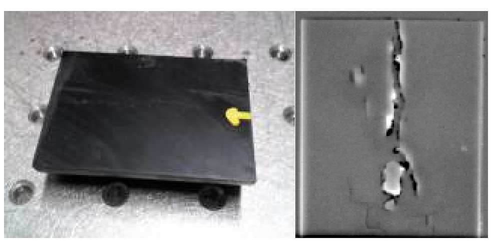
INFLUENCE OF HIGH SPEED JOINING PROCESS ON THE INTEGRITY OF COMPOSITE PARTS

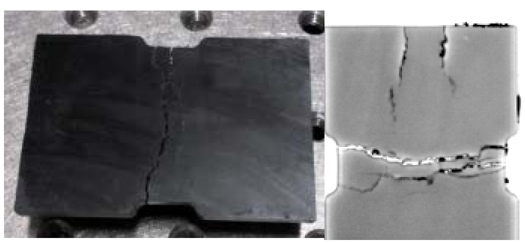
Active Thermography Inspection

Use a heat source to heat the part to be inspected and detect temperature variations with an infrared camera. When the heat flow in a material is alterated by the presence of discontinuities (cracks, pores,..), causes surface temperature contrasts. That can be detected by the camera.

Test done using optically excited thermography in order to check PA 6.6 GF30 + Al 6082.
PURPOSE: Determine damage caused to composite due mechanical joints between composite-metal.







Cracks in the surface detected

In a sample of polyamide several holes with a diameter of 1mm were drilled for inspecting them by the opposite side.
The **sub-surface** and **volumetric** indications in this sample have **not** been **possible to detect**.

INFLUENCE OF HIGH SPEED JOINING PROCESS ON THE INTEGRITY OF COMPOSITE PARTS

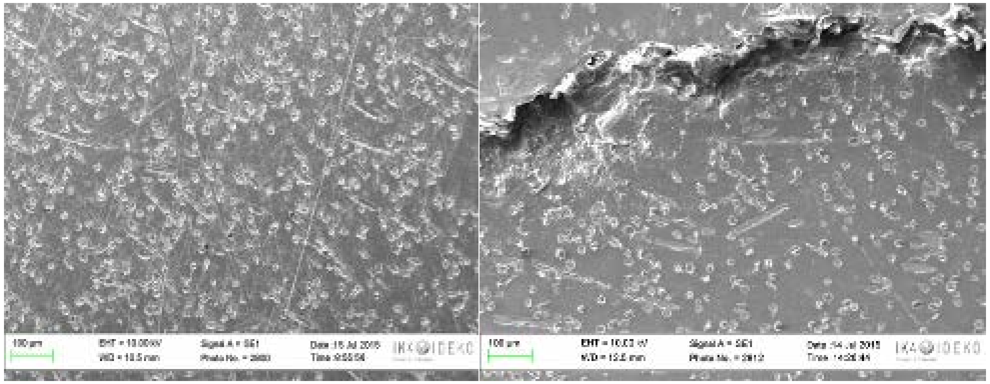
SEM Inspection

Debounding of the fibres studied comparing the morphology of samples with no visible cracks and one with had clear cracks.

Samples were cut, sanded and polished to analyse the internal morphology by SEM.

Non-cracked Cracked

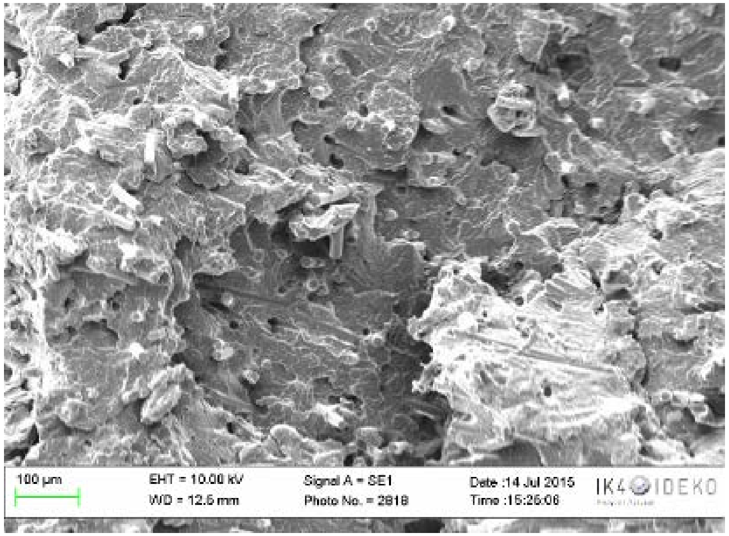
Diameter and shape of the holes are similar in both samples → EMJ process does not give rise to debounding of the short fibres in the polyamide matrix



INFLUENCE OF HIGH SPEED JOINING PROCESS ON THE INTEGRITY OF COMPOSITE PARTS

SEM Inspection

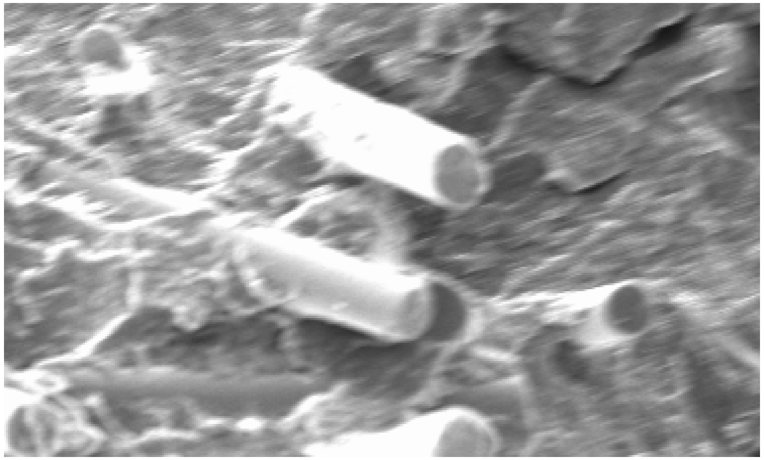
Morphology of fracture surface



The fibres are well bounded to the matrix.

The irregularity of the fracture surface indicates the fibres have an important contribution in the fracture mechanism, probably due to good adhesion between matrix and fibres.

Excellent interface adhesion between fibres-matrix

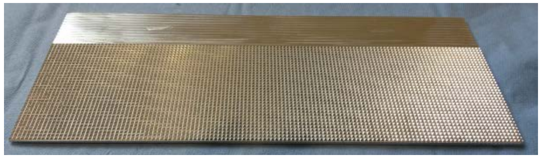


<u>Conclusions:</u>

- No matrix degradation
- No delamination or debounding
- Cracks effect when energy level or the joining process is higher than impact strength of material.
- Energy level could be used increases when continuous fibre is used.

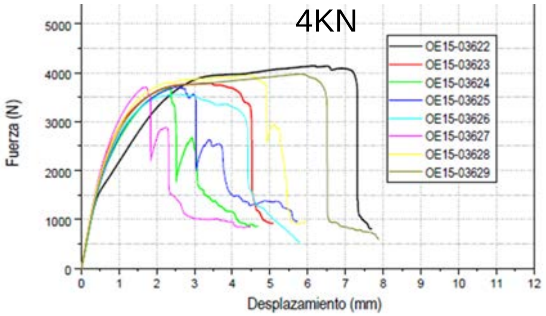
INFLUENCE OF HIGH SPEED JOINING PROCESS ON THE INTEGRITY OF COMPOSITE PARTS

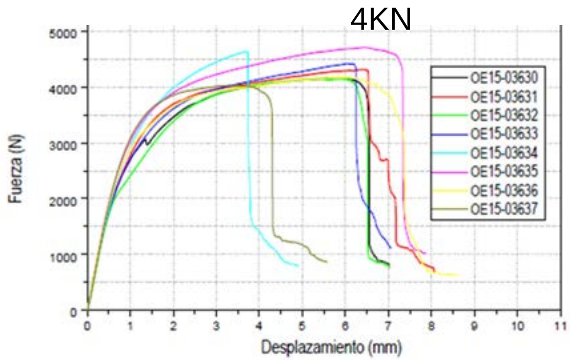
Features and behaviour of SHEETS samples used

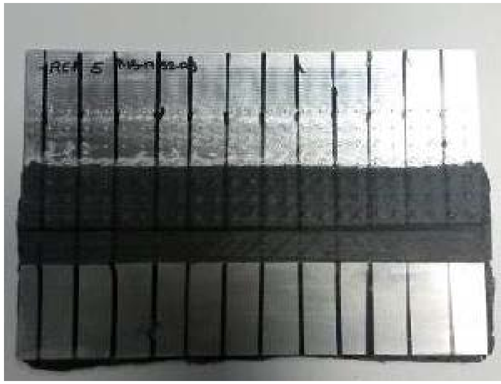


PYRAMIDS

NEEDLES



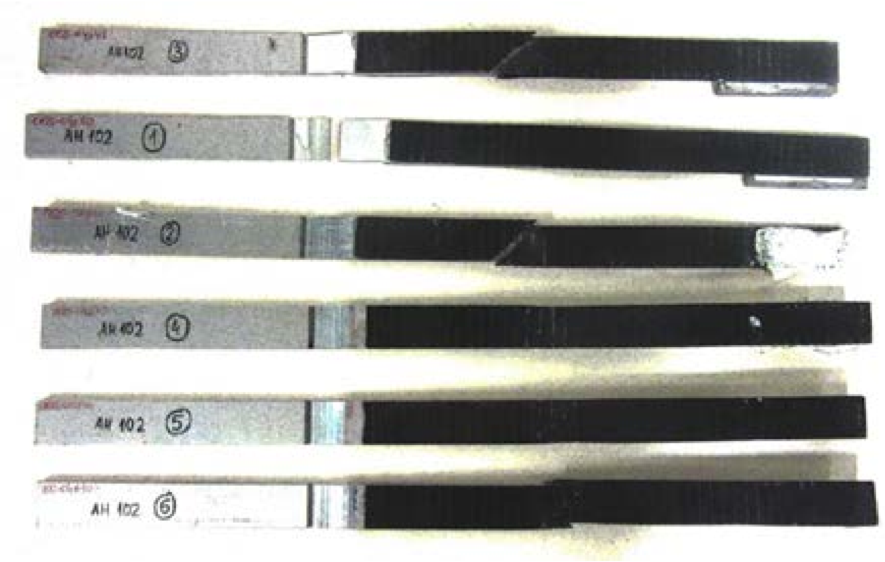


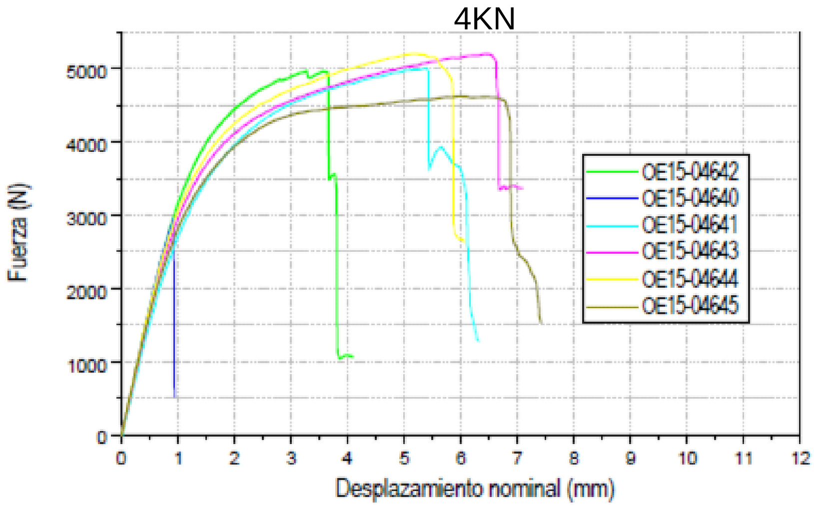


METAL MORPHOSIS

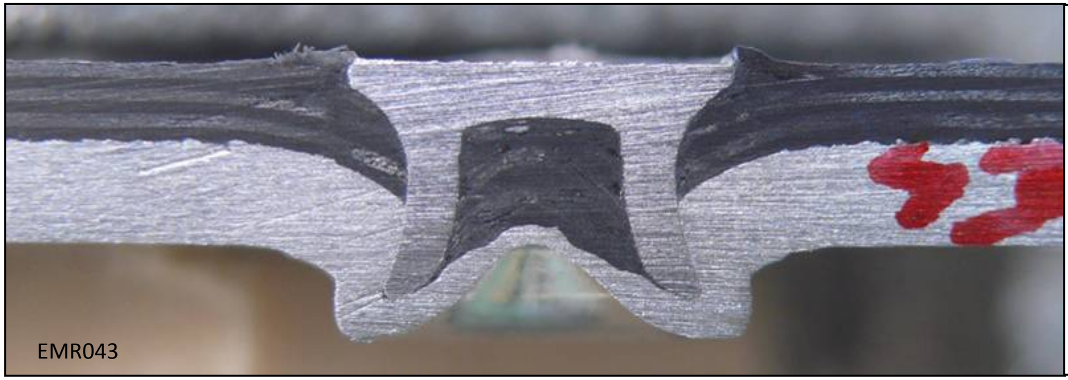
INFLUENCE OF HIGH SPEED JOINING PROCESS ON THE INTEGRITY OF COMPOSITE PARTS

ALUMINIUM SHEET JOINING TO THE HYBRID COMPOSITE PART



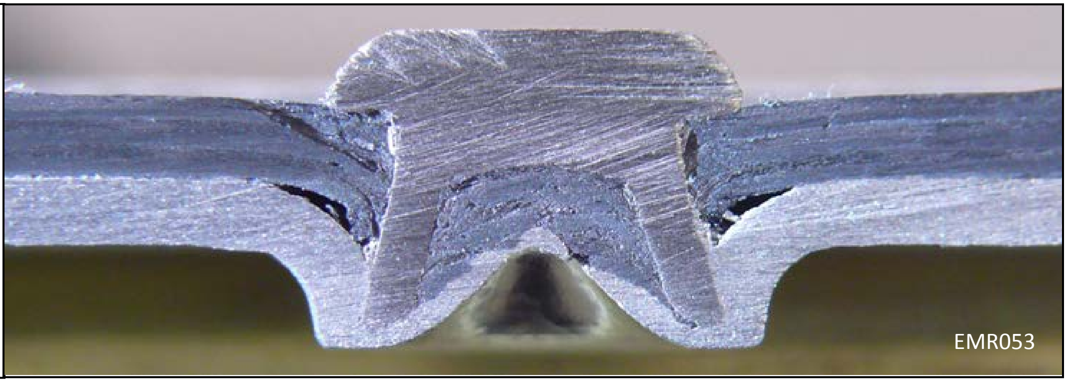


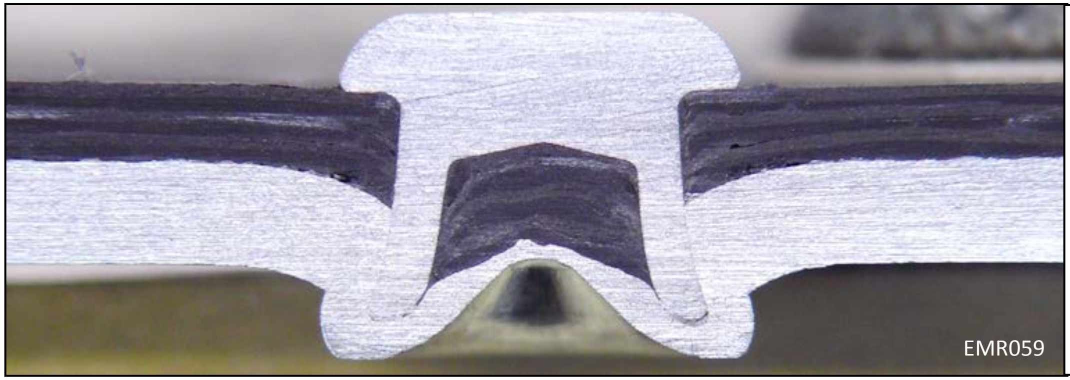
INFLUENCE OF HIGH SPEED JOINING PROCESS ON THE INTEGRITY OF COMPOSITE PARTS



Punch side sheet:	CFRP (Ideko) 1,7 mm
Cover sheet:	none
Die side sheet:	AW5754; 2.0 mm
Rivet:	RIVSET® SKR 5 x 5 H2
Die:	LWF-1
Pulse Energy:	580J

Punch side sheet:	CFRP (Ideko) 1,6 mm
Cover sheet:	none
Die side sheet:	AW5754; 1.5 mm
Rivet:	RIVSET® FRK 5 x 5 H0
Die:	LWF-1
Pulse Energy:	500J





Punch side sheet:	CFRP (Ideko) 1,6 mm
Cover sheet:	none
Die side sheet:	AW5754; 2.0 mm
Rivet:	RIVSET® FRK 5 x 5 H0
Die:	LWF-1
Pulse Energy:	550J

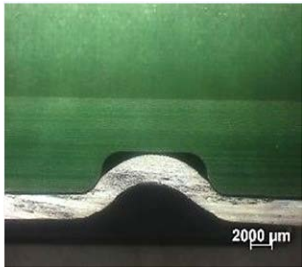
RECOMMENDATIONS CONCERNING THE MATERIALS TO BE USED FOR A CERTAIN APPLICATION

Materials requirements depending of the joining process

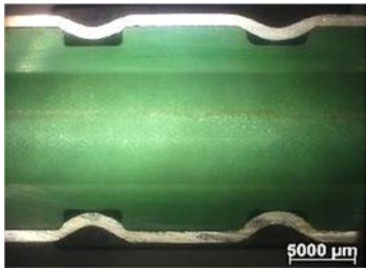
Joining processes of tubes (Crimping)

Seven design concepts with different materials analysed (WP3).

Most promising concepts (3,4,7) for achieving a high joint strength and high resistance



CONCEPT 3:
Joints with EPGC 22 tubes → highest tensile strength (11-37kN) with an energy range of 3-11kJ. Highest impact resistance (up to 11kJ without fracturing)



CONCEPT 4:
EPGC 22 tubes → highest joint strenght (40-65kN) comparing with PA6.6GF30 (33-46kN)

CONCEPT 7:
Joints with PA6.6GF30 bars → highest tensile strenght (26-43kN) with an energy range of 9-12kJ. Highest impact resistance (up to 13kJ without fracturing)

Composite materials for joining MUST **be able to be machined or moulded with grooves** → create mechanical interlock

Inserts presence ↑ energy that can be used → make difficult production process

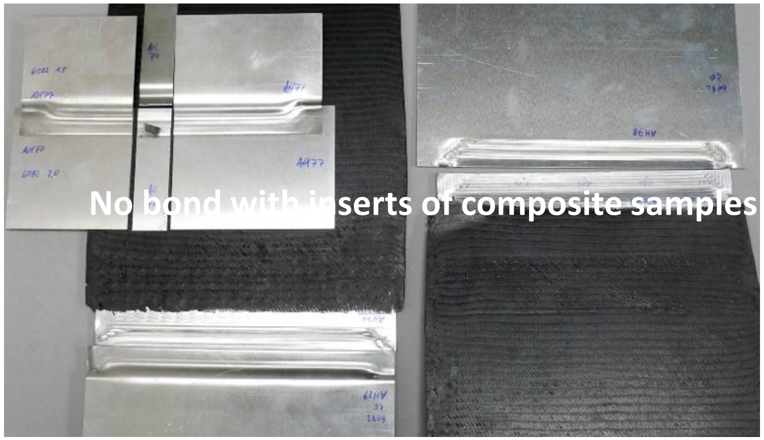
Material with continuous fibre not best way to create grooves → Fibres cut while machined and not good to copy the mould complex geometry (moulding with grooves)

METAL MORPHOSIS

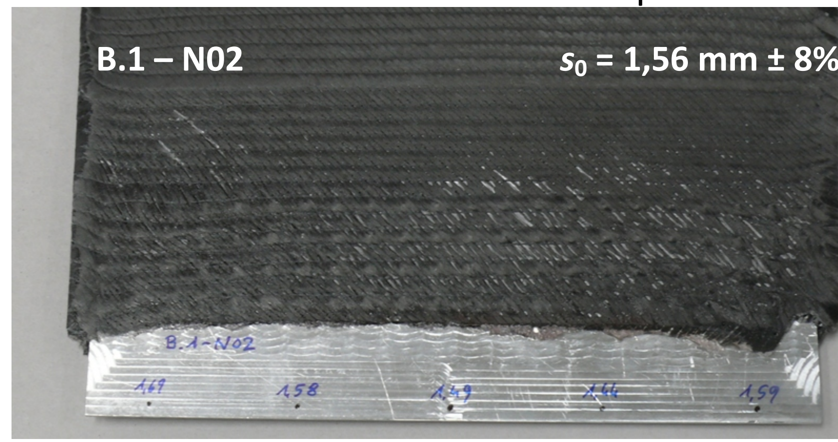
RECOMMENDATIONS CONCERNING THE MATERIALS TO BE USED FOR A CERTAIN APPLICATION

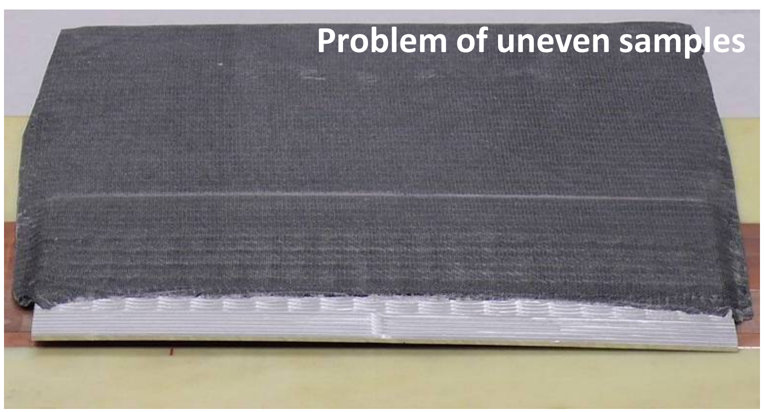
Joining processes of tubes (Crimping)

First results on Ideko samples



Thickness variation of metal insert: 1.0 mm up to 1.8 mm





Requirements to semi-finished material for (both) MPW concepts:

- tolerance of thickness of flyer sheet shall not exceed EN standard for wrought aluminium products
- tolerance of flatness of flyer and parent sheet shall not exceed EN standard for wrought aluminium products
- surface shall be free of oil or coating material (neither metallic coating nor plastic)
- cut edge of flyer blank shall accurately follow the coil conductor geometry

Additional problems can result from:

- Deep milling traces on surface
- Thickness variation of composite and resulting changes of distance between flyer and coil
- Insufficient clamping of joining partners to fix all geometrical parameters during the process

HIGHLIGHTS OF MOST SIGNIFICANT RESULTS

1. Injection moulding process of short glass fibre reinforced polyamide was developed:
    - Mould design
    - Cavity design
    - Injection moulding process optimized by simulation
    - Specimens of composites and hybrid part for tubular design concepts were manufactured by injection moulding
2. Double grooves specimens have been manufactured successfully by machining
3. New process to produce double groove specimens with continuous fibre in the surface was analysed.
4. Continuous carbon fibre reinforced epoxy resin specimens with and without inserts were manufactured by impregnation by hand and vacuum bagging.
    - The accuracy of the thickness is suitable for riveting by EMJ.
    - The adhesion between insert with needles and pyramids are good enough for welding.
5. Degradation and delamination or debounding effects do not appear in the studied concepts of the tubular samples.
6. Cracking effects appears when the energy level of the joining process is higher than the impact strength of the material. This effect is emphasized with the gap between the metal and the composite and it is attenuated with the use of metal insert between them.
7. The energy level that could be used in the joining process increases when continuous fibre composites are used, but in the case of this geometry with grooves is very difficult to produce composite parts with continuous fibres in the grooves.
8. The requirements of the hybrid parts for welding processes are mainly the tolerance of thickness and flatness. The surface must be free of oil or coating material.

METAL MORPHOSIS

Optimization of joining processes for new automotive metal-composite hybrid parts

Thank you very much

Grant Agreement Nr: 609039
Collaborative Project - FP7-2013-NMP-ICT-FOF(RTD)

Co-funded by the European Union