Hybrid metal-composite solutions for different industrial sectors

E-Lass Conference, Lightweight Applications

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• AIMEN Technology Centre & Advanced Materials
• Current challenges of the industry
• Multi-material approach
• Multi-material challenges
• AIMEN R&D multi-material Projects
• **AIMEN Technology Centre & Advanced Materials**
  • Current challenges of the industry
  • Multi-material approach
  • Multi-material challenges
  • AIMEN R&D multi-material Projects
We are a Technology Centre sited in the Northwest of Spain, founded in 1967, specialized in R&D and providing advanced technological services in the field of:

- joining technologies
- advanced materials
- robotic, automation and control
- laser technologies applied to materials processing

Headquarters (7,500m²) and Laser Processing Centre (11,100 m²) (O Porriño, Spain)
R&D&i

- Applied research
- Extensive network of industrial partners
- Management of R&D&i Funding Programs

1. Polymers and Composites
2. Structural and Mechanical Integrity
3. Laser Based Manufacturing
4. Additive Engineering
5. Micro and High Precision Manufacturing
6. Smart Systems
7. Smart Manufacturing
8. Environmental and biotechnologies

In 2017:

R&D&i in figures

- 66 Ongoing projects
- 11 New approved projects
- 33% R&D&i in the european scope
Composites and Polymers Manufacturing

- Out of autoclave (VBO, filament winding, RTM, Press forming, LRI)
- Thermoplastic composites Automated processes (ATL, AFP)
- Process monitoring (embebed sensors)

Smart polymers and composites

- Nano-additive foams
- Nano-additive polymers and composites (thermal and electrical conductivity)
- Self-sensing materials

Multi-materials

- Metal - polymer/composite
- One-shot process
- Joining improvement
- Surface technologies (laser texturing)
- On-line process control

Additive Manufacturing

- 3D printing: new filament development (nano additive polymers, coated fibber)
- Automated composite layering
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NEEDS OF THE INDUSTRY

LIGHTWEIGHTING

vs

PERFORMANCE (mechanical prop., security...)

NEW FEATURES

REPAIR OF DAMAGES

REINFORCEMENT

LIGHTWEIGHTING

REPAIR
Industry, and specifically transport industry (mainly automotive), is the 2nd highest source of CO₂ emissions in the EU.

Europe is playing a very active role in the global scenario.

EU industry has to meet wider and ever increasing demanding regulations.

An average gap reduction of 20 gr CO₂/km has to be implemented in the next 4 years.

A combination of good design practice, appropriate targets and specifications and novel material technologies will yield lightweight transport.
NEEDS OF THE INDUSTRY: how to response from materials science

Metallic materials are the best option for everything

BUT..!!!
How much do you weigh?
How much fuel do you consume?
You look a little corroded...

Let’s replace every metal with composites!!

BUT...!!!
How much do you cost?
How long it took to manufacture you?
Does your behavior in service meet all the requirements?
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MULTI-MATERIAL / HYBRID APPROACH

WEIGHT REDUCTION
requirement translated downstream to EVERY SINGLE COMPONENT

<table>
<thead>
<tr>
<th>MATERIAL</th>
<th>WEIGHT REDUCTION (%)</th>
<th>COST</th>
</tr>
</thead>
<tbody>
<tr>
<td>Magnesium</td>
<td>60-75</td>
<td>1.5-2.5</td>
</tr>
<tr>
<td>CFRP</td>
<td>50-60</td>
<td>2-10</td>
</tr>
<tr>
<td>Aluminium</td>
<td>40-60</td>
<td>1.3-2</td>
</tr>
<tr>
<td>Titanium</td>
<td>40-55</td>
<td>1.5-10</td>
</tr>
<tr>
<td>GFRP</td>
<td>25-35</td>
<td>1-1.5</td>
</tr>
<tr>
<td>HSS</td>
<td>10-15</td>
<td>1</td>
</tr>
</tbody>
</table>

MULTI-MATERIAL DESIGN; overcoming THE COST BARRIER
Top Material Families for Lightweighting

Question: Which material family are you relying upon most heavily to help meet the new CAFE fuel economy standards?

- 25% Aluminum
- 32% Multi-Material Solution
- 21% Multi-Material Solution (2015 Response)
- 17% Advanced High-Strength Steel
- 11% Engineering Plastics
- 11% Advanced Composites

Base: 452 Not Shown: Magnesium 1%; Other, 14%
Base: 684 Not Shown: Magnesium 1%; Other, 5%
Multi-material combines the properties of different materials (2 or more) to obtain a final product with a synergy of their properties. The right material (only) in the right place.

Combination of materials of diff. nature in a single structure → optimum material for each purpose

- performance/cost ratio better than a bulk material
- more efficient resources use
MULTI-MATERIAL CONCEPT

POLYMERIC MATERIAL + METALLIC MATERIAL = PMH POLYMER-METAL HYBRID

POLYMERS
- THERMOPLASTIC COMPOSITES
- THERMOSET COMPOSITES
- POLYMERIC FOAMS

STEEL TITANIUM ALUMINIUM

SYNERGY OF PROPERTIES

Different properties!!!
MULTI-MATERIAL CONCEPT: WHY COMPOSITES?

DRIVERS FOR THE USE OF COMPOSITES

- High specific mechanical properties
- Weight lightening
- Corrosion resistance
- Fatigue behavior
- Flexibility in design and manufacture
- Thermal and acoustic insulation
- Improved vibration resistance
- Low coefficient of thermal expansion
- Electromagnetic permeability

Fibre reinforced plastics used in structural parts (Source: SGL Group)
MULTI-MATERIAL CONCEPT: WHY COMPOSITES?

Thermoplastic (TP) Composite & Metal Components

- **TP-MATRIX**
  - PP
  - PPS
  - PEI
  - PA
  - PEEK
- **FIBRES**
  - CARBON
  - GLASS
  - ARAMID
  - UHMWPE
  - NATURAL
  - FIBRES
- **METALLIC PART**
  - STEEL
  - ALUMINIUM
  - TITANIUM

Thermoset (TS) Composite & Metal Components

- **TS-MATRIX**
  - EPOXY
  - POLYESTER
  - VINYLESTER
  - PUR
- **FIBRES**
  - CARBON
  - GLASS
  - ARAMID
  - NATURAL
  - FIBRES
- **METALLIC PART**
  - STEEL
  - ALUMINIUM
  - TITANIUM

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MULTI-MATERIAL / HYBRID CHALLENGES

MATERIALS
STEELS AND HIGH MODULE STEEL ALLOYS + TITANIUM + ALUMINIUM, etc

LOW THICKNESS

THERMOPLASTIC (PA for automotive, PEI, PPS and PEEK for aeronautics) and THERMOSET COMPOSITES

MANUFACTURING PROCESSES
TREND TO THE MAXIMUM AUTOMATION
MULTI-MATERIAL / HYBRID for AUTOMOTIVE

NEW BMW 7 SERIES – CARBON CORE.

FAURECIA
PA / CFRTP & Steel with overinjected PP in mould
MULTI-MATERIAL / HYBRID CHALLENGES

MATERIALS
CONVENTIONAL STEELS (MEDIUM QUALITY)
  ↓
  HIGHER THICKNESS

THERMOSET COMPOSITES
HARD ENVIRONMENTAL CONDITIONS
LOW COST

MANUFACTURING PROCESSES
LOW COST
LOW AUTOMATION
EASY APPLICATION
**MULTI-MATERIAL/HYBRID CHALLENGES**

- **METALLIC-COMPOSITE DISSIMILAR JOINT**
  - Adequate joint resistance
  - Durability (long term performance)
  - Avoid galvanic coupling
  - Thermal fatigue (coef. Thermal expansion)
  - Manufacturing process (cost effective)

- **DURABILITY** of multi-material solutions
- Characterization of multi-material components, mainly **NDT**
- Manufacturing process: **ONE-SHOT** processes, adaptation of existing processes
- **PROCESS MONITORING & CONTROL**
- **Joining** the multi-material component to other parts
- **MULTI-MATERIAL DESIGN**
- Take into account the multi-material concept to design production processes
- **Regulation** context (Solas, etc)
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MULTI-MATERIAL METAL-COMPOSITE:
AIMEN’S RESEARCH EVOLUTION


MARITIME INDUSTRY

REPAIR of METAL PARTS
• CRACKS
• CORROSION
METAL REINFORCEMENT
• REMODELING THE STRUCTURE
• INCREASE CARGO CAPACITY IN SERVICE

WIND ENERGY / ON & OFFSHORE

MULTI-MATERIAL DESIGN
LIGHTWEIGHTING OF ORIGINAL COMPONENT
OPTIMIZE MECHANICAL BEHAVIOR
(IMPACT, FATIGUE)
MULTI-MATERIAL STRUCTURAL ANALYSIS

AUTOMOTIVE / AERONAUTIC

LAY2FORM: “Efficient Material Hybridization by Unconventional Lay-up and Forming of Metals and Composites for Fabrication of Multifunctional Structures”

RAMSES “Realisation and Demonstration of Advanced Materials Solutions for Sustainable and Efficient Ships”

ComMUnion “Net-shape joining technology to manufacture 3D multi-materials components based on metal alloys and thermoplastic composites”

MOSAIC “Materials On-board Steel Advancements and Integrated Composites”

CO-PATCH “Composite patch repair for marine and civil engineering infrastructure applications”

MIAMI “Development of multi-material structures for offshore applications with severe fatigue and durability stresses in marine environment”

EMMA “Development of light and low cost multi-material structures for the automotive industry”

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MARITIME INDUSTRY: joining thermoset composites to steels

- Crack repair
- Steel reinforcement
- New multi-material structures

Lab small and medium scale

Manufacturing processes: HLU, LRI, RTM & prepregs.
Direct joining & Adhesive Joining
Monitoring and Control systems applied (FBGs)

Real scale
The COPATCH solution bases its operation on the transfer of stress from the damaged structure (steel) to the composite material through the adhesive bondline.

Composite arrests crack growth, increases the module and maximum load of the structure.
Multi-material off-shore structures subjected to adverse conditions.
- Steel / filament winding composite.
- Monitoring of fatigue and corrosion.

**DEMO CASE:** *Transition part of the tower of and offshore windmill*

Multi-material manufacturing based on filament winding

Structural and corrosion monitoring based on embedding fiber optic sensors
Coating development of FBGs

FBGs embedded on composite laminated and interlayer steel-composite
NET-SHAPE JOINING TECHNOLOGY TO MANUFACTURE 3D MULTI-MATERIALS COMPONENTS BASED ON METAL ALLOYS AND THERMOPLASTIC COMPOSITES

http://communionproject.eu

- H2020-FoF12-2015
- 15 partners from 5 different EU countries
- Coordinated by AIMEN
- Key and complementary expertise covering the value chain
- End-users:
  - Automotive: Gestamp (TIER1)
  - Aeronautic: Aciturri (TIER1 of Airbus)

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The dissemination of the project herein reflects only the author’s view and the Commission is not responsible for any use that may be made of the information it contains.
Automotive & Aeronautics: joining metal alloys and TP-composites

- Direct TP-composite to metal joining optimization
- Demonstrate durability (corrosion, thermal fatigue, etc.)
- Develop a cost-effective process

- Automatic tape placement of CF tapes
- Direct bonding between CF and metal
- High-speed laser texturing of metal surfaces:
  - Highly reproducible
  - Easy automation
  - Environmental friendly tool
LASER TEXTURING AND CLEANING OF SURFACES

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

Polygon scan laser (Source: FhG-ILT)

Texturized surfaces details (Source: FhG-ILT & AIMEN)

IMPROVED WETTABILITY AND MECHANICAL INTERACTION COMPOSITE-ADHESIVE/METAL INCREASED

LASER ASSISTED SYSTEM TO HEAT LARGE WIDTH TPCs/ FLEXIBLE HEAD FOR METAL-COMPOSITE JOINING FOR COMPLEX SHAPES

- VCSEL heating system (Source: Philips)
- Automatic tape placement (Source: FhG-IPT & AIMEN)
- Process control (Source: FhG-IPT & AIMEN)
- Adjustable heating profile (Source: Philips)

PRECISE CONTROL OF HEATING DISTRIBUTION
ADJUSTMENT TO COMPLEX GEOMETRIES
PARAMETERIZED ENRICHED CAD/CAM SYSTEM

DECISION SUPPORT SYSTEM (DSS)

SELF-ADAPTIVE SYSTEM

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

DESIGN AND MULTI-SCALE SIMULATION

ON-LINE QUALITY DIAGNOSIS SYSTEM BASED ON NDT’S

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

KNOWLEDGE BASE SYSTEM

SELF-ADAPTIVE SYSTEM

ENRICHED CAD/CAM SYSTEM

IDENTIFICATION OF OUT OF RANGE STRUCTURES

 DSS: REDUCE THE LEAD TIME IN NEW PRODUCT DESIGN
 ENRICHED CAD/CAM: OPTIMIZE THE SET-UP CONFIGURATION PROCESS

AUTOMOTIVE & AERONAUTICS: joining metal alloys and TP-composites

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

PREVENT THE DEFECTS PROPAGATION TROUGH THE DIFFERENT STAGES

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AUTOMOTIVE & AERONAUTICS: joining metal alloys and TP-composites

IMPACT

✓ At least 20% decrease in the consumption of high cost and critical materials.

<table>
<thead>
<tr>
<th>Reference</th>
<th>Material</th>
<th>Weight (kg)</th>
<th>Cost: material (£)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Traditional bearing rib</td>
<td>Ti6Al4V</td>
<td>100 (ref. value)</td>
<td>6000 (considering ref. weight)</td>
</tr>
<tr>
<td>ComMUnion bearing rib</td>
<td>Ti6Al4V /PPS-CFRT</td>
<td>50+15 (titanium+CFRT)</td>
<td>4500</td>
</tr>
</tbody>
</table>

✓ At least 30% improvement of product performance.
✓ High level of automation and lower production times compared to current technologies.

<table>
<thead>
<tr>
<th>Joining metal/CFRs components</th>
<th>Material</th>
<th>Fabrication</th>
<th>Joining technol.</th>
<th>Surface modification</th>
<th>NDT</th>
<th>Control</th>
</tr>
</thead>
<tbody>
<tr>
<td>Currently manual</td>
<td>Metal/TSC</td>
<td>Separately: TSC are manufactured by hand lay-up, infusion</td>
<td>TS adhesives</td>
<td>Manual or automated, little innovative (sand blasting, primer)</td>
<td>Offline</td>
<td>No</td>
</tr>
<tr>
<td>ComMUnion approach</td>
<td>Metal/CFRT</td>
<td>Direct joining: CFRTs are joined to metal surface by laser assisted automated tape placement (with TP adhesive at interface)</td>
<td>Innovative high speed laser texturing and cleaning</td>
<td>Innovative high speed laser texturing and cleaning</td>
<td>Online</td>
<td>Online control of joining parameters</td>
</tr>
</tbody>
</table>
DEVELOPMENT OF LIGHT AND LOW COST multi-material STRUCTURES FOR THE AUTOMOTIVE INDUSTRY

Case of study: Bumper: 3,8-3,3kg
Weight saving: 30-40%

Potential weight savings in a medium vehicle: 140kg*

BIW (Body in white): 20% of the total weight, 63% metal

Architecture
More efficient power trains
Resistance to friction
Aerodynamics
Surface laser treatment of steel (reduce thickness)

TS-composites (CF/epoxy prepregs)
Press-forming (curing + joining)

TP-Composites (PA/CF):
- Prepregs (reinforcements): press-forming for consolidation and joining
- PA + short fiber (pellets): overinjection

AUTOMOTIVE:
joining TP-Composites and TS-Composites to metal alloys

multi-material
TP-composite+Steel bumper

LCA
Weight
Mechanical Performance

multi-material
TS-composite+Steel bumper

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✓ Multi-material systems represent a very attractive performance / cost solution.

✓ They have different applications in different industrial sectors: repair, reinforcement, and new component.

✓ It is an intermediate approach to the complete replacement of a metallic component with a composite one.

✓ They combine the advantages of materials of different nature, maximizing the benefits of both and reducing the limitations.

✓ An ad-hoc design must be carried out according to performance specifications.

✓ Current trends are:
  • Optimization and greater knowledge of dissimilar unions (surface treatments)
  • Improve productivity by integrating the manufacture of the multi-material component in the existing processes of both metal and composite.
  • Robotization and process automation
  • Implement control systems over each step of the process in real time.
Thanks for your attention!