MAINFORUM™ 2025

Mexico's Automotive Innovation Network

Lightweight Structures in Composite Materials, from Aircraft to Cars. Challenges for Mass Production

Javier Coleto PhD.

Business Development Manager

TECNALIA

CLAUT

tecnalia Inspiring Business

carbures carbon structures

1.- SHORT INTRODUCTION OF THE COMPANIES

2.- COMPOSITES IN AERONAUTICS. BACKGROUND & CURRENT STATUS

3.- COMPOSITES IN AUTOMOTIVE STRUCTURES. BACKGROUND AND NEW OPPORTUNITIES

4.- CHALLENGES FOR MASS PRODUCTION

5.- APPROACHES TO OVERCOME LIMITATIONS

6.- THERMOSETS

7.- THERMOPLASTICS

8.- CONCLUSIONS

CARBURES

http://www.carbures.com/

- Created in 2002 as a spin-off of the University of Cádiz, Spain, with a main mission of manufacturing and commercialising technological products made in carbon fibre composites.
- Global Presence (presently at Europe, US and China) and multisectorial: space, aeronautics, automotive, railway… and civil infrastructures.
- Tier 2 that develops and manufactures carbon fibre composite products for all structural applications where lightweight is a target.
- Strongly devoted to R&D in new materials (ex.: graphene composites) and composites recycling.
- Along 2013, Carbures adquired some engineering and production companies to strengthen its production capabilities and commercial possition in its strategic sectors of interest.

http://www.tecnalia.com/

- Private applied research center, with headquarters in the north of Spain, other locations: France, Serbia, China, Mexico…

- The largest private non-profit Research in the south of Europe (fourth in Europe).
- Staff of 1500 researchers working for more 4000 customers. Turnover of 110M€
- Active and relevant presence in the European Research Area
- Partner of the European automotive associations EARPA and ERTRAC EARPA: European Automotive Research Partners Association / ERTRAC: The European Road Transport Research Advisory Council

Composites in Aeronautics. Background

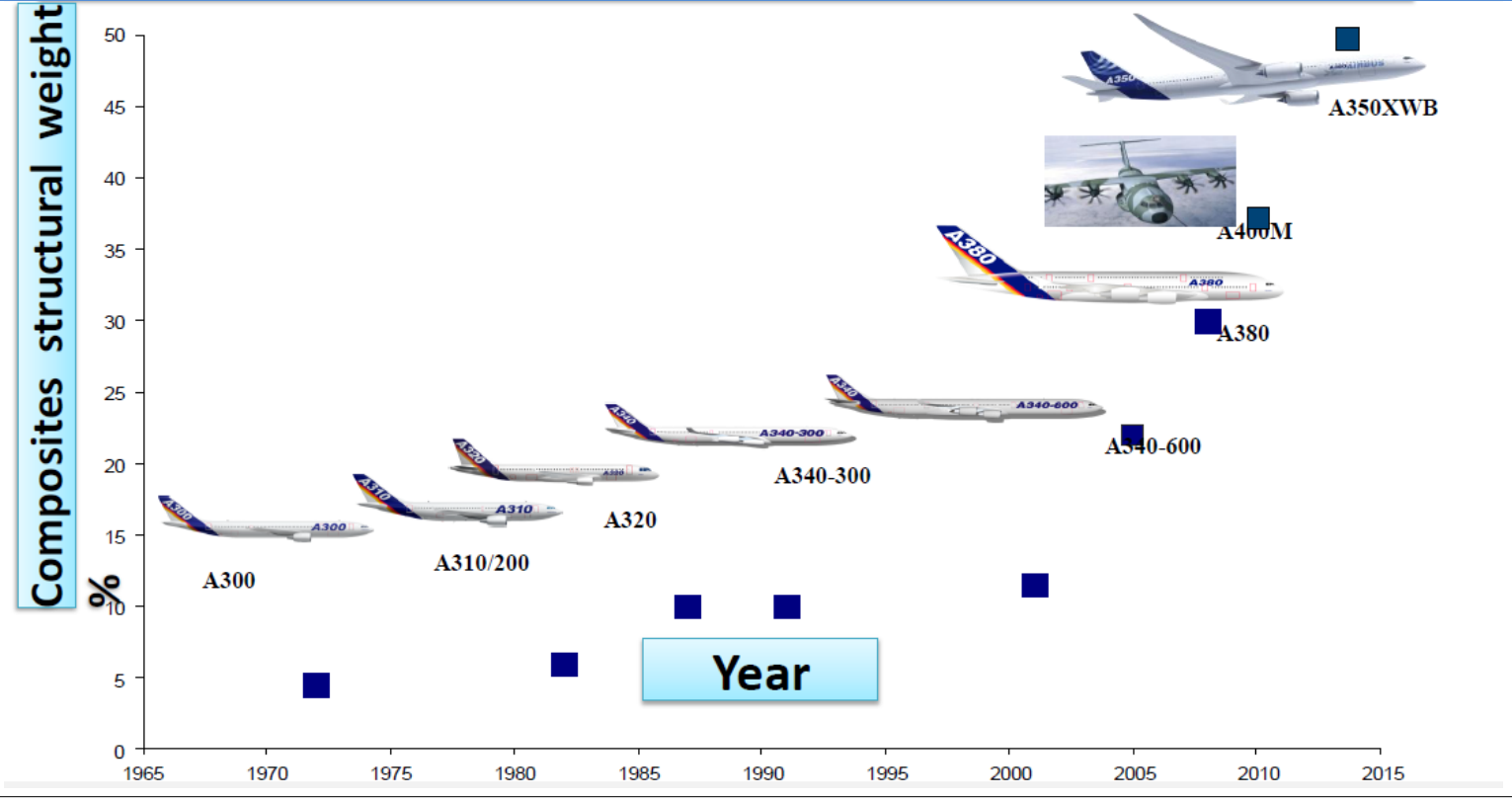
Oportunities for Composites in Transport

- Low density
  - 70% Lighter than steel
  - 40% Lighter than Aluminum
  - 35% Lighter than Magnesium Alloy
  - 50% Lighter than SMC
- Excellent strength-to-weight ratio (twice the specific strength and stiffness of steel)

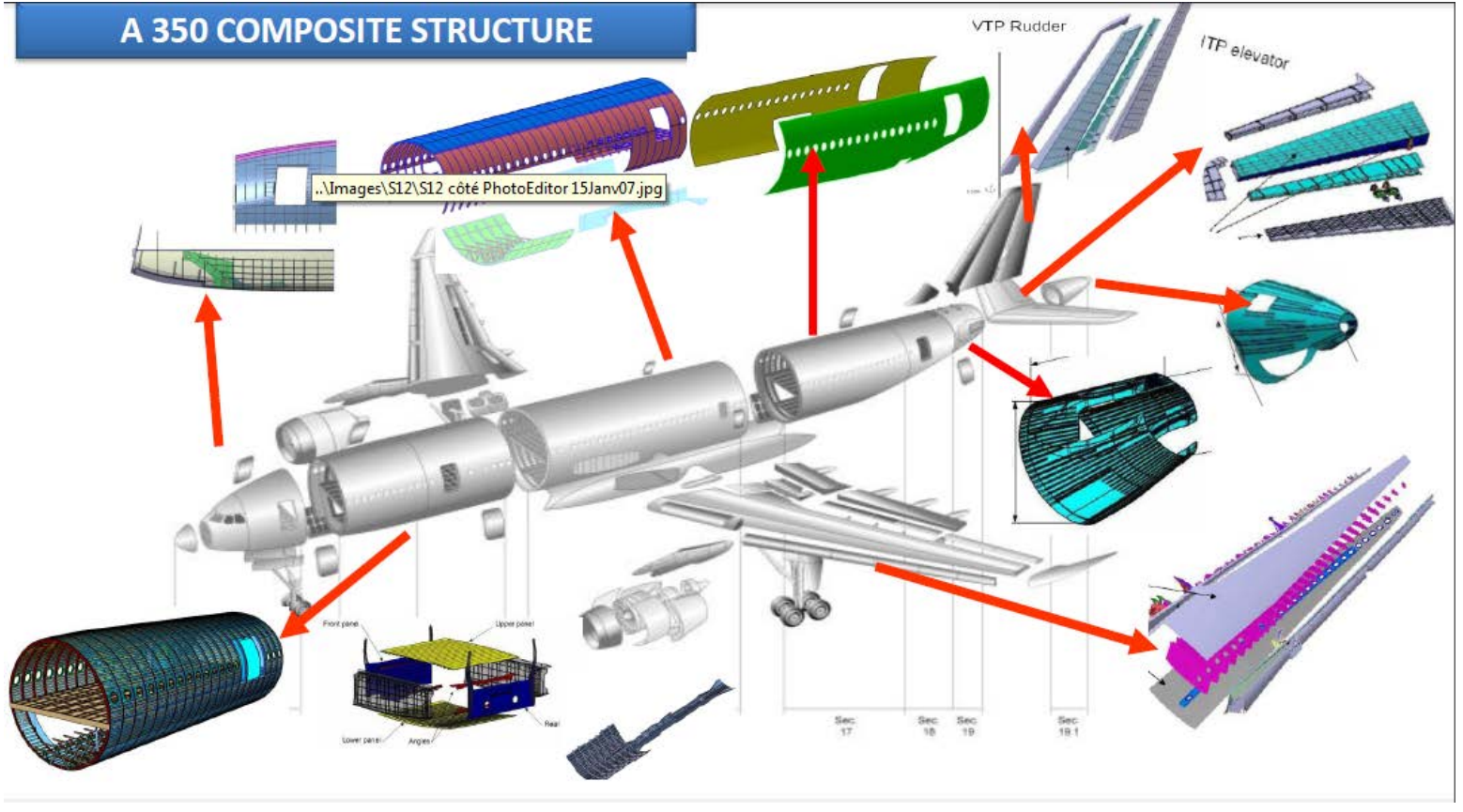
Every Kgr reduced in the total aircraft weight means a saving of 3500$/year in fuel. Current aircrafts' performance has been dramatically increased by the extensive use of CFRP.

Composites in Aeronautics. Background

AIRBUS AIRCRAFT COMPOSITES STRUCTURAL WEIGHT EVOLUTION

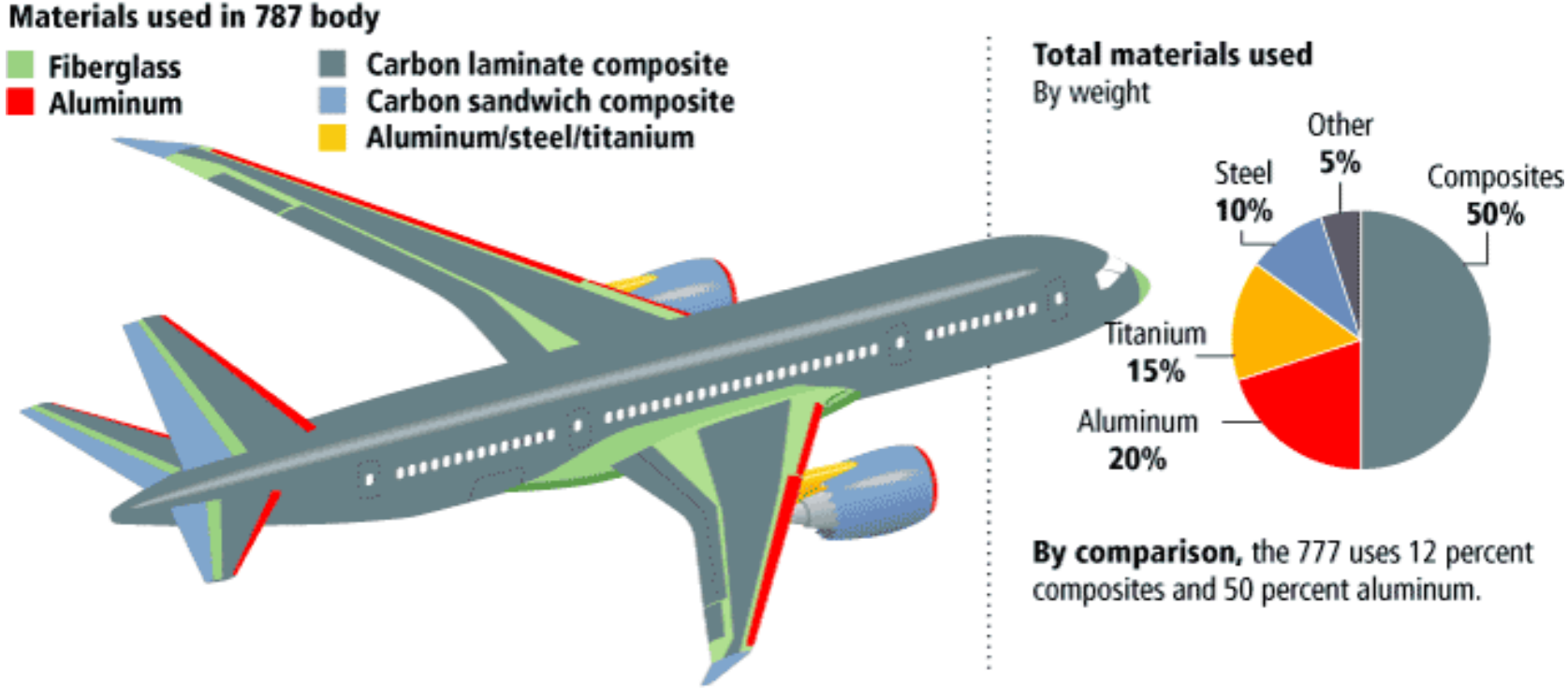


Composites in Aeronautics. Extensive use in Structures



Composites in Aeronautics. Extensive use in Structures

BOEING 787 COMPOSITE STRUCTURE



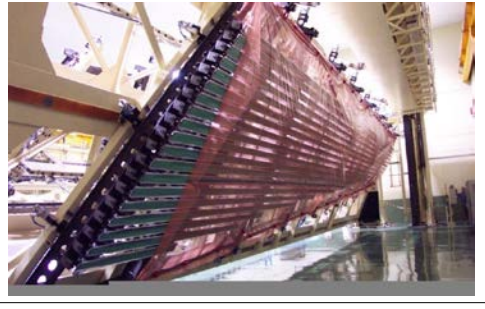
Composites in Aeronautics. From Manual to Automatic

Hand lay-up

Automatic cutting & ply positioning

Stringer Positioning

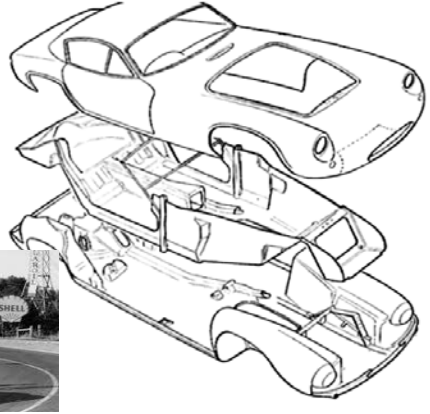
Automatic Stringer Positioning

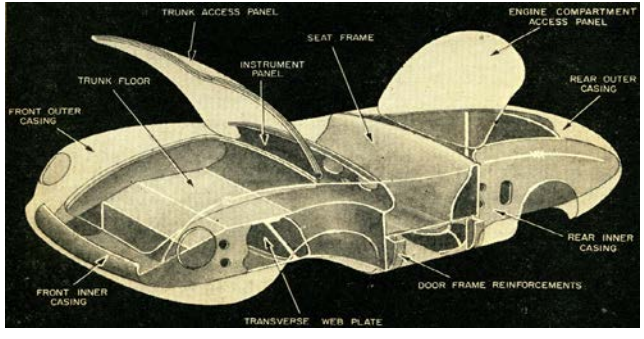


Composites in Automotive Structures. Background

- Lotus Elite is introduced in 1957 with full stressed glassfibre composite. (6 Le Mans category wins)

- Ferdinand Porsche received a patent on November 26th, 1957 for ***"self-supporting bodies of synthetic material for motor vehicles."***





Composite materials provide big advantages for vehicle's structure

Composites in Automotive Structures. Background

F1

McLaren 1981

McLaren F1 1993

McLaren Mercedes SLR 2003

VW Bugatti Veyron 2005

Manufacturing innovation for mass production

Toyota / Lexus LFA 2009

McLaren MP12C 2010

Audi / Lambo Aventador 2011

Large scale manufacturing (30000 units per year)

BMW i3 / i8 2013

Mass Production

Automotive Frontiers.

Since first application in 1981 up to now, nobody has manufactured more than 5000units in composite material. The BMW I3 is a step change for the future: manufacturing more than 30000 units/year

Composites in Automotive Structures. State of the art

The future is now: Carbon fibre composites for cars are already in mass production

Structural components market in US$

Leipzig Manufacturing Plant

- ***Production range:***

up to approx. 40,000 units in 2018-2019

(Source JEC)

Composites in Automotive Structures. New Opportunities

CO_2
Greenhouse gases

European Union legislation adopted in 2009 sets mandatory emission reduction targets for new cars.

Car manufacturers are obliged to ensure that their new car fleet does not emit more than an average of *130 grams of CO_2* per kilometer (g CO2/Km) by 2015 and *95g by 2020*.

http://ec.europa.eu/clima/policies/transport/vehicles/cars/index_en.htm

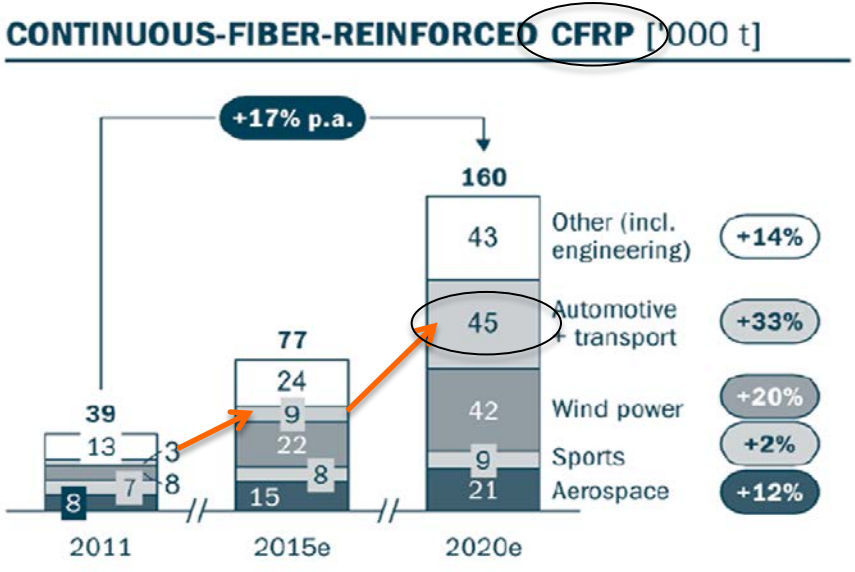
- **Increased Efficiency in Combustion Engines**
- **New Powertrain Systems**

Weight Reduction in Vehicles is a Must

Source: The Material and Energy Impacts of Passenger Vehicle Weight Reduction (September 2010)

Composites in Automotive. New Opportunities

- **WEIGHT REDUCTION VS**
- **EMISSIONS AND CONSUMPTION:**



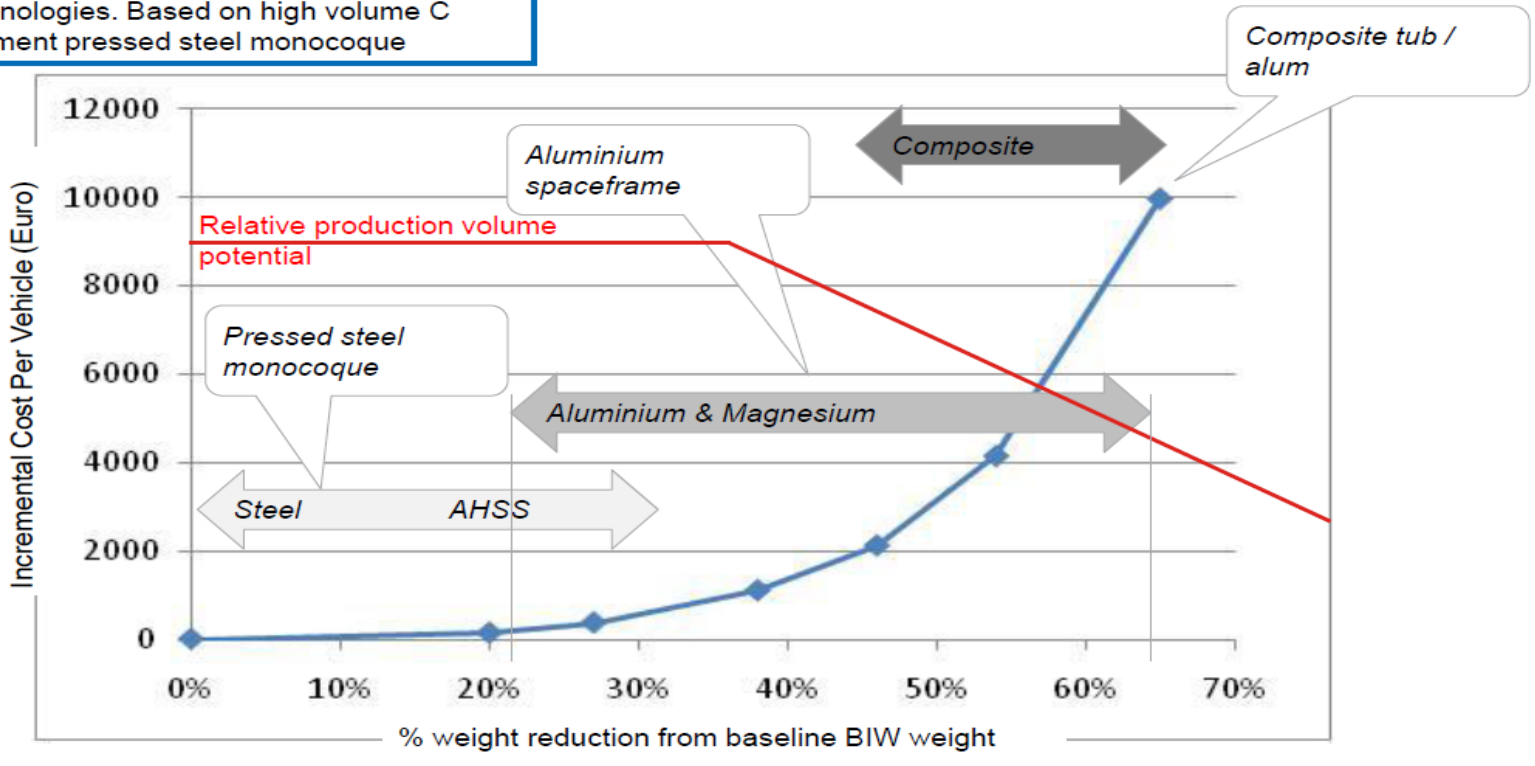
"10% reduction in vehicle weight can result in a 7% consumption improvement "

Fuente: The Material and Energy Impacts of Passenger Vehicle Weight Reduction, (September 2010)

- **"The market for high strength fiber reinforced composite will experience solid growth until 2020."**
- **"At a rate of 17% per year, demand made for CFRPs will grow significantly stronger than demand for GFRPS"**
- **"Currently, the use of CFRP in automobile construction is relatively low. Growth rates expected are much higher here than in other sectors"**
- *Source: Composites Market Report 2012*

Composites in Automotive Structures. New Opportunities

Estimated cost increase for BIW lightweight technologies. Based on high volume C segment pressed steel monocoque



Composites can provide up to 60% potential weight reduction, but today at a penalty cost of 10000€ /car

Challenges for Mass Production

… in addition to materials costs, there are other important factors that must be tackled …

- Raw **material cost** is today 20 times higher than acceptable, but this will change.
- **Process time** must be reduced significantly
- **Process cost** must also be cheaper (10 times less).
- **Design Criteria & Tools**
- **Quality and reciclability**

Challenges for Mass Production. Material Costs

Large improvements are needed to decrease costs by:

ASSUMPTIONS

Process

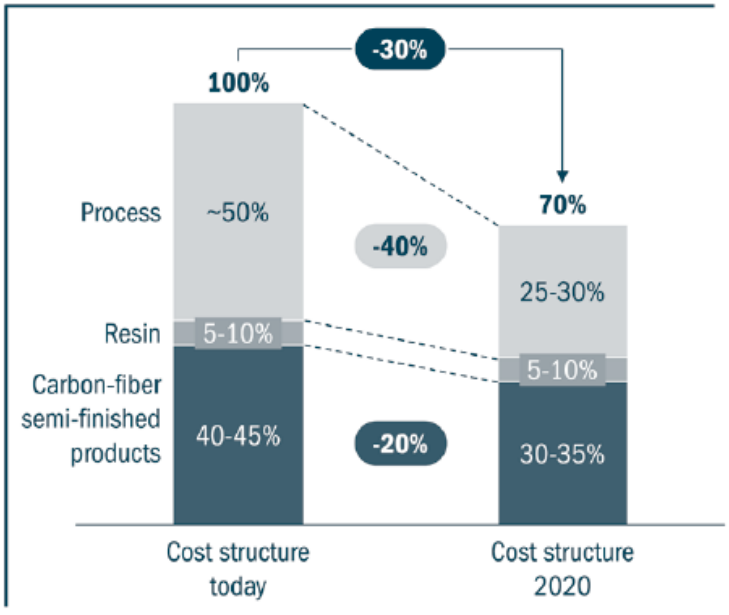
> **Process costs decrease by 40%:**
- Reduced cycle times due to enhanced resin properties
- Reduced labor costs due to sensible automation
- Process simplification

Material

> **Carbon fiber costs decrease by 20%** due to incremental improvements

> Costs for **resin** remain more or less **constant**

CARBON-FIBER REFERENCE PART IN 2020



Largest chances for cost reduction associated to improvements in raw materials, processes and finishing.

Challenges for Mass Production. Supply chain. Alliances

USA: Sport vehicles with composite movable parts

Corvette 2013, Teijin USA

DOW chemical

Toray USA

Japan: Toyota leading with Lexus brand. Rest of manufacturers not very active

Toray Japan

Teijin Japan

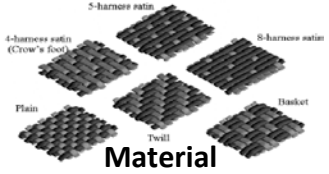
Asia: developing of composite for aeronautics

UK: McLaren Automotive, F1 Expertise

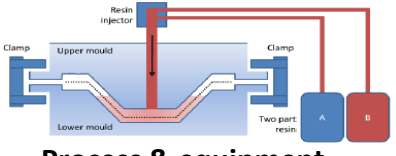
Italy: Significant background, small niche OEM´s and Tier 1, Lamborghini-ACRC, Dallara, ATR group

Austria: Carbotech, KTM technologies, for manufacturing of small series

Germany: Significant activity by BMW and AUDI, with collaboration SGL group



Material Manufacturers

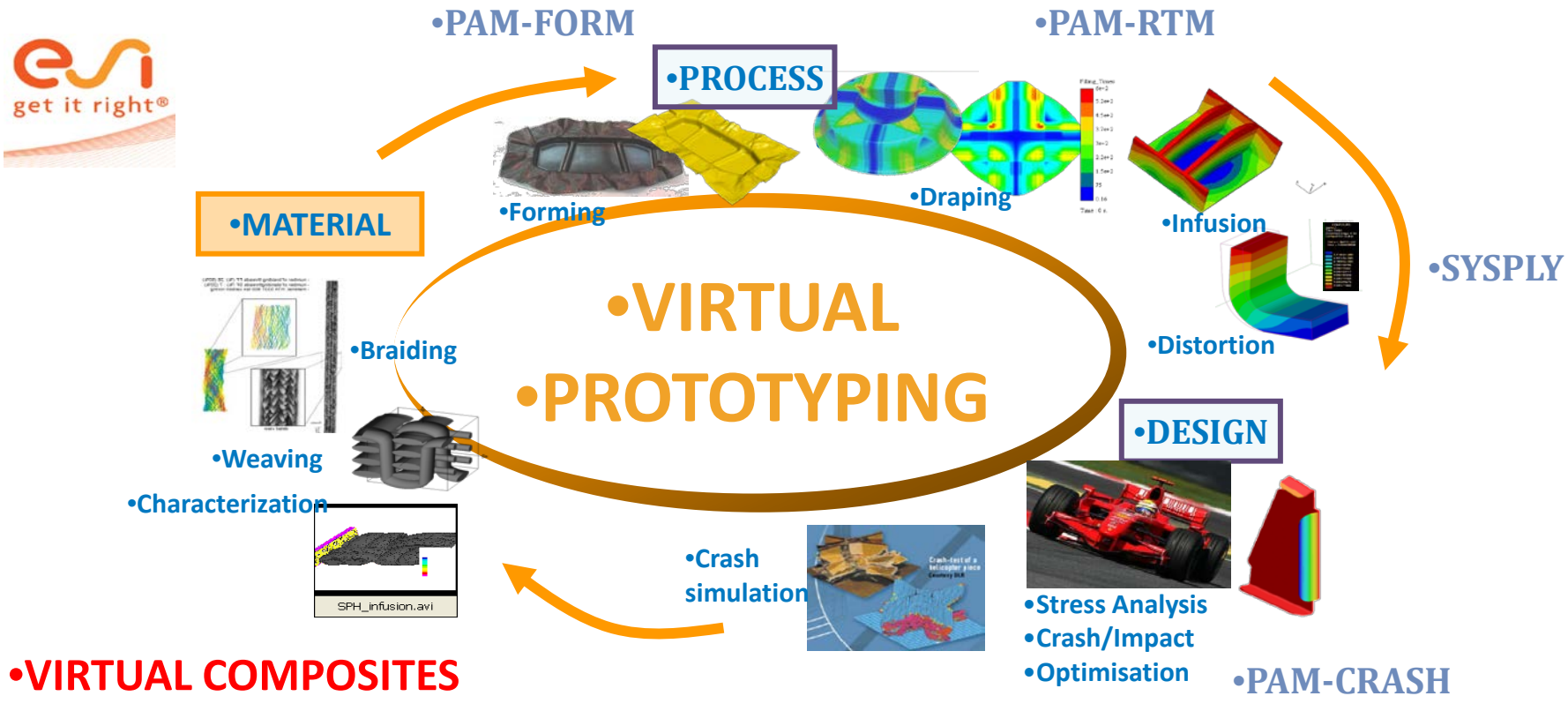


Process & equipment developers

Automotive Frontiers.

Large automotive OEMs are securing supply chain for future mass production of components in composites

Challenges for Composite in Automotive. Design Tools

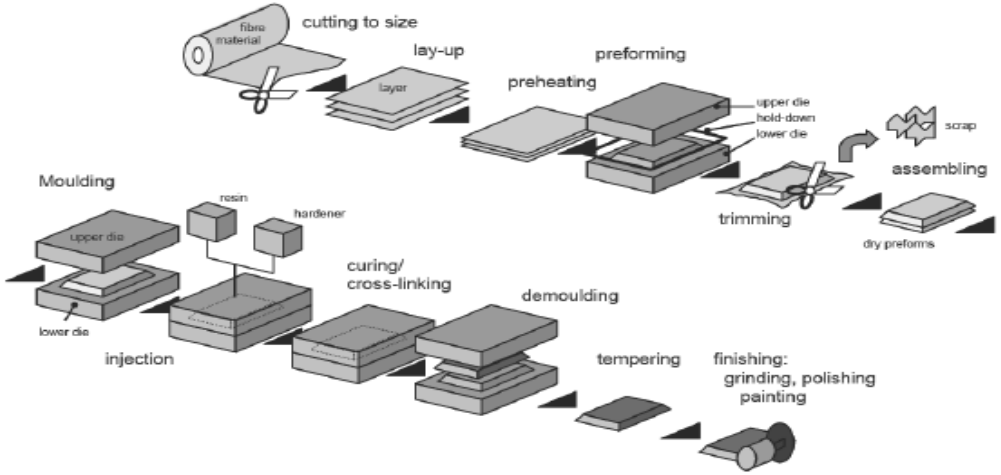


Existing CAD/CAE design tools widely used in aeronautic and automotive companies.

Challenges for Composite in Automotive. Sustainability

- Reciclability and sustainability is a must in the automotive industry. There is a need for new materials and processes to meet these demands.
- Thermosett composites difficult and expensive to recycle (resin and fibre separation) vs Thermoplastics, easily recyclable.
- Harmful organic volatile compounds released during manufacturing processes.
- Life cycle of components must be considered since first stages of design.

Approaches to overcome limitations. Thermosets. OoA



RTM versus Pre-preg

HIGH POTENTIAL OF RTM FOR PROCESS COST REDUCTION

Advantages and potential of RTM technology (Resin Transfer Moulding):

- Ability to produce complex integrated structures in "one shot"
- Use of cheaper raw materials with no shelf life limitations
- Ideal for serial production
- Potential for automation
- Reduction in energy consumption; heat placed just where needed
- Enables high level of integration in structure design

⇨ **COST REDUCTION**

Approaches to overcome limitations. Thermosets. OoA

Carbures' solution for high volume production

	ELEMENTS/YEAR*	APPLICATIONS
▪ INFUSION SILICON BAG	3.000-5.000	Non structural & decorative
▪ VACUM ASSISTED RTM	5.000-50.000	Non structural, decorative & structural
▪ RMCP	> 50.000	Structural

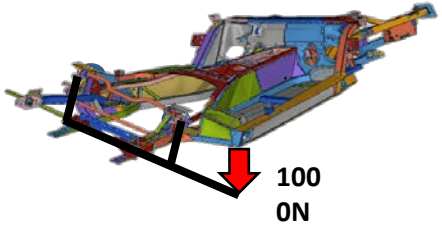
RMCP

Rapid Multi-injection Compresion Process

New manufacturing process out of autoclave. patented by Carbures. *Patent Nº (ES) P201230230*

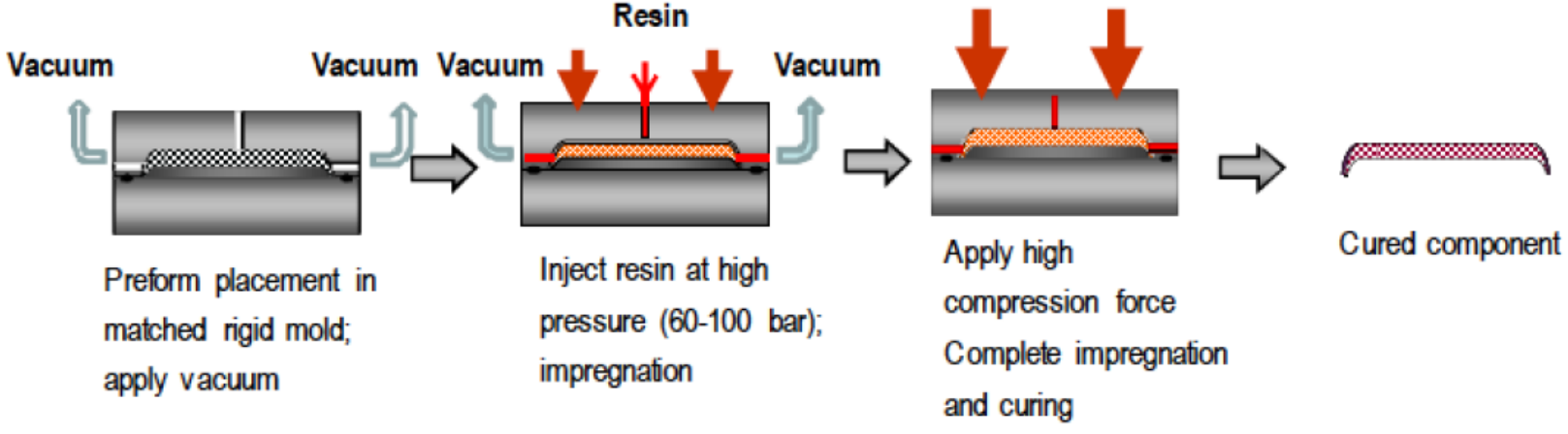
Approaches to overcome limitations. Thermosets. OoA

Carbures' RMCP reduces two hours in comparison to a conventional RTM



	RTM	RMCP
TOOL ADJUSTMENT AND HAND LAY-UP	25 min	5 min
RESIN INJECTION	35 min	4 min
RESIN CURE	90 min	4 min
RELEASE	10 min	2 min
	160m	**15m**

Approaches to overcome limitations. Thermosets. RMCP



ADVANTAGES

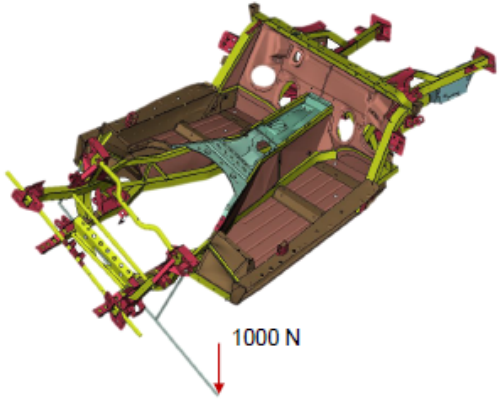
- Rapid mold filling
- Accelerated resin reactivity
- Excelent surface properties
- Low tolerance in thickness
- Improved quality
- Significant reduction of aire entrapments
- High process stability and repeabilit
- Use of internal release agent

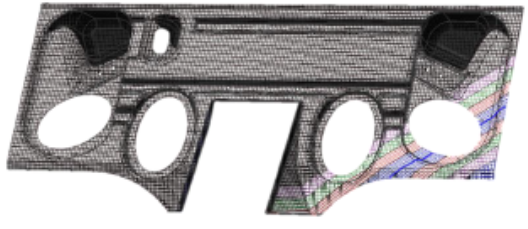
Carbures Automotive Projects

- The following structures were studied for a composite model:

- Target:
  - Reduce the weight of the assembly (by 50%)
  - Utilize advanced material in secondary structure of the vehicle
- Approach: Match/Exceed the strength of metal and match the stiffness of baseline model (steel)

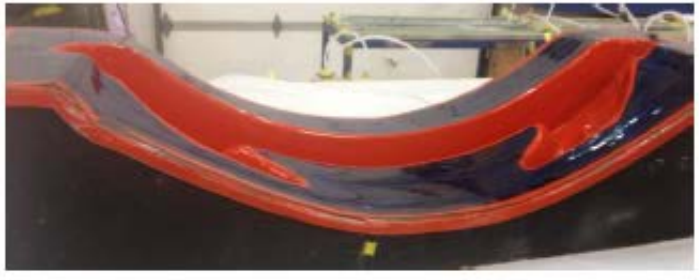
- Stiffness Ratio: 0.07%
- Total Weight of parts: 12.1 kg
- Weight Reduction: 54%

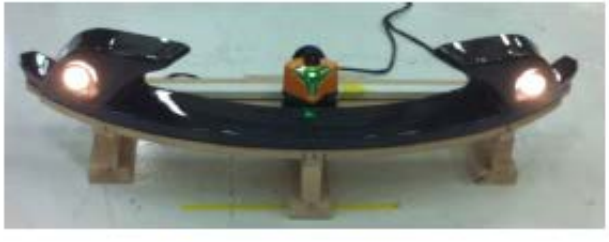




Carbures Automotive Projects

- Tesla Roadster
- Carbon lip and Shroud combo unit.
- Exterior part class A finish





Approaches to overcome limitations. Thermosets. OoA.

Tecnalia's solution for Automatic Dry Carbon Fibre Preforming.:

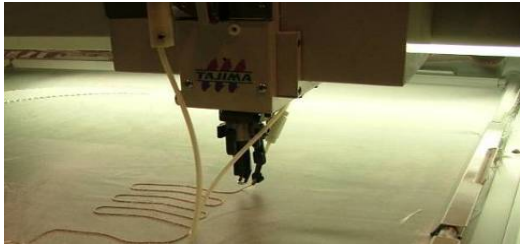
Preforming as a Key Process in RTM

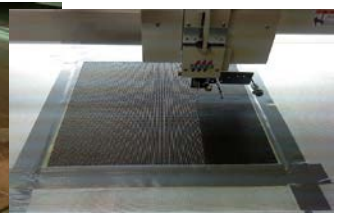
Technologies

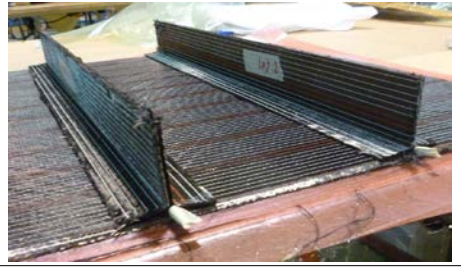
- Tailored Fibre Placement
- Stitching
- Hot forming with binders and veils

Applications

- High speed RTM, LRI, etc…
- Structures undergone to impact, high mechanical requirements
- Complex parts & geometries
- Self heated parts and tooling







Approaches to overcome limitations. Automatic Preforming

Approaches to overcome limitations. Automatic Preforming

Tecnalia's Approach with Robotic Solutions

FUNCTIONALITIES

- 2D fiber pattern handling (selection, picking, positioning, pre-draping, fixing).
- Binder activation
- Preform compaction
- Artificial vision for quality assurance

THE BENEFITS

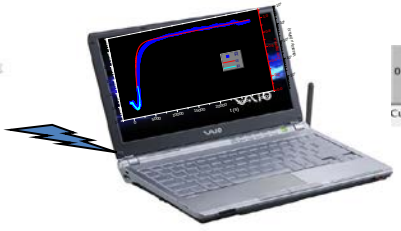
- FULLY AUTOMATED manufacturing of dry 3D COMPLEX preforms
- SHORT overall production CYCLE TIME, FROM SEVERAL HOURS TO MINUTES
- FLEXIBLE compactation system to provide a wide range of geometries to be addressed with the same system
- Enhanced QUALITY control and repetitivity
- Significant range and type of materials/ fabrics to be used including CF and GF preforms of different types
- LOW ENERGY CONSUMPTION due to selected heating implemented

Approaches to overcome limitations. OoA Process Control

Tecnalia's Approach for OoA Process Optimization, Monitoring & Control

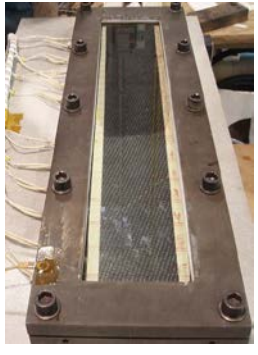
Target

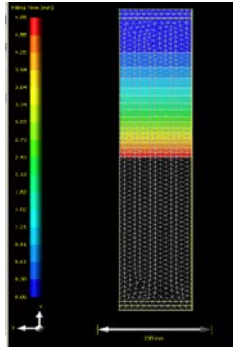
- Reduction of cycle time: Costs and energy saving
- Quality control



Technologies

- Real-time monitoring (control software)
- In-mould integrated sensors and HW for interrogation
- Process modelling





Manufacturing Processes

- LCM processes (RTM, infusion)
- OoA prepreg novel curing techniques

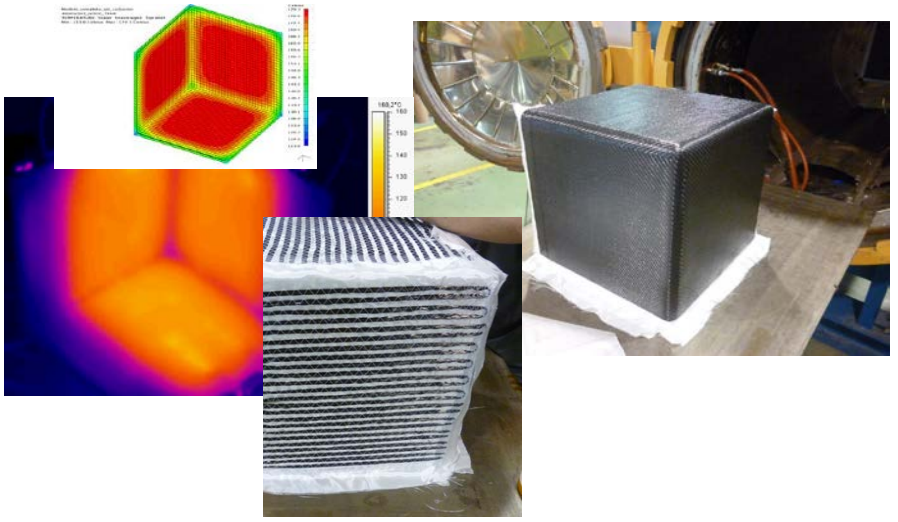
Approaches to overcome limitations. OoA Process Control

Tecnalia's Automotive Demonstrators

Audi Fender by SOTIRA, Fr

Process: RTM

Tooling for Composite Manuf.



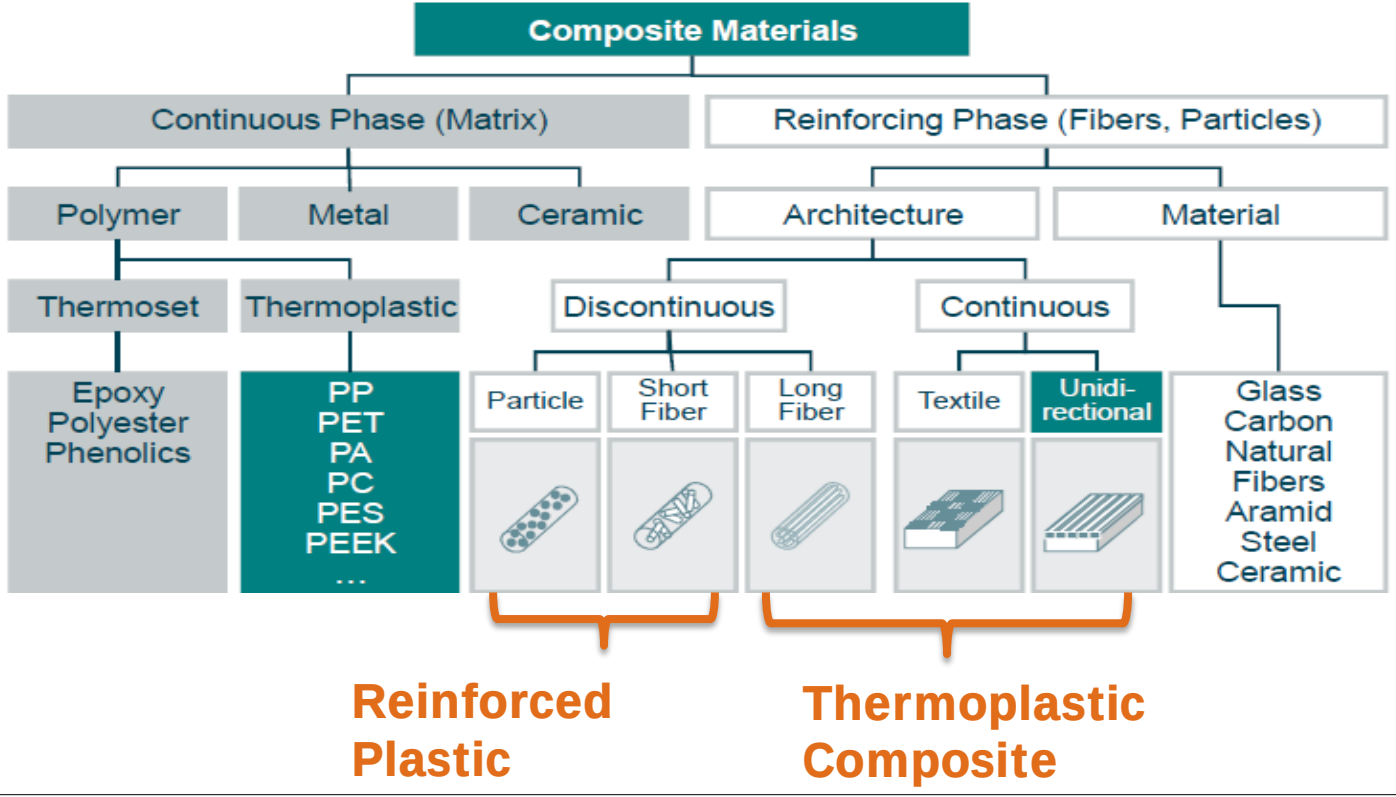
Approaches to overcome limitations. Thermoplastics

Thermoplastic Composites Contribution to Structural Automotive Applications

- Manufacturing Processes Automation
- Weight Reduction/fuel saving
- Lower raw material costs (ej, Epoxy vs PA6)
- High capability for multifunctional integration in a single part
- Excellent Crash Performance
- Welddability
- Recyclable. Meet European Automotive Standard (2000/53/EC-End Life of Vehicles)

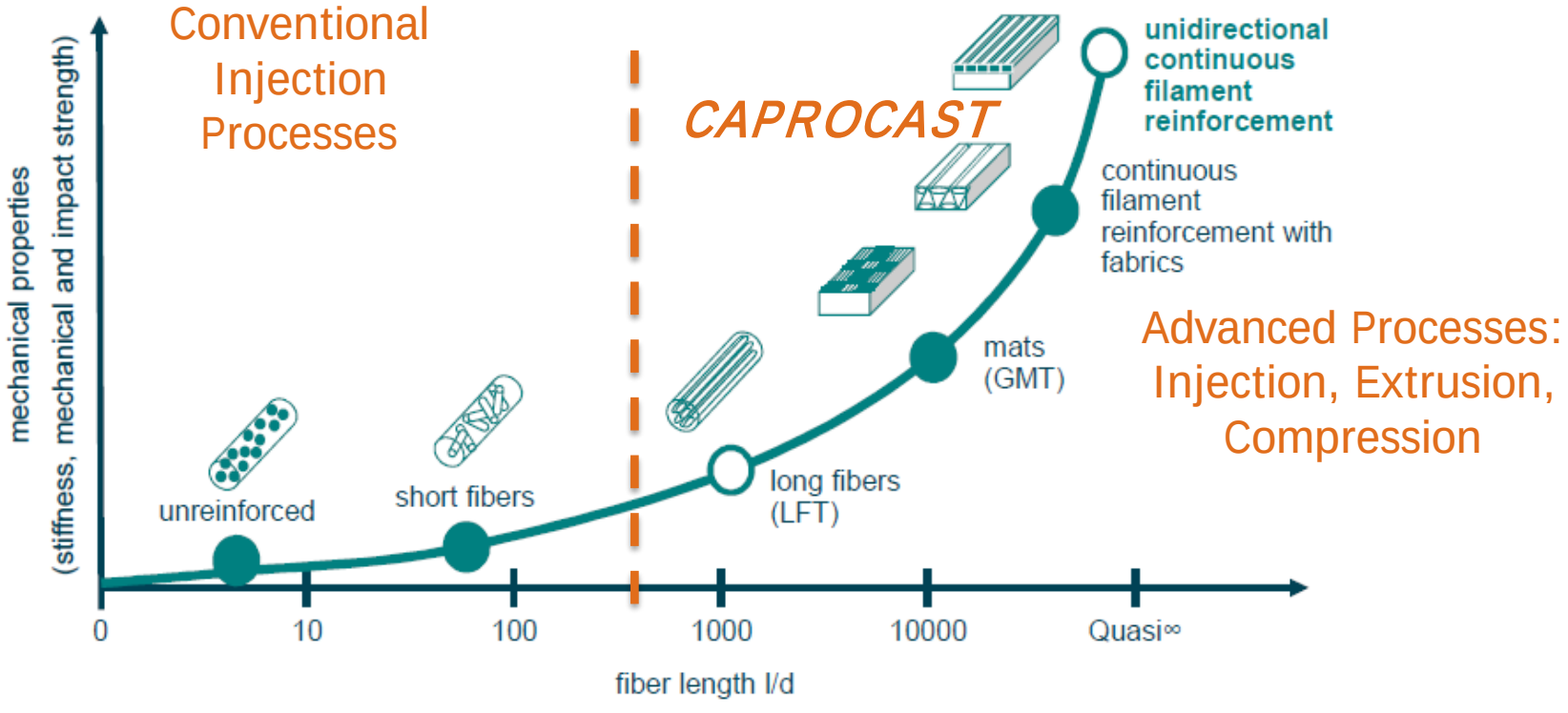
Approaches to overcome limitations. Thermoplastics

Thermoplastic Composites Contribution to Structural Automotive Applications



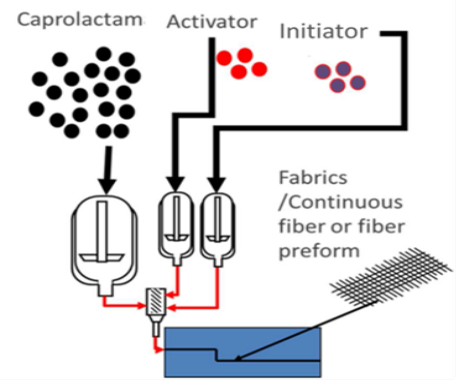
Approaches to overcome limitations. Thermoplastic RTM

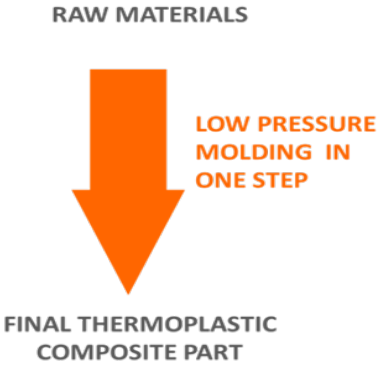
Tecnalia's approach for TP Composites: Thermoplastic RTM. CAPROCAST



Approaches to overcome limitations. Thermoplastic RTM

CAPROCAST Process Description:





Process parameters:

- ❖Dry monomer : >0.04% humidity
- ❖Melting temperature : 70ºC<Tm<140ºC
- ❖Raw materials during the process under inert atmosphere
- ❖Laminar flow during de mould filing
- ❖Mould temperature: 155ºC< Tmold <190ºC
- ❖Mould general characteristics:

3 Patents on the process and manufacturing devices

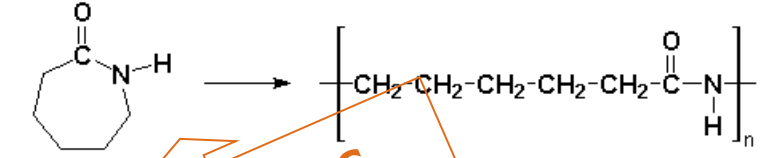
Approaches to overcome limitations. CAPROCAST

•ε-CAPROLACTAM
•Monomer PolyamideA 6

+ •Activating
+ •Catalyst

= •POLYAMIDE 6
•(NYLON 6)

Molecular Weight:	113,2 mol/g
Boiling Temp.:	267° C
Melting Temp.:	70° C
Viscosity at 70°C:	10 cps
Density:	1,02 g/cm³
Flash point:	125° C
CAS number:	105-60-2



•Liquid at 70ºC

•Anionic Polymerisation of Caprolactama to form Polyamide 6

- Very low viscosity monomer > Easy infiltration of fibre preforms
- Composite material component is produced inside the mould
- High percentage of structural reinforcement can be achieved

Approaches to overcome limitations. CAPROCAST

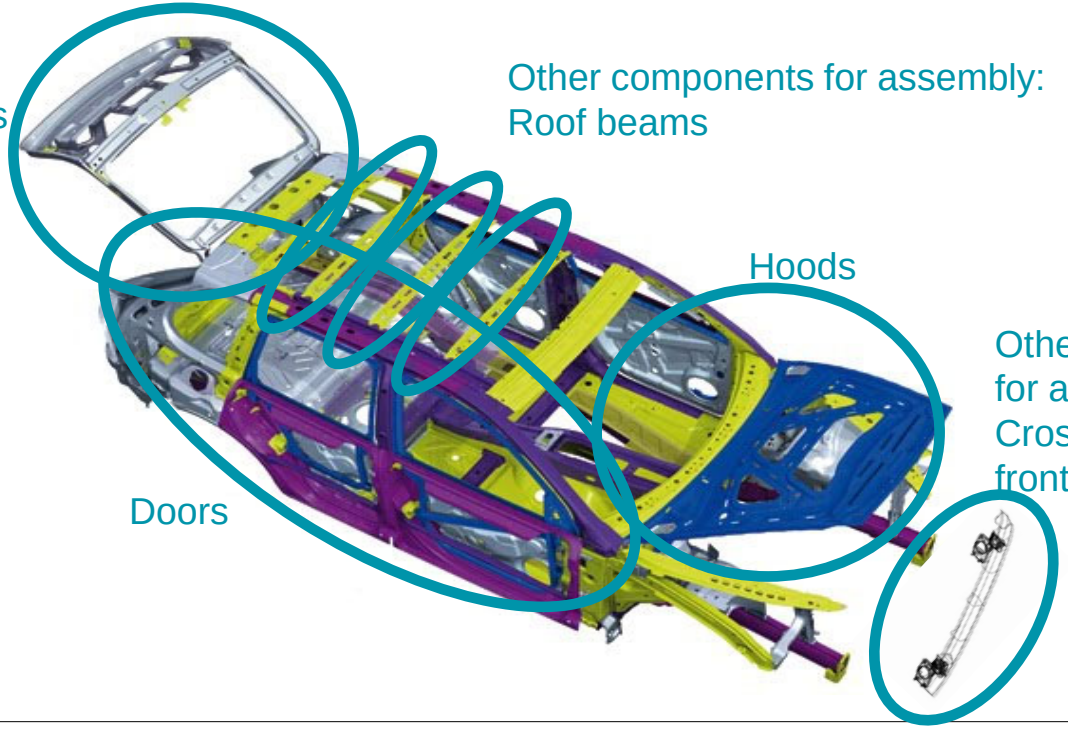
High Potential for Production for:

- Small structural components out of assembly line: 10Kg
- Closures and large structural components for assembly line: 70Kg

Rear Doors
and bumpers

Leaf Springs

Fenders



Other components for assembly:
Roof beams

Hoods

Other components
for assembly
Cross beams,
front bumper…

Doors

Conclusions

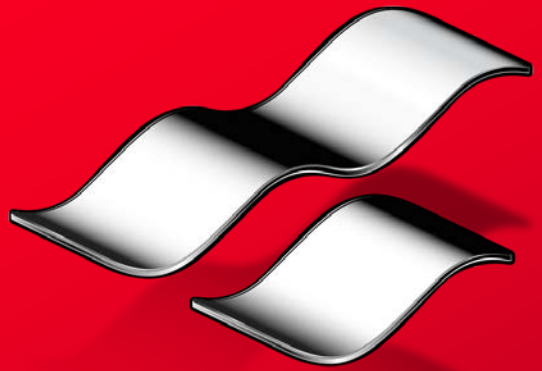
- Composite materials represent an **huge potential for business opportunities** in the automotive sector, where weight reduction is a must to meet future regulatory demands for lower CO_2 emissions of cars.

- For many years composite materials have been used for interior and non critical components in the automotive sector, but today there is a strong tendency to introduce **composite materials in structural applications**, looking for a significant weight reduction.

- However, there is still a **large room to improve processes and reduce costs** to meet demands of OEMs for typical mass production of automotive components.

- Some **technological manufacturing solutions for mass production of thermoset and thermoplastic composites** have been showed in this presentation, but many more are yet to come in order to see a massive introduction of composite materials in structural components of future cars.

Javier Coleto: javier.coleto@tecnalia.com
Pablo Martínez: pablo.martinez@tecnalia.com
José María Tarragó: josemaria.tarrago@carbures.com



¡MUCHAS GRACIAS!

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