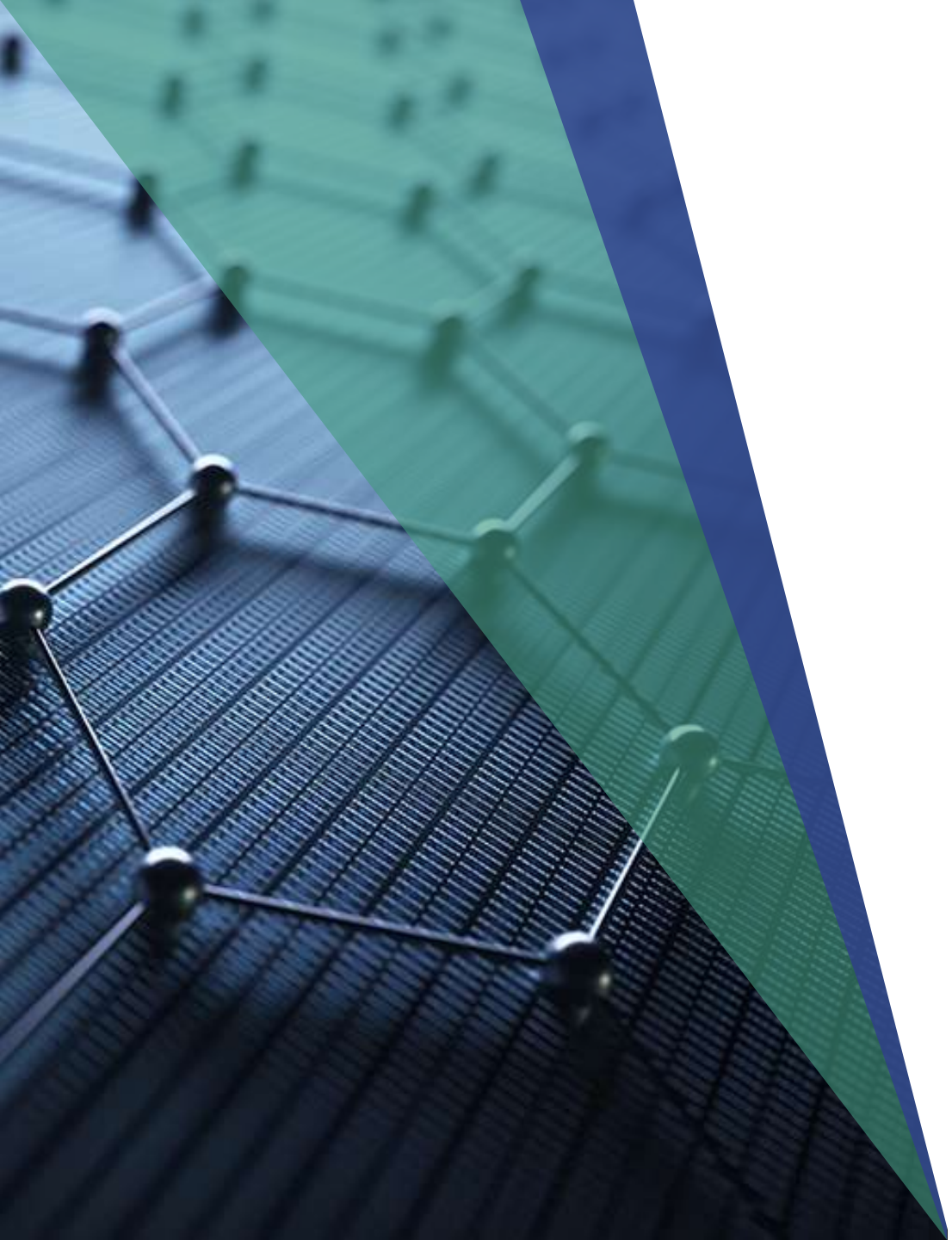

GIANCE

Fused with Sustainability

Graphene reinforcement of Circular Recyclable Crosspreg®, reactive, mass productive, composite

Crossfire

GRAPHENE FLAGSHIP

UK Research and Innovation

Funded by the European Union

This project has received funding from the European Union's Horizon Europe research and innovation programme under Grant Agreement No 101119286 and UKRI under Grant Agreement No 10090645 and No 10101683.

Development made in cooperation with the following GIANCE partners :

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Reducing Energy Consumption in Mobility

Less Weight = less Energy to move it

What's lighter than Composites ?

Graphene reinforced Composites !

Crossfire, together with the GIANCE partners, went developing the Chemistry and the Industrial Methods to add Graphene in Crosspreg®, an innovative reactive hybrid TP/TS resin, and get important Mechanical Reinforce improvements, while keeping the already existing Circular Recyclability, Mass Productivity and low LCA characteristic aspects of Crosspreg®

Crosspreg® is a Crossfire proprietary brand

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Crosspreg® in a glimpse

- Solid and stable Powder at RT …… no Solvents, no VOCs emissions
- Melts down by heat, at below the capillarity level of viscosity (100mPa/sec)
  - Impregnates the fabric by capillarity, and wets it perfectly …… sizing like
- Cures at isothermal conditions (160-180°C) in a very few minutes (3-10)
  - Ideal for a close moulding transforming at low pressure
    - Lowest investment costs
    - Low energy costs
- Thermoplastic behaving over its Tg
  - Easy/quick thermoformable at about 180°C
  - Repairable cured by prepreg Crosspreg® over curing
- Thermoplastic and metal bonding while curing
  - Polyesters/PP, Steel/Aluminium, Wood/paper, …
- Circular Recyclable EoL
  - The secondary RM obtained has its Value higher than the recycling cost

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Graphene inside Crosspreg®

- Crossfire developed a method to add Graphene, as any 2D material, to Crosspreg®, from its aqueous dispersion (Patent Application in progress) to a clean, no dust, industrialization
- A Crosspreg® , Graphene added solid, RT stable, reactive powder is obtained

- GIANCE UC1 and UC2 cases asked for the Lightweight in 2 automotive (Stellantis) parts
  - UC1 asks for a Cheaper and Lighter solution than the current SMC withy carbon
  - UC2 asks for a Super Lighter and cost competitive solution than the current steel

- The Crossfire decision was to utilize the minimum amount of Graphene (to avoid the known mechanical parameters drop by adding fillers) and have it chemically bonded to the resin/fabric composite system, to increase the mechanical parameters
  - The Graphene chosen grade is Graphenea GO (Graphene Oxide)
  - Its Carboxylic functionalization, is highly compatible with Crosspreg® and with the Glass Fabric microrough surface activity
  - The key question is about taking the GO particle in contact with the Glass fabric microrough surface ….. It fits for Crosspreg® !

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The Development basic inputs

- Fix the low viscosity level of the molten resin ……. Average low (70-80 mPa/sec)
- Add the GO % balanced on the Carboxyl bonding availability in the Resin/Fabric composition (internal Know how) fixed at 0,2% of the total resin weight
- Laminate the GO added resin on a GF UD600gsm
- Cure a 5 layers layup to build Testing plates (400x400x2mm)
  - Cure another 5 layers plate without GO on the same GF UD600gsm
  - The resin/GF ratio is 50/50 in volume or 600/300 gsm in weight

- Run quick verification at the internal 3-point Load/Deflection test, with and without GO in comparison
- Run the complete product card at the Giance Consortium dedicated partners
  - Eurecat for a quick beginning phase screening
  - Fraunhofer – Darmstadt for the Hot/RT/Cold and ageing testing
  - CRF for the final Cards

- The data went used to FEM simulate both UC1 and UC2 and decide the real parts layup

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Some initial laboratory data

- 3-point Load/Deflection
  - 150x30x2,2mm specimen
  - 100mm span
  - **Crosspreg GO GUd600 x 5 layers**

	Reference	0,2% GO
Deflection (mm)	22	17
Load (kN)	0,206	0,303
E Modulus (N/mm2)	46639	54367

- **Load …….. about 50% higher**
- **Deflection …….. about 20% lower**
- **E Modulus …….about 16% higher**

But the Tensile tests did not show any improvement

Why ?

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The GO chaining theory

- The very low viscosity of Crosspreg® drives the GO particles toward the Glass fabric and enters in contact (wet) with its active fibres surface roughness by capillarity
  - A better fibre wetting is demonstrated by the cured specimen NO water absorption
- The GO carboxyl get in contact and react with the fibres and/or their Organosilane sizing
  - One way or the other, GO chains with the Glass
- And the Crosspreg® resin also gives GO other possibilities to chain with its Epoxy component

- The result might be an incremented fibre/resin chaining, demonstrated by the Load/Deflection sensible improvements. The next coming Shear Tests will give us the possible confirmation of this theory
- The Tensile testing of a UD composite is dominated by the pure UD tensile strength

- Another parallel trial made by the same composition added by 0,2% of Nanoplateles Graphene gave no effect, on the 3-points Load Deflection

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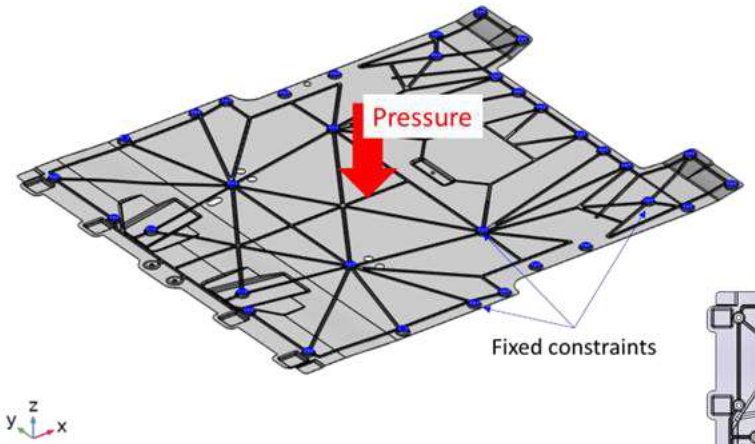
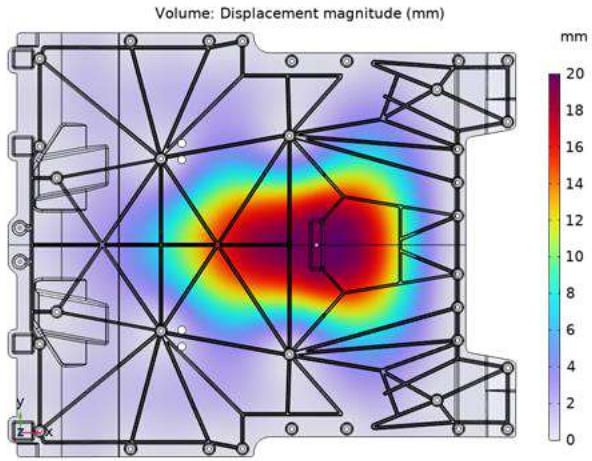
GIANCE UC1 – the aerodynamic shield of Maserati Levante

Current release





1310 mm

1565 mm

Carbon SMC 57% chopped carbon

- Flex Modulus 30500 Mpa
- Load to break 460 Mpa
- Max displacement 20mm
- Resonance frequency 25,6Hz
- Total weight 4,6Kg
- Cost/unit 170€

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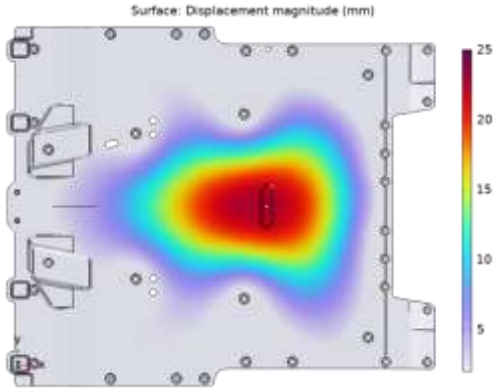
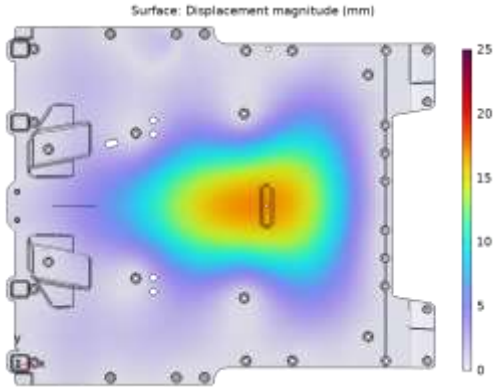
Scanning solutions



4 layers of UDG600
Flex Modulus 54300 Mpa
Load to break 1,2GPa
Max displacement 22,3 mm
Resonance Frequency 19,2 Hz

Total weight 6,6Kg
Cost/Unit 160€



1 layers/side of Bi-axial G600 +PET foam
Max displacement 17mm
Resonance Frequency 29,5Hz

Total weight 5,1Kg
Cost/Unit 140€

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GIANCE UC1 – the aerodynamic shield of Maserati Levante

Crosspreg® GO The Cheapest solution

- **CrosspregGO-G500Bx Black**
- 2 Bi-axial G500g + 500g Resin with 0,2% GO
  - PET150-5 from bottles recycling as core
    - Total part weight 4,5Kg
    - Total unit cost 120€

- **Low investment** :
  - 100t press, isothermal operation, automated feed and pickup
  - Short curing cycle (5min) ; no post-cure
  - Ready to be assembled on vehicle

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GIANCE UC1 – the aerodynamic shield of Maserati Levante

Circularity

- **Circular Recyclable**
  - By Glycol Solvolysis, to full recover of Resin Monomers and fabric, both to reuse
  - Graphene remains either in the solvent and in the monomers (no dust release)

- **Circular Re-usable**
  - The cured part can be thermoformed to produce another component
  - Heat up to about 190-200°C
  - Close and shape in a RT mould ; just a few seconds

- **Circular repairable**
  - The cut part, after cleaning, can be repaired just by curing over a sized Crosspreg®GO GBx500 black prepreg. The Cured surface is reactive to a new curing operation, and the part gets consolidated

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Improving the stone chipping resistance

- GIANCE Project have set 2 methods
  - **Spray coating** of a Graphene enhanced surface glassy reinforcement by Nanoprom
    - It targets the Surface Hardening and the Surface Tension lowering (improved Cx and cleanliness)
  - **Addition, in the curing phase**, of a 200um thin Metallocenic PE film
    - It chemically bonds Crosspreg® in the curing phase
    - It's highly resistant to scratch and chipping

- Both methods/additions don't affect any aspect of Circularity

- The Proto mould is close to be ready, and the Experimental Moulding days are fixed in the 7-8th of October

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Material cards

A full characterization testing is in process with the aim to check :

- The Thermal Shock to detect eventual delamination or cracks
- The accelerate Ageing by thermal Cycling
- The Impact at Cold temperature
- Water absorption and humidity pickup
- Het ageing
- Dimensional stability under thermal and hydro stresses
- Burn resistance according to the relevant Norms
- Chemical Resistance at typical automotive fluids

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Crossfire and Graphene

- **A Great Discovery !**

- Initial semi-industrial volumes of Crosspreg®GO-G can already be processed and supplied
  - Works with Carbon, Pyrolysis recycled Carbon, Natural fabrics, Aramide are in progress

- But not only Graphene for mechanical reinforcement !
  - Conductivity, EMI shielding, Ballistic, Surface hardening, Electronics …….

- The Graphene active inclusion in our resin system is ongoing and semi-industrial already

- New Developments are already in place with other Graphene grades and other 2-D materials like Mxene and Boron Nitride

- We are ready to run new customers dedicated developments

- **Thanks a lot, to GIANCE and the Graphene Flagship**

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Thanks for listening!

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October 2023