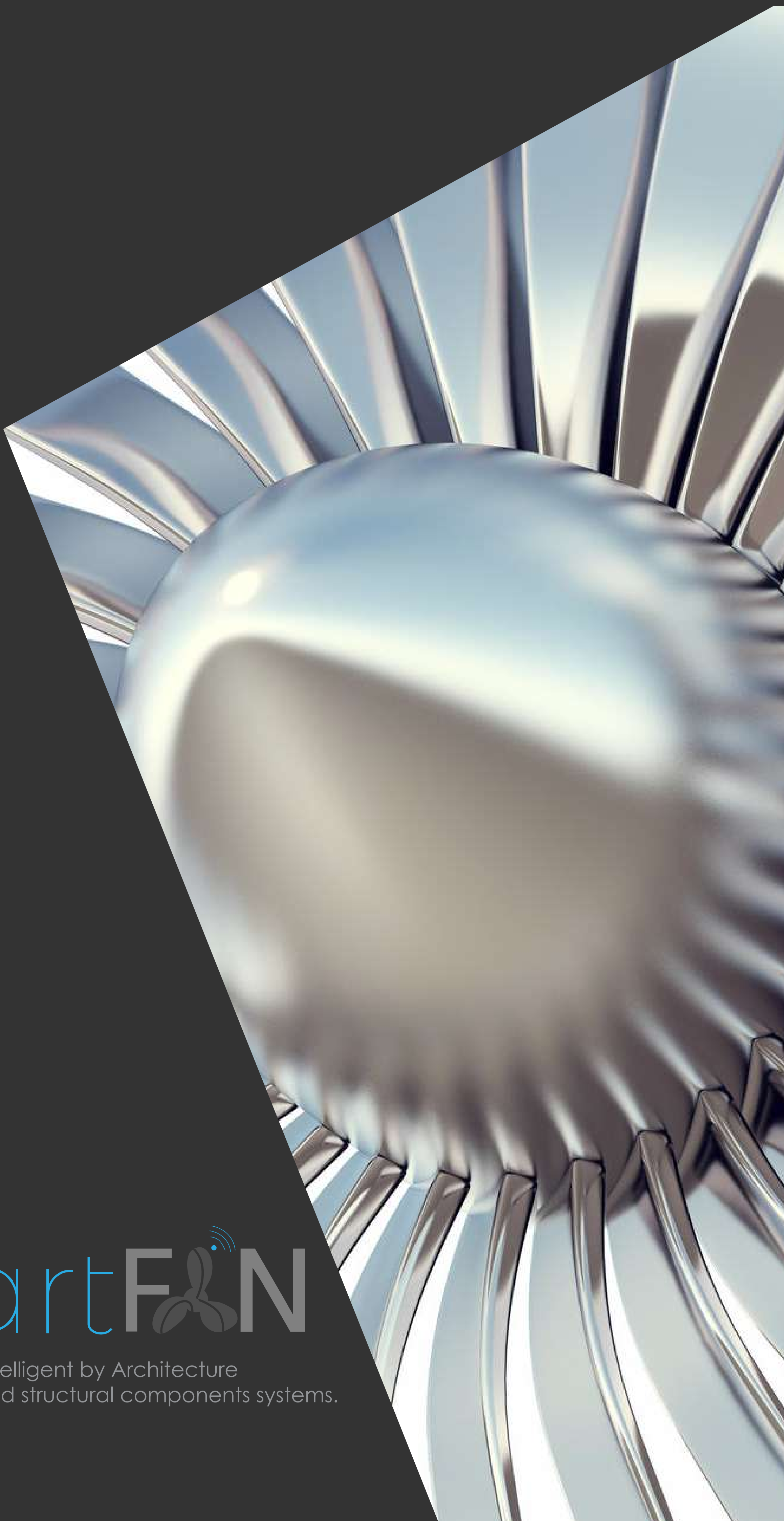


Volume 5

SmartFAN

Smart by Design and Intelligent by Architecture
for turbine blade fan and structural components systems.

Partners

1.National Technical University of Athens (**NTUA**)

2.Warrant Hub SRL (**WG**)

3.Association pour le Developpement de l'Enseignement et des Recherches Aupres des Universites, des Centres de Recherche et des Entreprises d'Aquitaine/CANOE Platform (**ADERA/CANOE**)

4.Dallara Automobili SPA (**DAL**)

5.Instituto Tecnologico De Aragon (**ITAINNOVA**)

6.Elica SPA (**ELICA**)

7.Foundation for Research and Technology Hellas (**FORTH**)

8.Innovation in Research & Engineering Solutions (**IRES**)

9.Techedge GMBH (**TECHEDGE**)

10.Inegi - Instituto de ciencia e Inovacao em Engenharia Mecanica e Engenharia Industrial (**INEGI**)

11.Politecnico di Torino (**POLITO**)

12.Thales SA (**TRT**)

13.Universita Degli Studi di Roma Tor Vergata (**UNITOV**)

14.The University of Birmingham (**UoB**)

15.3D NewTechnologies for medical and non-medical implementations (**BIOG3D**)

16.Open Source Management Limited (**OSM**)

17.Stratosphere (**Stratosphere**)

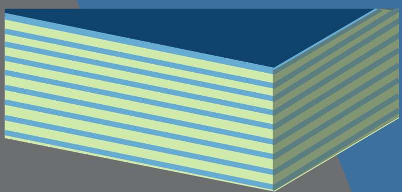
18.Lavrion Technological and Cultural Park (**NTUA /AMDC**)

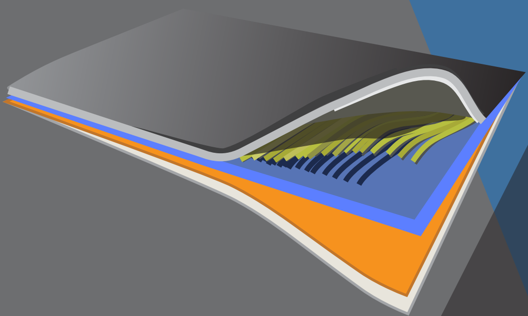
SmartFAN Framework

Smart by Design materials

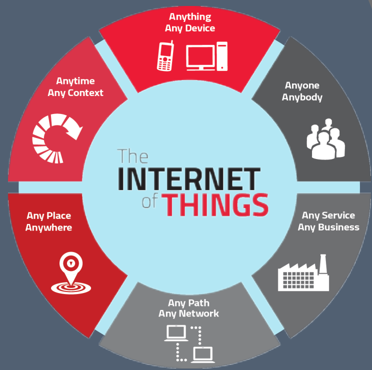
- Self-repair or self-healing materials
- Material for vibration suppression
- Lightweight composites
- Internal damage and process history
- Shape change
- Energy storage
- Functionally graded composite materials (FGCMs)

... now





SmartFAN L&G Concept



- Advanced sensors (nanosensor technology)
- Damage detection
- Self-repair, Self-actuation
- Self-sensing, Self-morphing
- Magnetic functionality (for non-magnetic materials)
- Optical functionality
- Sound and vibration damping
- Thermal management in ICT

Intelligent by Architecture structures

Fabrication of large surface electrodes for supercapacitors using spray-gun deposition method

THALES

During the last six months, TRT in collaboration with FORTH was able to spray mixture of Graphene nanoplatelets (GNP) and Carbon Nanotubes (CNTs) on a large surface (30cm x 30cm) of commercial aluminum collectors.

Electrodes obtained through spray-gun deposition method of GNTS/CNTs

It is the first time that a deposition by spray is performed on a so large surfaces. This state-of-the-art technique will be implemented on the new roll-to-roll machine that will be delivered. Thanks to that, an industrial production of low-cost supercapacitors can be predicted in the next two years.

In the next months different mixtures of GNP and CNTs will be tested in order to define the best compromise in term of capacitance and power delivered.

In the frame of SmartFAN this technology will be implemented also for spraying on fabrics in collaboration with NTUA and FORTH for automotive applications. This work is in progress.gress.

FORTH

Micro-capsules for self-healing and self-sensing

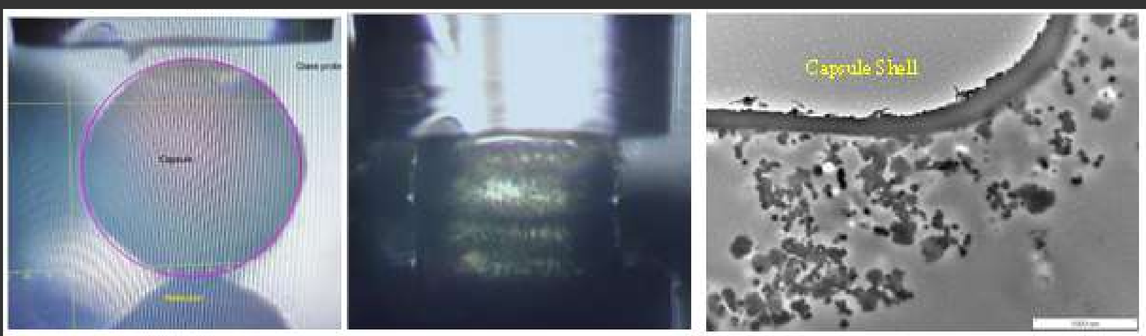
One of the main tasks of FORTH during M25-M30 period was the production, characterization and provision to SmartFAN partners of Self-healing capsules (SH).

To evaluate the healing effect of self-activated samples fracture toughness test was also performed (up to 50mm displacement). The modified CFRP samples presented the same mechanical behaviour as the neat (virgin) samples.

For the modified specimens, at the end of the first loading, they restored to their initial status (zero loading) and left to heal for 48 hours. The results were promising as the modified specimens reached an average 80% of their initial maximum load.

SH synthesis, SH optical microscope characterization, Single SH capsule

Furthermore, the mechanical properties of self-sensing microcapsules fabricated by ITA have been evaluated by a micromanipulation technique at UoB. Single microcapsule with a diameter up to 200 μm was placed between two parallel surfaces made of a force
transducer probe and sample stage of a
microscope to a given deformation or rupture at a pre-set speed, and the force imposed on the microcapsules was measured simultaneously.
Multiple capsules are randomly selected for the compression test and the statics result are used to analyse the relationship of rupture force, displacement and stress with the size of the capsules



Microcapsules for self-sensing testing

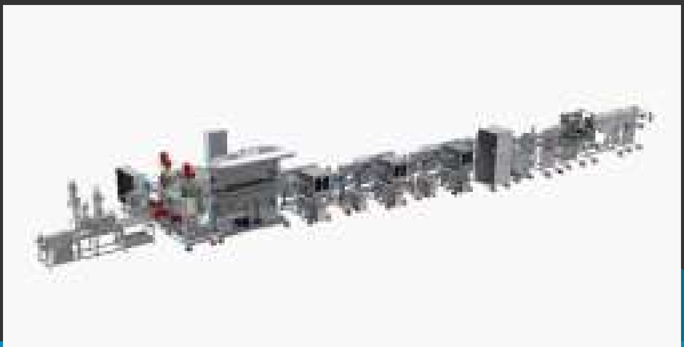
CANOE

CARBON FIBRE ACTIVITIES

Within the scope of SmartFAN, CANOE is actively developing formulations and processes for nano-enabled sizing systems for carbon fibres. Main objectives are the improvement of both mechanical properties (Inter Laminar shear strength) and electrical conductivity of CFRPs.

Using different kinds of nano-fillers commercially available or synthesized by NTUA, fibres are sized by CANOE and processed into CFRPs by infusion (CANOE) or pre-preg manufacturing and lay-up (INEGI). These developments have led to promising results for applications in high-end structural applications for instance.

Carbon fiber sizing application



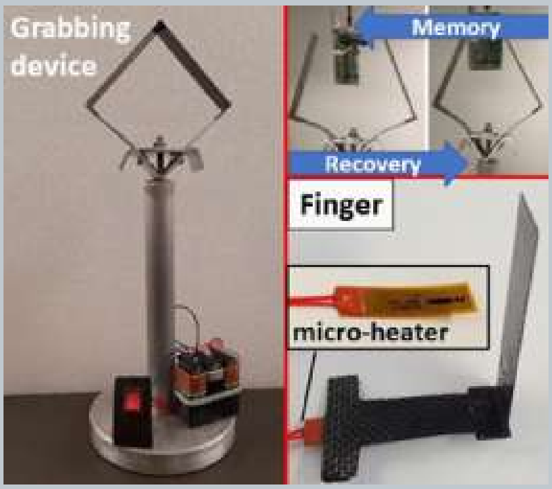
Pilot-scale fiber wet spinning line

To complete the existing carbonization line in CANOE – on which SmartFAN sizing developments at larger scale will be performed - a wet-spinning pilot line will be installed during summer 2020 in CANOE facilities in Lacq. This solvent spinning line will be able to produce around 3 t/y fibers and will allow the spinning of various types of polymers.

SHAPE MEMORY POLYMER COMPOSITES FOR GRABBING DEVICES

The Department of Industrial Engineering of the University of Rome Tor Vergata has produced the first lab-scale prototype of a smart grabbing device with shape memory polymer composites (SMPC) and integrated heating system. This device is obtained by assembling SMPC "fingers" to form the grabbing hand. The proposed architecture of the finger allows producing functional modular structures with different operational configurations.

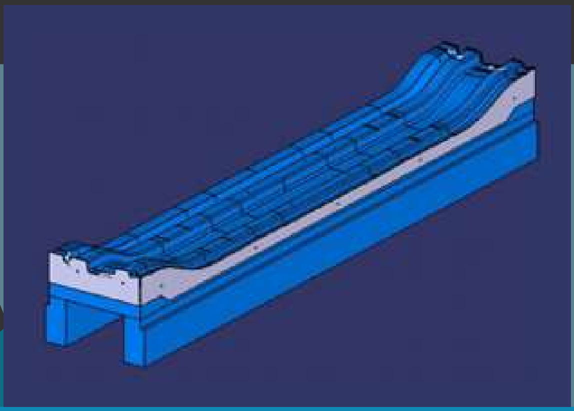
Different tests were performed on flat objects (PCB) to show the grabbing ability and good results were achieved. Next steps will be to scale up the size of the grabbing device and to automate the memory stage of composite assembly. The use of consolidated manufacturing technologies and the interesting properties of the SMPCs are the driving forces for their diffusion for "in Space" and "on Earth" applications.



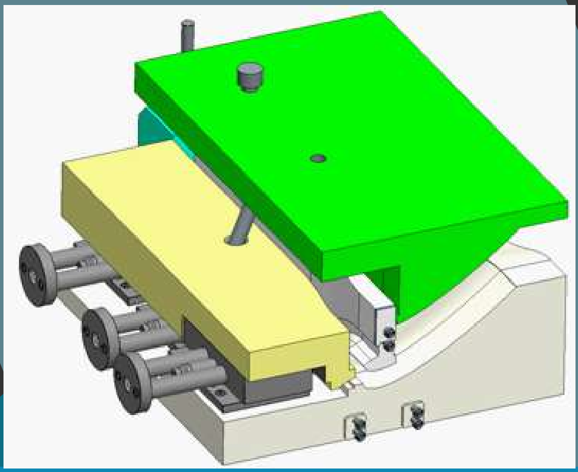
Prototype of the smart grabbing device

UNITOV

Dallara



The first layout of the tooling for the production of the structural bulkhead



Second layout of the tooling

FRONT WING DEMONSTRATOR

An innovative front wing for racing cars has been developed as a demonstrator for the SmartFAN project. The aim is to produce this complex part with compression molding technique. This results in a reduction of the production costs, allowing the part to be more suitable for the large scale production. The wing will also include a self-sensing system to monitor the damage state.

To achieve this ambitious result, the parts composing the wing (i.e., the outer shells and the bulkhead), were completely redesigned for compression molding. The design of the tooling is currently under development, however, a first layout of the tooling was obtained.

A mold with movable parts to produce the outer shell with the presence of an undercut is under development and will be completed in the next weeks, as well as a tooling for the bonding of the structural components.

Axial fan design and laboratory tests

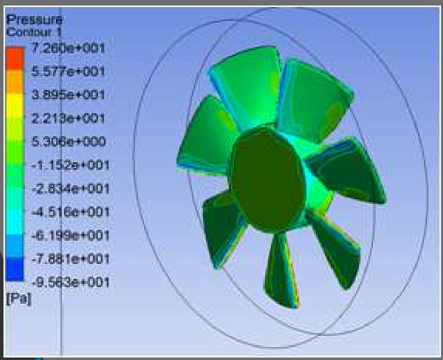
ELICA

In accordance with SmartFAN goals, ELICA carried out a CFD (Computational Fluid Dynamic) optimization process in order to define the geometric properties of an axial fan (blades number and their shape in particular) to obtain maximum values of the Fluid Dynamic Efficiency (FDE), according to geometric constraints of the technological application.

Developed different nanoformulated thermoplastics (CANOE) have been moulded into plates for safety testing at ELICA.
Safety tests showed that some CNT filled polymers are not allowed for range hoods, but only for air treatment applications.

During next phase, both electrical resistance tests and fluid dynamic performance tests will be carried out on the axial fan. In particular, the impeller will be installed in a standard application to verify materials and life test.

Furthermore, 3D printed plates axial fan by NTUA (shown at the next page) are under safety testing.



Pressure field on impeller blades (from CFD)

Axial Impeller moulded with PP modified with CNTs

NTUA

3D printing of Smart-Fans

3D printing technology has also been exploited in order to manufacture Smart-Fans for ELICA. NTUA used an Industrial Markforged 3D printer, part of the SmartFAN's Pilot Line. This printer utilizes dual printer heads to print both composite, non-composite materials, reinforced or not with carbon fibres using a variety of filaments.

A polyamide-based thermoplastic filament has been used, reinforced with chopped carbon fibres and flame – retardant additives, in order to fulfil the requirements of ELICA, regarding the flame-retardant properties of the fans that are intended to be used in domestic applications.

NTUA used designs by ELICA for the Smart-Fans and printed fan prototypes. Also, 20 SDT plates were printed for ELICA to carry out various flammability measurements.

Industrial Markforged X7 3D printer – Part of SmartFAN's Pilot Line

Smart-Fan Design, SDT Plates& Axial Fan Prototype

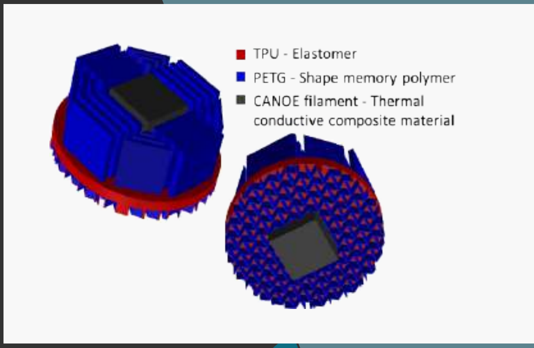
BIOG3D

Development of bioinspired 3D printed processor cooling system

Within SmartFAN, BioG3D is responsible for the design and development of a 3D printed processor cooling system with smart functionalities, aiming to improve heat flow performance and induce self-morphing capabilities.
A twofold strategy has been defined for the development process, in order to exploit composite materials developed within SMARTFAN in combination with design flexibility and multi-material fabrication enabled by 3D printing technology.

To this end, pre-programmed architectures based on auxetic patterns with autonomous self-morphing properties and controlled bending response have been investigated. In parallel, the thermoplastic materials that will be employed in different regions of the 3D printed component have been selected, followed by a parametric study of the 3D printing process for the selection of optimum printing settings for each material.

In the upcoming period, design and material aspects will be further elaborated for the selected heat sink demonstrator part, to optimize airflow and increase heat convection through controlled responsiveness to thermal stimuli.



Heat Sink 3D model

Establishment of continuous CFs 3D printing pilot line

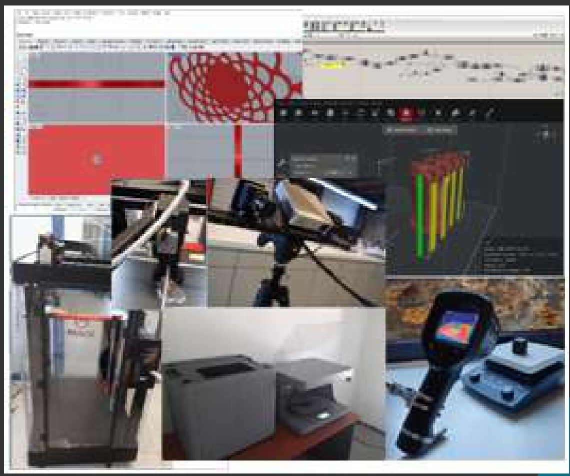
BIOG3D, NTUA, LTCP

Within SMARTFAN, a pilot line has been established in Technological Cultural Park of Lavrion by BioG3D, NTUA and LTCP, to demonstrate a digitalized manufacturing workflow of 3D printed composites with complex bioinspired structures and advanced materials.

The pilot line incorporates the latest advances in extrusion-based 3D printing (industrial grade 3D printing systems employing Fused Filament Fabrication and Continuous Fiber 3D printing), a 3D scanning system and an infrared thermal camera for monitoring thermal managing materials, as well as advanced CAx software tools, to pave the way for the next-generation fabrication methodology of freeform composite components. In this context, both open and closed materials 3D printing systems are employed, from initial design inception and material research to 3D product validation.

Towards the development and validation of new sets of performant thermoplastic composites, BioG3D is developing an open-materials prototype 3D printing feeding system for composite production with tailored fiber placement, enabled by Coaxial Continuous Fiber 3D Printing.

Additionally, to facilitate the use of the pilot line, dedicated methodologies and best practices have been developed, for design and process parameter optimization, investigation of aspects related to material-level behavior, as well as structural-level behavior of the 3D printed composites, for standard engineering polymers and experimental materials.

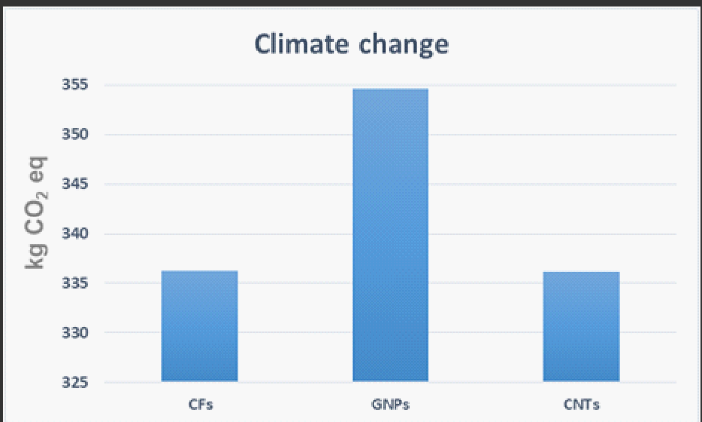


Continuous CFs 3D printing pilot line features

IRES

Comparative cradle-to-gateLCA approach of PA, PLA and PP reinforced with CFs, CNTs & GNPs filaments

- Climate change, fresh water & Marine eutrophication, Freshwater ecotoxicity, Land use and Mineral fossil & ren. Resource depletion impact categories were selected as the most affected among others.



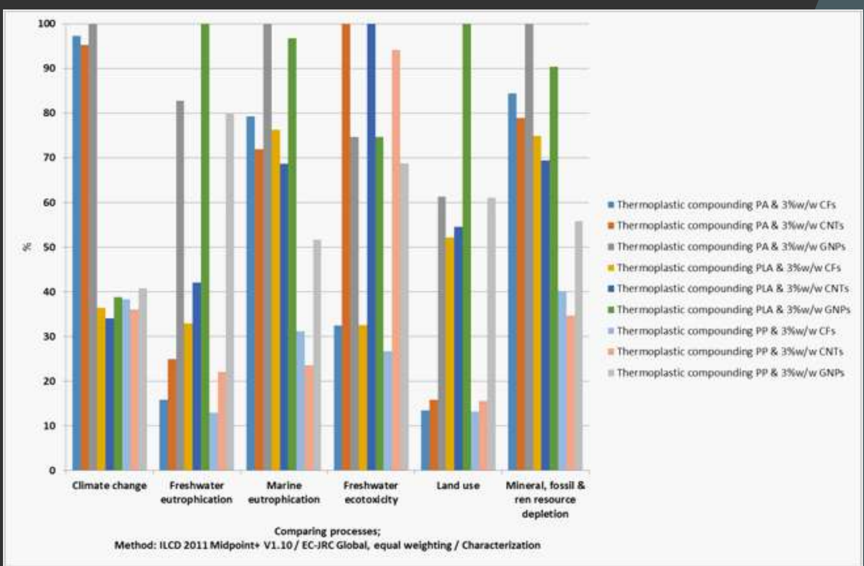
- **CF**, **CNTs** & **GNPs** production has a clear environmental **hotspot** over the composite filament production processes.
Reinforced PA has the highest environmental impact on climate change independently of the type of reinforcement due to the fossil fuel origin production and the related emissions to air, water and soil.

- PA, PLA and PP with **GNPs** present higher environmental impact compared to the other reinforcements in fresh water eutrophication, marine eutrophication and land use.

- PA, PLA and PP with **CNTs** mainly affect the fresh water ecotoxicity.

- The majority of the developed composite filaments have a high impact on Mineral eutrophication and Fossil & renewable resource depletion.

- Accounting for all impact categories and assuming equal weight, **PP with 3% CFs filament** seems to be the most preferable optionbased on the **decision making** process through the LCA approach.



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