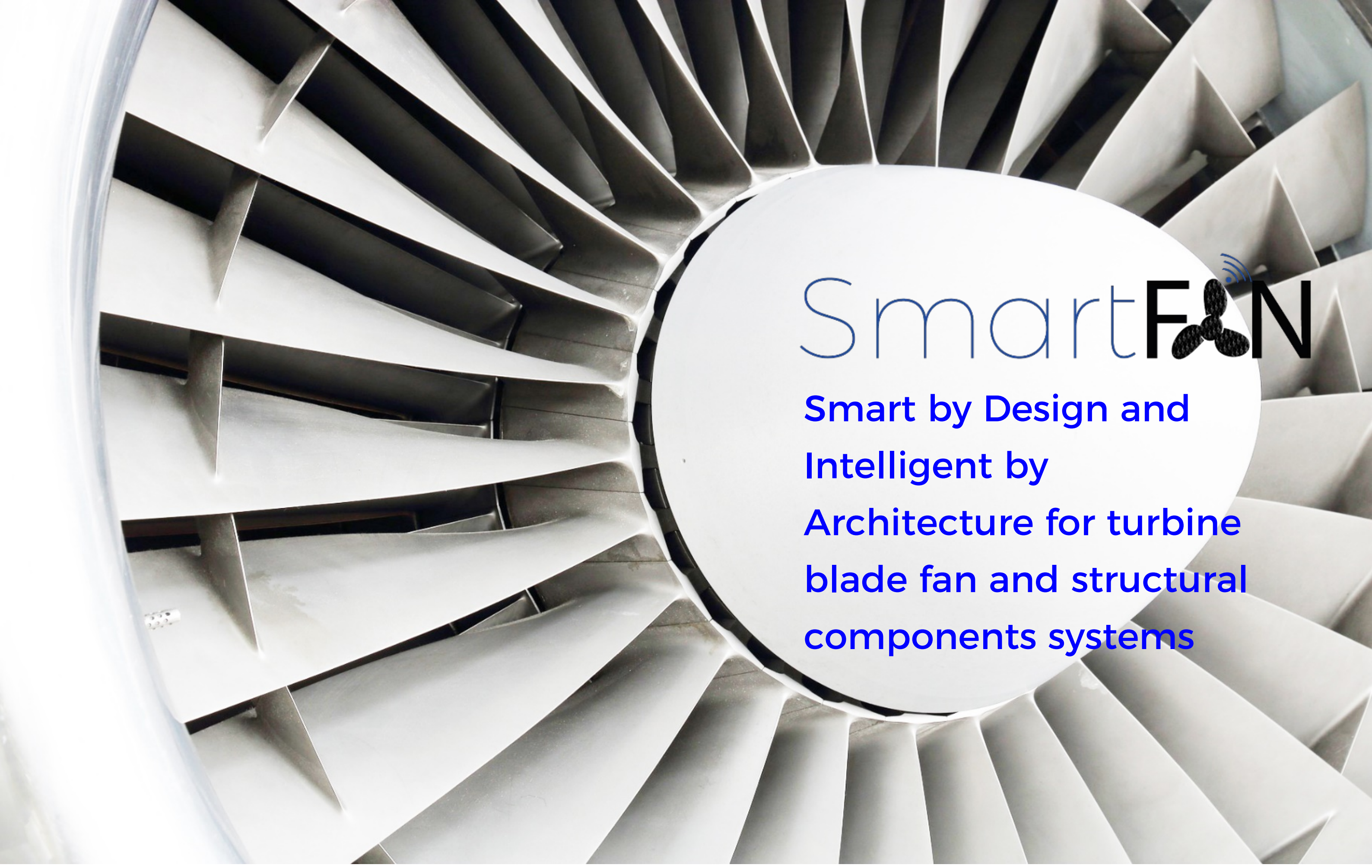

Smart by Design and Intelligent by Architecture for turbine blade fan and structural components systems

Project Full Title
Smart by Design and Intelligent by Architecture for turbine blade fan and structural components systems

Project Acronym
SMARTFAN

Grant Agreement Number
760779

Topic
NMBP-04-2017 Architectured/Advanced material concepts for intelligent bulk material structures

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Start date of the project
January 1st, 2018

Duration
48 months

Project Coordinator
National Technical University of Athens

Project Website
http://www.smartfan-project.eu

SMARTFAN project at its turning point shows the first results

SMARTFAN, a H2020 project funded by the European Union with almost 8 million euro, is at its turning point: the project has started on January 1st, 2018 and it will last **48 months**. It is coordinated by R-NanoLab of the NATIONAL TECHNICAL UNIVERSITY OF ATHENS and the consortium is composed by 3 industries, 9 research institutes and 6 SMEs from 8 different countries. SMARTFAN project aims to **develop smart materials for final application on intelligent structures.** This will be done through **two main concepts**: Layer (L) concept and Grid (G) concept. Different micro- and nano-components, will be used due to their extraordinary physico-chemical properties, to achieve smart functionalities.

In order to develop **lightweight composite materials** and transfer the properties of smart components into **bulk materials**, polymer-based matrices, such as Epoxy, PLA, Acrylics etc., will be used due to their compatibility with the above-mentioned components, their **low cost** and their **recyclability/reusability**.
SMARTFAN will develop materials and product architectures, with integrated functionalities, that will interact with their environment and react to stimuli by employing biomimetic, self-sensing, actuating and damage-repairing technologies. Their smartness is based on bio-inspired engineering and intelligent communication through **Internet of Things (IoT)**. Another goal of SMARTFAN is to develop **"smart" intelligent composites that will be recyclable and reusable**.

After 2 years from the beginning of the project, the partners have already achieved some interesting results: **INEGI** studied **the influence of carbon-based nanomaterials** having different geometries, including one dimensional (1D-) carbon nanofibers (CNFs), and two dimensional (2D-) reduced graphene oxide (rGO) or graphene nanoplatelets (GNPs), on the mechanical and electrical performance of the epoxy resin. These carbon-based nanomaterials have been produced by SMARTFAN partners, **NTUA and FORTH**, under optimized conditions. Since continuous conductive networks are susceptible to external mechanical stimuli, 2D-rGO or 1D-CNFs nanocomposites were investigated as promising in-situ strain sensors. INEGI also used the modified epoxy matrices for **manufacturing of nano-enabled carbon fibre reinforced polymer** (CFRP) composites. The incorporation of carbon-based nanomaterials displayed a positive effect on both mechanical and electrical performance of the materials, which are being investigated for the production of racing car components. Great results have been already achieved for nano-enabled CFRP composites, especially in terms of their resistance against delamination.

CANOE has worked on **more than 20 different TP polymer formulations**, varying polymer matrixes and wt% of nano fillers. Five selected formulations have been produced at 15 kg scale to enable demonstrator fabrication (domestic appliances). Moreover, few km of 3D printing filament with enhanced thermal conductivity has been manufactured for 3D printing of processor cooling system. This research work is ongoing as industrial scale trials are still in progress. CANOE is also working on **Smart particle integration into Carbon Fiber Reinforced Polymers**: main research target is to improve the transverse electrical conductivity in CFRPs (perpendicular to fiber plies) and to use the electrically conductive behaviour of the CFRP to obtain smart-composites with self-sensing properties. Smart materials are ready and provided to partners, Epoxy replacement with acrylic TP resins in CFRPs has just been initiated. This work will be continued for recyclability issues for automotive applications.

During these first 24 months of the project, different magnetic nano-particles (MNPs) and their incorporation in polymers to introduce induction heating capability has been investigated by **ITAINNOVA**. This material functionality can be used for healing, welding and deformation control in shape memory polymers, opening new opportunities for different applications. In SMARTFAN, the MNPs have been successfully incorporated in PLA (Polylactic acid) matrix. Furthermore, 3D printing filaments with the modified PLA have been manufactured and will be used to test the material development in a product demo case. ITAINNOVA has also been investigating about the **utilization of microcapsules with fluorescent substances**, as an additional functionality to reveal damage. In this sense, microcapsules considering different chromophore fillers have been synthesized and incorporated in epoxy resins. The first performance trials carried out evidenced the potential of the technique, allowing to identify cracks that

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cannot be detected by visual inspection. Currently the application of this technology in composites prepregs is being analyzed by INEGI. In parallel, ITAINNOVA has being developing **molecular dynamics (MD) models** to determine interfacial properties of some of the filler/polymer nanocomposite systems being addressed in the project and also to determine coarse graining (CG) potentials needed for the meso models.

To assist design and development of SMARTFAN materials with specific multi-functionalities, **Multi-physics modelling tools have been applied by Politecnico di Torino**. Multiscale simulation has been performed to understand the influence of graphene-reinforcement on the thermo-physical properties on polymer nanocomposites. The study shows that the mechanical strength of composite is improved by more than 30% compared to neat polymer by addition of 2 wt% of graphene, while the effect of graphene reinforcement on thermal properties is negligible. Moreover, one of POLITO's task in the SMARTFAN project is **to design and develop EMI shielding material for shielding the electromagnetic radiation in the X band** (8 – 12 GHz) **and Ku band** (12 – 18 GHz). Therefore, finite element modelling simulation is ongoing to understand the effect of various parameters (electrical conductivity, magnetic permeability, dielectric losses and thickness) on the EMI shielding behavior of the material.

Two CFRP demonstrators, an energy absorber for the automotive industry for large scale production and a front wing for racing cars, were designed by **Dallara** within frame of the SMARTFAN project. The aim is to reduce the manual operations and, consequently, the cost of the part. A new concept was introduced in the design of the front wing to allow the production by compression molding, including a geometry with an undercut. First tooling to produce both demonstrators were produced in October 2019, and a first prototype was manufactured. In the next months these demonstrators will be manufactured with the SMARTFAN materials, resulting in high performance and self-sensing parts with competitive cost.

During the first 24 months of SMARTFAN, **BioG3D** has dealt with **the design and development of the Heat sink of a bioinspired processor cooling system** with improved overall effectiveness, through 3D printing. The targeted properties for the heat sink is the increase of the heat flux through its whole volume, the decrease of the operating noise and the decrease of the system's weight. Towards this direction, structures that self-response by pre-programming their architecture were designed and composite filaments reinforced with carbon-based nanoparticles were employed.

Techedge is undergoing experimental studies on IoT and signal processing equipment, in order to create Machine Learning (ML) and Artificial Intelligence (AI) applications to analyse data coming from fan devices based on technology developed by the SMARTFAN partners. The goal of these studies is to find the best architectural solution (both hardware and software) to achieve the IoT implementation and data analysis at its best. In this direction several IoT devices (as Arduino Nano/Uno and Microsoft Sphere) and edge computing hardware (as nVidia Jetson platform) are being testing to realize a fully operational pipeline, from data acquisition to ML and AI applications.

Finally, since June 2019, **recycling activities** in SMARTFAN have been initiated by **NTUA**. The aim was to propose guidelines regarding the recycling of polymer composites, considering both thermoplastics and thermosets. In order to provide proper guidelines to the project partners, an internal investigation started within the consortium, to identify the scrap materials that are abundant and need specific handling; industrial partners have been contacted for this reason.

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