Multifunctional smart composite with integrated self-sensing, self-heating and self-healing capabilities manufactured using 3D printing (SMART-S2H3D)

The need for sustainable development, combined with the depletion of natural resources, impose a responsible obligation on us to design structures that are resilient and safe. To ensure the safe use of different types of structures, structural health monitoring systems, using sensors mounted to the structure, are now widely used. However, thanks to advances in materials science, a new class of so-called smart materials has emerged enabling innovative solutions and enhanced functionality. These modern materials can for example sense their own condition, opening up new perspectives in the design and operation of structures and in the monitoring of their reliability.

The search for technological solutions to the ever-increasing demand for the design of materials with new, advanced and multifunctional properties is one of the greatest challenges facing researchers involved in the development of civil, mechanical, aerospace, automotive or biomedical engineering. The latest developments in computer-aided design and additive manufacturing technology, commonly referred to as 3D printing, make it possible to produce complex components with precisely designed parameters. However, the use of 3D printing, makes it possible to go a step further, towards embedding a "sensor" system directly into the material. The components that act as sensors can simultaneously reinforce the composite, creating a smart material with increased strength and functionality.

The aim of the project is to develop a new multifunctional composite material with integrated self-sensing, self-heating and self-healing functions. Two types of material will be developed. In the first, pathways made of conductive material with added carbon particles will be printed into a polymer matrix. The second type of material will use continuous carbon fibres, which will be embedded in the polymer matrix during the 3D printing process. The materials obtained in this way, thanks to their built-in electrical conductivity, will be able to detect and report damage and, in some cases, initiate repair processes, using their conductive properties to activate regeneration mechanisms. In addition, they will have heating functionality that can be used as a de-icing mechanism or to prevent icing of surface components operating in cold environments.

The proposed experimental and numerical studies will provide an understanding of the coupled electro-thermo-mechanical behaviour of a multifunctional composite fabricated by 3D printing. The project will explore the relationships between the various features of multifunctional composites, which will be crucial for the development of smart materials. As a result of the research, optimal conductive path configurations, volumes, geometries and interfaces between the conductive paths and the polymer matrix will be designed to enhance self-monitoring, self-heating and self-healing properties. The final outcome of the project will be the development of damage detection algorithms based on changes in electrical parameters. In a broader perspective, the results of the project will have a major impact on increasing the safety of structural components in various engineering fields and improving their new integrated functionalities.