Next Generation Combat Aircraft Technologies - NGCAT

4UFORCE

For Unprecedented Defence Capabilities, Capacities with Cementitious Matrix Composites -CeMC™

Duration of the project: 01/05/2025 -01/02/2028

Key words: Cementitious Matrix Composites / high temperature composites / impact blast resistant / stealth / Belgian Supply Chain

Budget: 2,367,691 €

of which RHID contribution: 2,247,000 €

PROJECT DESCRIPTION

Context

New technologies need new materials.
There is a need for materials able to withstand very high temperatures, while being lightweight and cost-effective. That is particularly true for specific military aircraft applications:

- Heat shields for structures from which missiles are launched. Those structures are often made in steel while the blast of the rocket can reach 1700°C, far above the melting temperature of steel. Current solutions, e.g. on the frigate are insufficient.
- Integration of fixed-forward effectors into platforms/ PODs resistant to heat and debris of launch.
- Aerodynamic heating. The temperature of leading edges and surfaces of next-generation hyper-supersonic and re-entry vehicles can exceed 1000 °C.
- Li-ion batteries are prone to thermal run away. For flying vehicles, a fire safe casing is needed to prevent disasters.

Polymer Matrix Composites (PMC) are used for aerostructures because of their very good stiffness and strength to weight ratios. However, their operating temperature is limited to about 250°C. On the other hand, ceramic matrix composites (CMC) can sustain very high temperatures but present brittle mechanical behaviours, are very sensitive to impacts and require very high processing temperatures.

So, there is room for the development of a new lightweight composite material that can be used in very high temperatures environments and that shows good properties regarding impact and blast scenarios.

General objectives

The goal of the 4UFORCE project is to work on Cementitious Matrix Composites (CeMC™), which are composites with inorganic matrix. CeMC™ bridges the temperature performance gap between PMC and CMC. In high temperature environments, where PMC would fail and need to be replaced with metals, CeMC™ offers a lightweight alternative suitable for service temperatures up to 1400°C whilst providing a non-brittle failure mechanism. CeMC™ are produced in a similar manner to PMC whereby fibres are impregnated with a resin which sets to form the structure and need only processing conditions below 100°C, allowing a simple route to manufacture. That low processing temperature also facilitates the inclusion of functional additives (for ballistic, stealth... aspects) in the matrix which would otherwise decompose or deteriorate at typical processing temperatures for manufacturing CMC. CeMC™ are composites that compete in ease of processing and cost (2-3 euro/kg matrix) compared to high performance CMC.

Methodology

The development of the new CeMC™ composite materials will be supported by physical testing and modelling/simulation. At least two sets of raw materials and preparation methods will be selected to produce CeMC™ materials with mechanical stability up to 1000 °C and 1700°C. A specific material model of the studied CeMC™ will also be developed. The performances of the new composite materials will be validated on three demonstrators in line with the NGCAT context, and compared to existing solutions:

- Heat shield resisting to exhaust fumes and debris from Exocet launch
- Heat shield of the FN-Herstal Rocket-Machine gun POD
- Fire-blast resistant casings for the safe storage of batteries on flying devices

In the 4UFORCE project, material systems that combine ceramic fibers from a mineral source, alumina, whiskers, functional additives and inorganic matrix compositions will be considered by MOSS composites and VUB. The matrix recipes will be developed by VUB. Different fiber types and hardening particles will be integrated in these matrices to enhance strength, durability, and performance and will be screened, tested by VUB and MOSS. SIOEN will focus on producing highly performant fabrics out of high-end thermally resistant selected fibers. Fabrics will be made by weaving with different patterns (plain weave, panama, atlas…), densities, openness..., and by multiaxial placement (different spacing, angles and fabric support, ...). MOSS will develop the three demonstrators. GDTech will use modelling and simulation to speed up the development and the validation of the materials (with numerical homogenization) and the demonstrators (finite elements models). FN-Herstal will provide and test the shield of POD.

Potential impact of the research on Defence

4UFORCE will demonstrate the partners' sovereign capability for the fast development and production of new advanced composite materials, that are lightweight, stiff, strong, that present better resistance to high temperature and impact than other existing materials, what is essential for the NGCAT program (and BDTIB in general). Using such materials will lead to more secure operations, while insuring better maintainability (thanks to better impact and temperature resistance), and a significant cost reduction potential. The knowledge generated in 4UFORCE will enable Belgium to position for the NGCAT/FCAS program with a unique solution. The results of the project will support the development of a competitive and credible national industrial and technological base in the field of security and defence.

Description of the expected final research results (model, scenario, report, workshop, publications, etc.) and valorisation perspectives at short and medium term.

The results of the project will be:

- New CeMC™ composite materials (fibers, matrix, additives; manufacturing; testing)
- Demonstration of the performance of the new materials in three applications (above-mentioned demonstrators)
- Associate material model, and finite element models of the demonstrators (digital twins)

Results will be communicated and disseminated via social networks, conferences and scientific publications.

The dual-use nature of the new CeMC™ composite materials will make it possible to address different markets besides Defence, like civil engineering, energy and applications related to fire resistant materials .

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