A Framework For Efficient Design And Manufacture Of Multifunctional Composite Materials For Light-weighting Aerospace Structures

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Research Background

Aviation accounts for 3% of global greenhouse gas emissions. Electrification of power and propulsion systems will directly support aviation decarbonisation [1]. A significant challenge for these systems is the step change in power ratings (MW to Multi-MW) and the associated high power densities required for electrical power system equipment (Fig 1). Carbon fibre reinforced polymer (CFRP) offers significant opportunities for lightweight components. The design of multifunctional, CFRP-based components with combined electrical, thermal and structural functionality offers a route to optimise the power density of electrical power systems [2]. A challenge to the design of multifunctional CFRP is the need for a multi-functional material selection framework to integrate with electrical, thermal and structural system design.

Research Aim & Objectives

This research presents a novel material selection framework for multifunctional CFRP components which conduct electrical current in the electrical power system of an aircraft.

The framework interfaces with the design of the electrical power, thermal and structural systems to derive materials requirements. Possible options to fit within the design space are identified and subsequently ranked. The framework provides a methodology to iterate to electrical power, thermal and structural systems to tune the design space to maximise the possibility of finding a viable solution and optimise the performance of solutions found.

Factor	CFRP	Aluminium
Weight density (g/cm^3) [3]	~1.7	~2.7
Tensile strength (MPa) [3]	2724	483
Electrical conductivity (S/m)	3×10^4	1.67×10^7

Table 1: Comparison of the physical properties of CFRP and aluminium

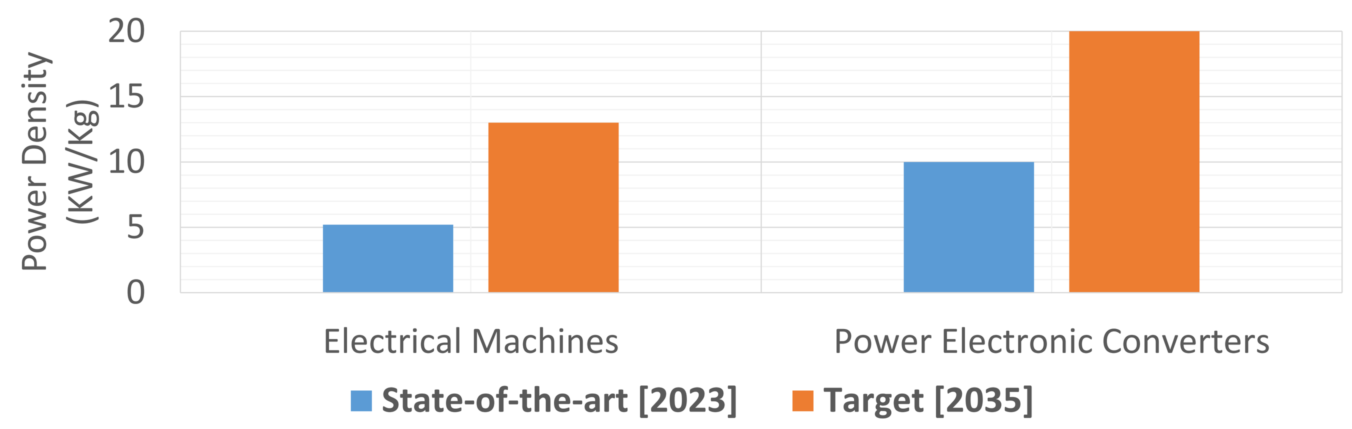
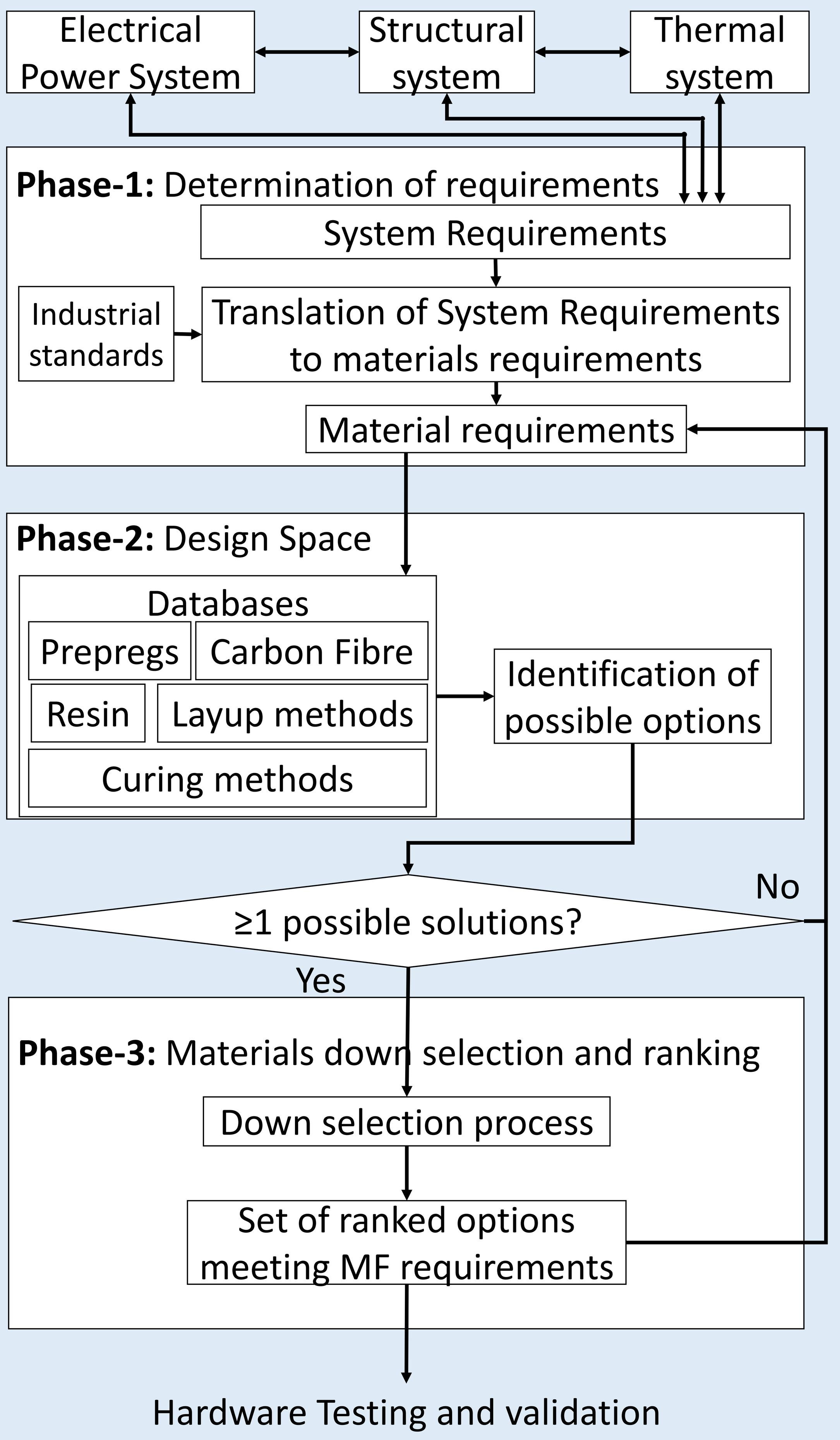


Fig 1: State-of-the-art vs. targeted power densities of electrical components [4][5]

Framework



Description

Phase 1

Structural, electrical, thermal and their interdependent requirements of systems are gathered and translated into materials requirements with consideration of industrial standards

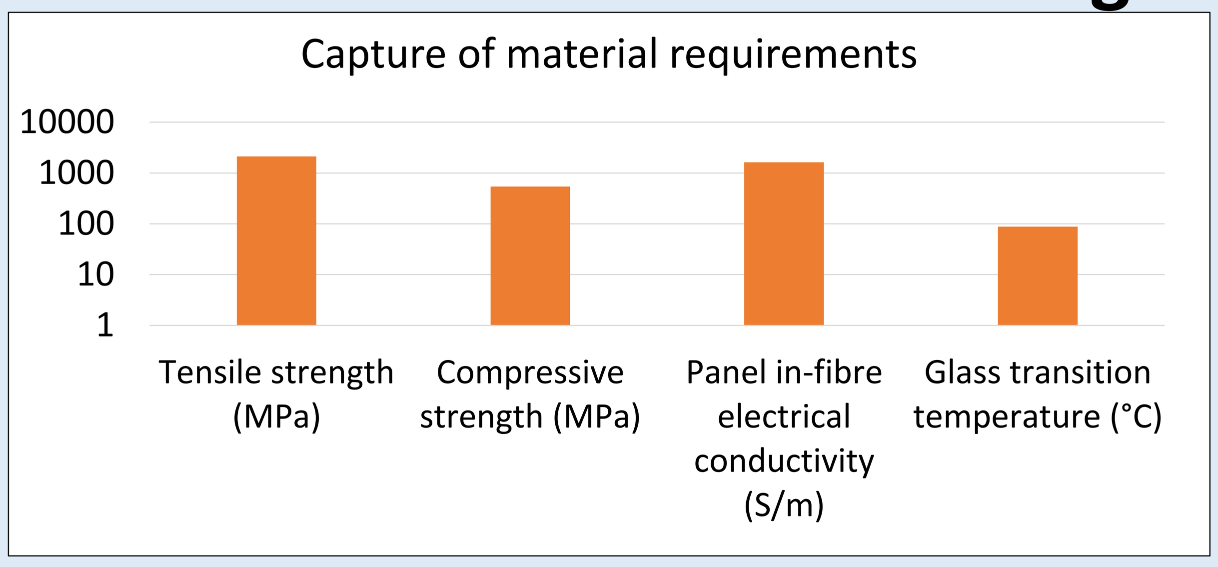
Phase 2

Possible options are identified from the databases of prepregs, carbon fibre, resin, and layup and curing methods

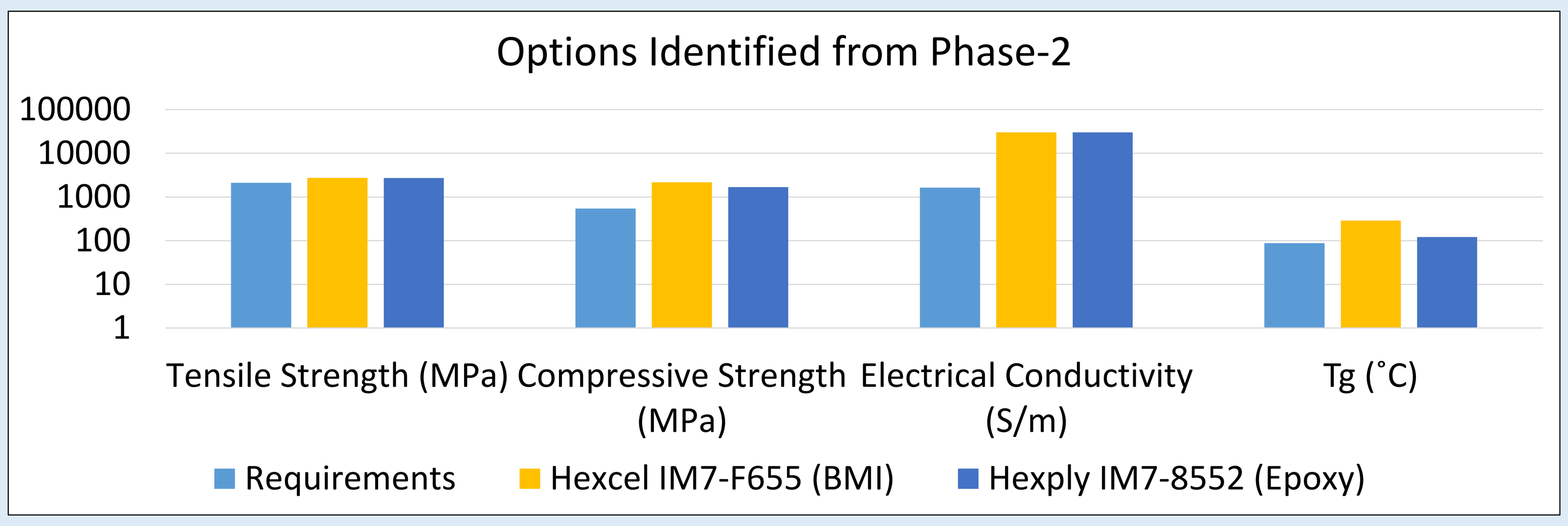
Phase 3

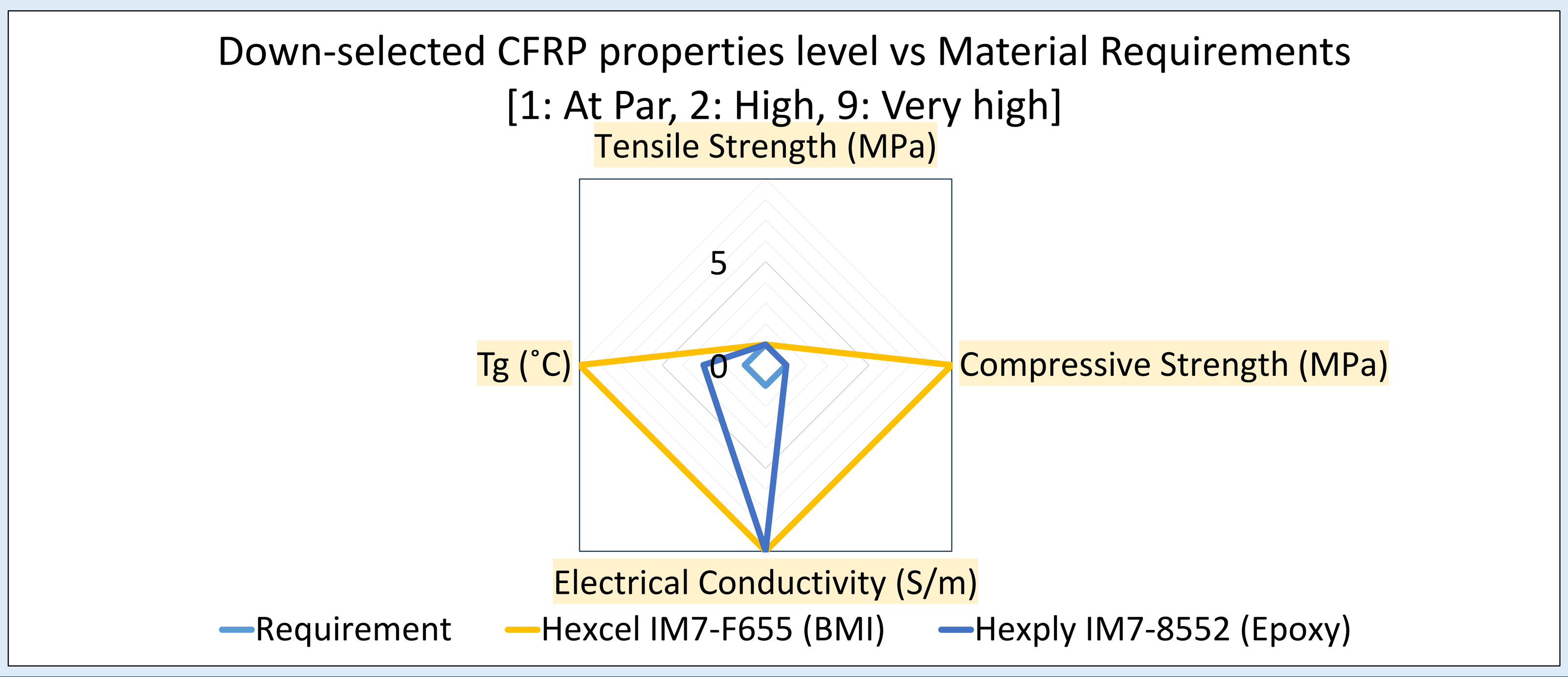
Down-selection and ranking of multifunctional CFRP which meet design criteria. Iteration of system requirements to find optimal solutions.

Example: CFRP structure to supply electrical current to the cooling fan



<u>Assumptions</u>
Structural section: Fuselage
Function: carrying current to power the equipment cooling fan's motor
Motor rating: 1KVA
Operating voltage: 270V_{DC}
Allowed voltage drop: 3.5%
CFRP lamination: [0]
CFRP dimension: 0.1x0.01x0.004m





Conclusions & Future Work

The presented multifunctional, CFRP-based material selection framework enables:

- Identification of multifunctional composite material that interfaces with electrical, thermal and structural systems.
- Identification of target performance levels of multifunctional CFRP.

Future work includes:

- Investigate the use of multifunctional CFRP to identify limitations and set design space thresholds for multifunctional CFRP design.
- Full exploration of the capabilities of the framework through further case studies.

References

[1] Wheeler, Patrick, et al. "Electric/hybrid-electric aircraft propulsion systems." *Proceedings of the IEEE* 109.6 (2021): 1115-1127.
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[3] "Carbon Fiber vs Aluminum", https://dragonplate.com/carbon-fiber-vs-aluminum#:~:text=This%20chart%20shows%20that%20carbon,1.71%20times%20that%20of%20aluminum.
[4] Zhang, Xiaolong, et al. "Large electric machines for aircraft electric propulsion." IET Electric Power Applications 12.6 (2018): 767-779.
[5] Ambitions of Investigation And Maturation Of Technologies For Hybrid Electric Propulsion, https://www.imothep-project.eu/ambitions-35, Accessed on: 28th September. 2023.