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Modelling multifunctional composites for further aircraft electrification

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The electrification of aircraft requires significant improvements in thermal management, weight reduction, energy storage and electrical distribution. The use of multifunctional composites is essential in these endeavours and provides an effective way to eliminate the mass of components by using existing structural elements to perform the same function. In fibre-reinforced composites, the mechanical and physical properties are highly anisotropic – with superior tensile strength, stiffness, thermal and electrical conductivities occurring in the in-plane fibre direction rather than in the out-of-plane direction. However, the electrical and thermal behaviours of composites are poorly understood, particularly for complex geometries with different stacking sequences. To more fully understand this behaviour, a multi-physics model will be produced to characterise the directional electrical and thermal conductivity of fibre-reinforced composites.

Multifunctional composites perform additional functions as well as providing stiffness and strength. This includes conducting electricity, being magnetically permeable, conducting heat and storing power.

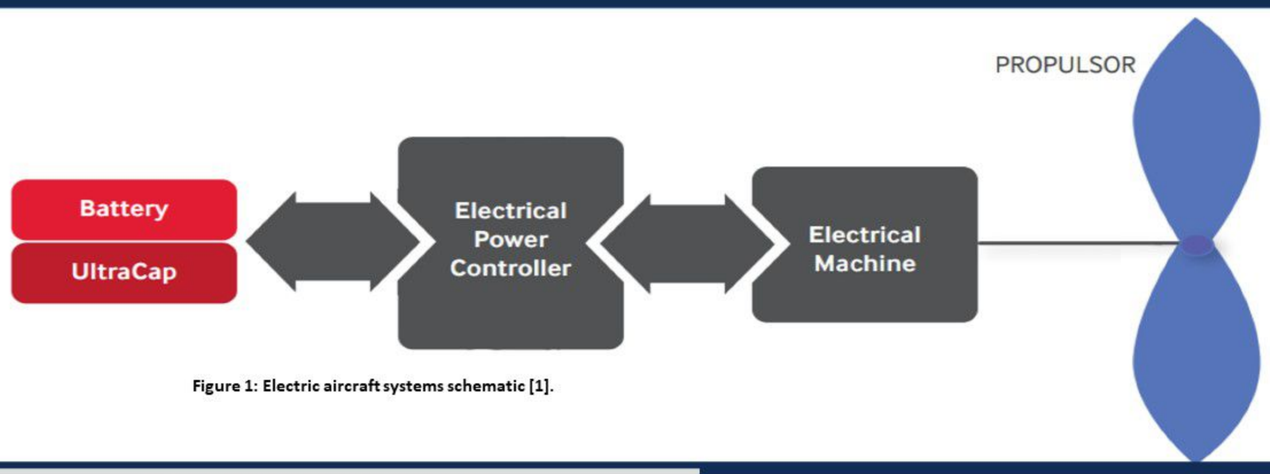


Figure 1: Electric aircraft systems schematic [1].

Structural supercapacitors

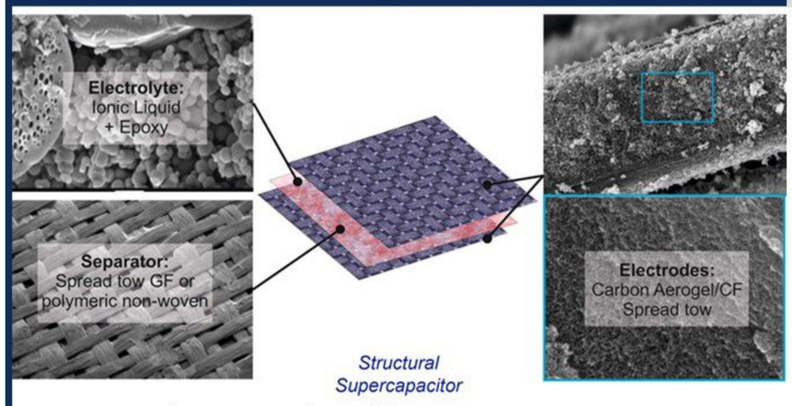


Figure 2: Structural supercapacitor schematic [2].

Structural supercapacitors are a method of energy storage capable of carrying load. This vastly increases power density by replacing existing structural panels.

Conductive composites

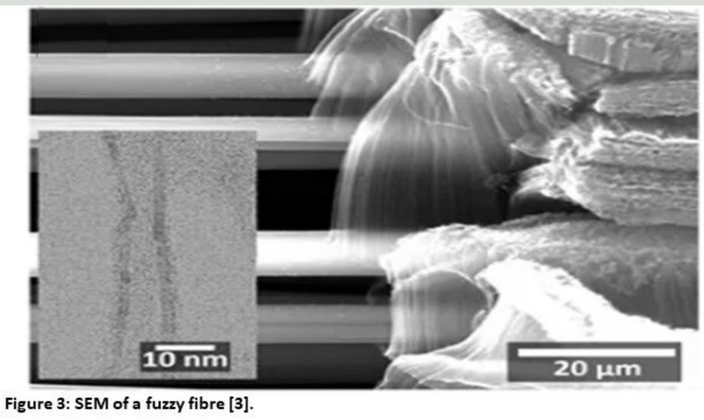


Figure 3: SEM of a fuzzy fibre [3].

Composites can be made far more electrically or thermally conductive with the addition of nano-inclusions, such as carbon nanotubes.

Permanent Magnet Motors (PMMs)

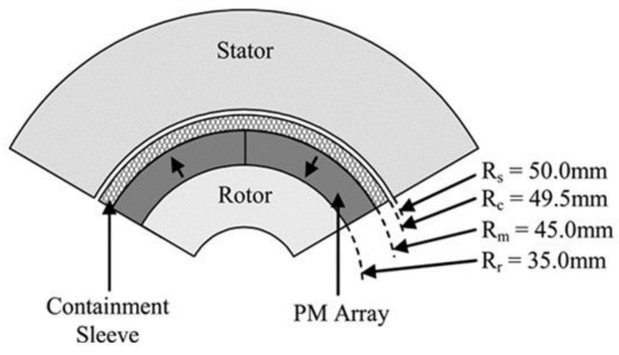
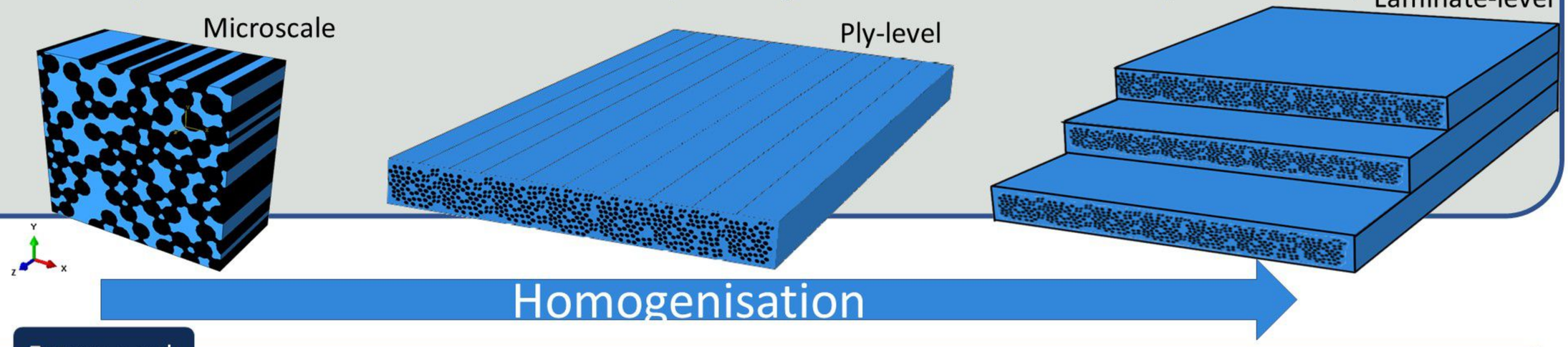


Figure 4: Partial cross-section of a PMM [4]

Components of PMMs have been replaced with composites featuring ferromagnetic inclusions to maintain a high magnetic permeability.

Model

To design multifunctional components, detailed knowledge of their physical behaviour is of paramount importance. Therefore a Multiphysics model is being produced which spans the length scales from microscale to laminate level. The aim is to predict the thermal and electrical behaviour of a component or laminate from the constituent materials; simulating fibre contact to account for out of plane conductivity.



Future work

To provide experimental validation, 8552/IM7 laminates will be produced. Thermal and electrical conductivity measurements will be taken in-plane, transversely and through-thickness. These data will be compared to modelling results for the same material. A validated Multiphysics model will enable precise multifunctional design to optimise the array of properties desired of a structure, hereby minimising mass and volume. Through this, it is hoped the new generation of electric aviation is realised.

References
[1]: Aerospace Technology Institute, "Insight: Electrical Power Systems," 2018
[2]: Greenhalgh, E.; "Future Challenges for Structural Power Composites"; Bristol Composites Institute / NCC Joint Conference, 2019
[3]: Pozegic, T.; "Multi-Functional Carbon Fibre Composites using Carbon Nanotubes as an Alternative to Polymer Sizing"; Nature Scientific Reports, vol 6, 2016
[4]: Yon, J.; "Analysis of Semi-permeable Containment Sleeve Technology for High-Speed PMMs"; IEEE Transactions on Energy Conversion, vol 27, 2012

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