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STRUCTURAL BATTERY COMPOSITE DEMONSTRATOR AND MULTIPHYSICS MODELLING

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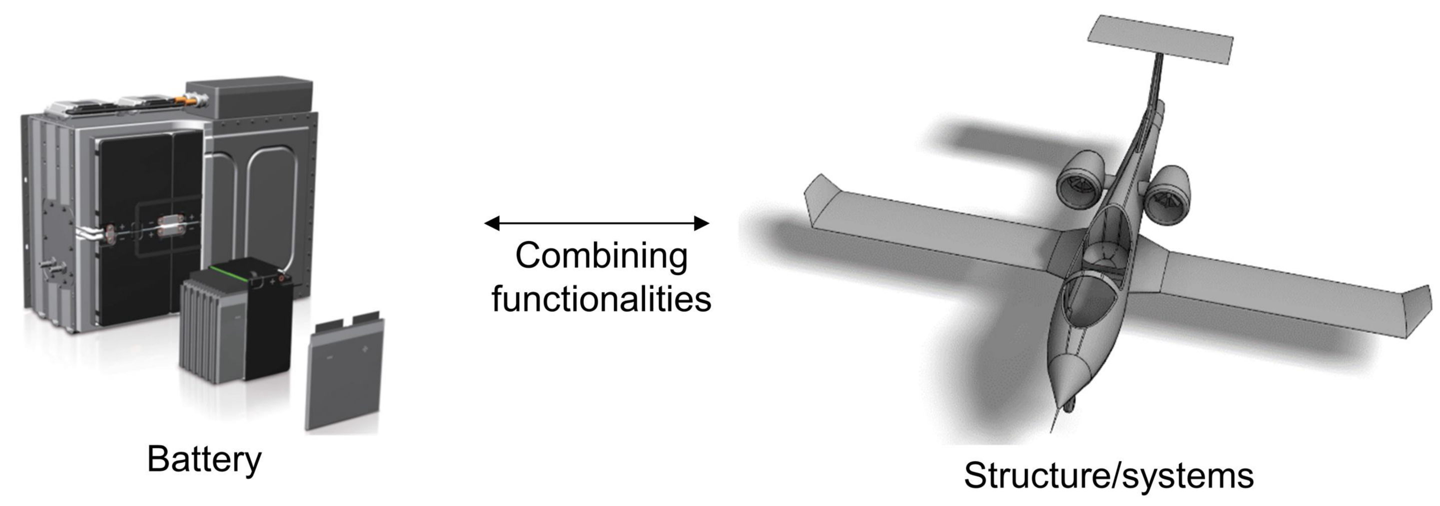
Introduction

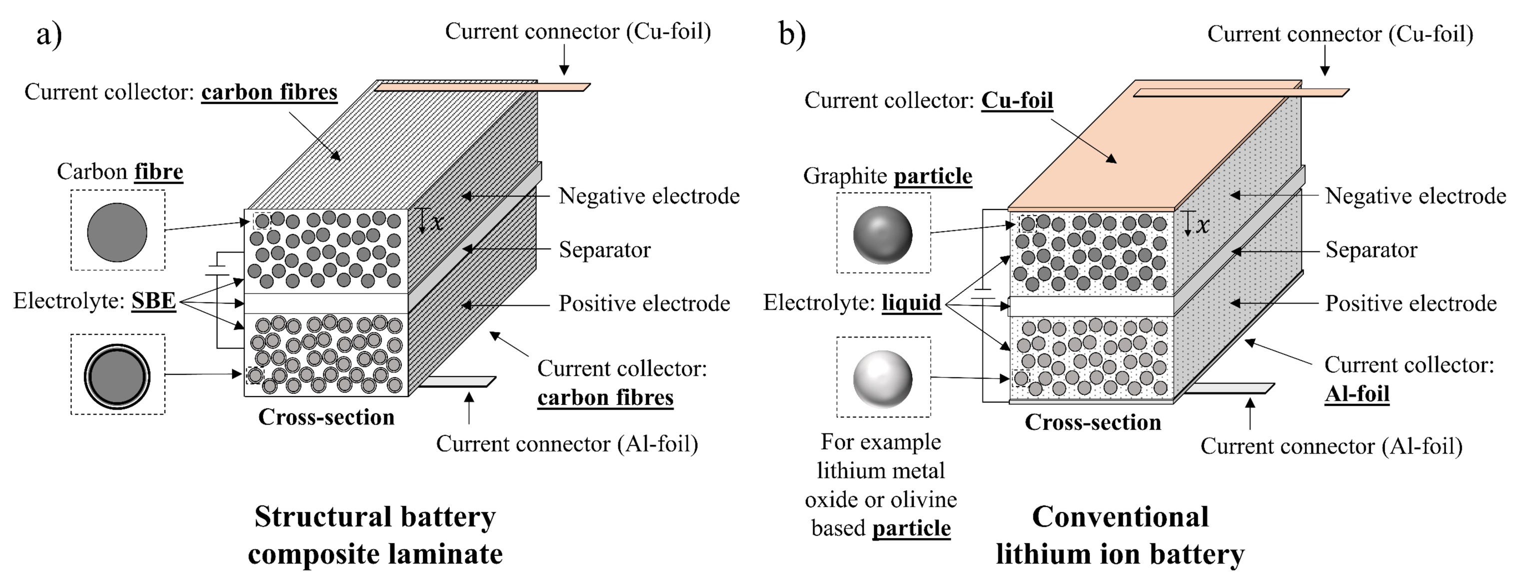
A potential solution to make all-electric regional aircraft is to use "massless" energy storage (illustrated in the figure to the right) such as the structural battery composite. This composite material has the ability to store electrical energy (i.e. work as a battery) in the load bearing part of a structural system [1].

Due to its multifunctional nature, multiphysics models are needed to predict the performance of this material. These models need to combine the electrochemical process (related to the battery functionality) with mechanical and thermal processes.



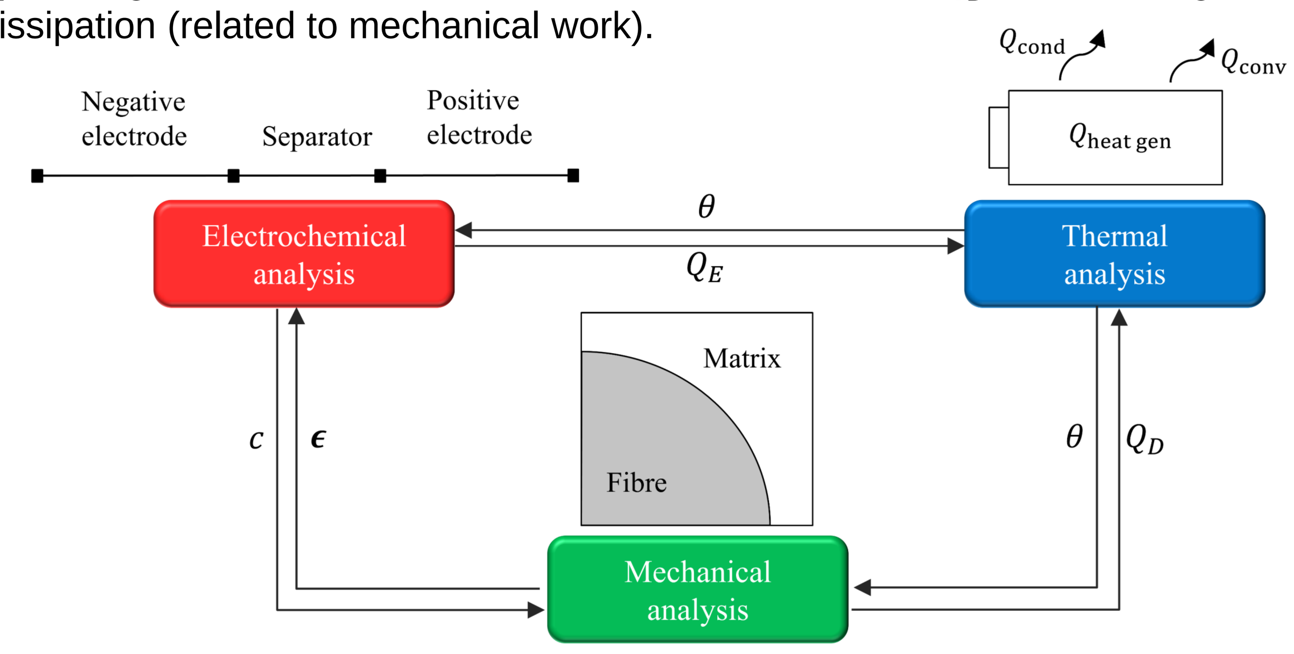
Structural Battery Composite

The internal structures of the laminated structural battery and a conventional Li-ion battery (for comparison) are schematically illustrated in figure below. (a) Shows the laminated structural battery and (b) a conventional lithium ion battery. The bold underlined text highlights the main differences between the two battery cells and SBE stands for Structural Battery Electrolyte (a bi-continuous polymer network containing a liquid electrolyte phase).



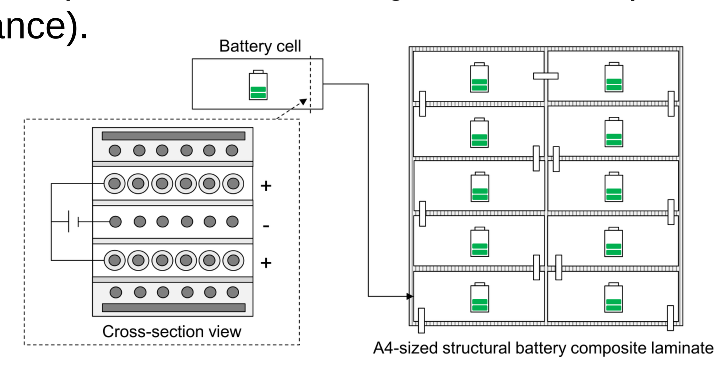
Coupled analysis

A schematic illustration of the coupled analysis for the laminated structural battery is presented below. Essential couplings are illustrated as arrows between each box, where θ is the temperature field, c is the lithium concentration in the electrode materials, ϵ is the mechanical strain, Q_E is the generated heat due electrochemical effects and Q_D is the heat generated due to energy dissipation (related to mechanical work).

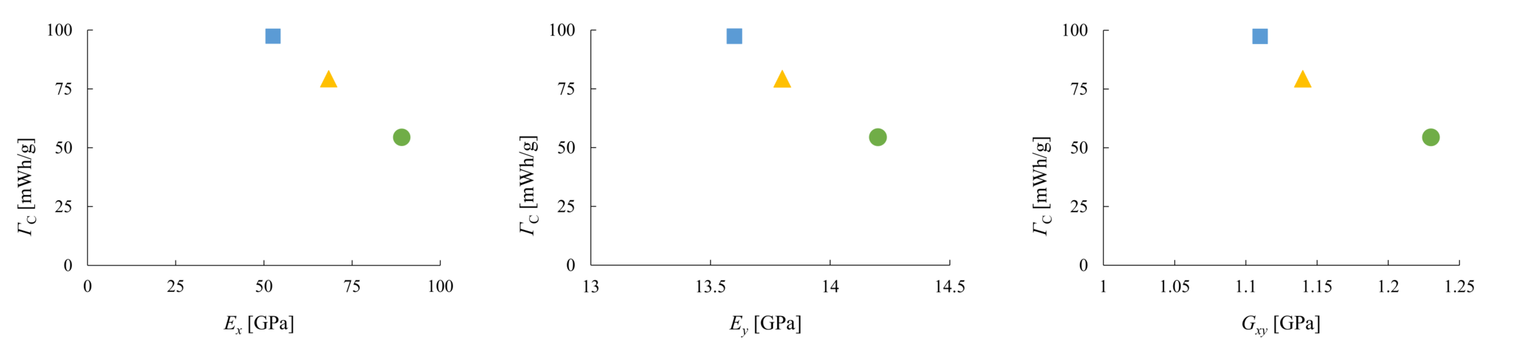


Demonstrator

As part of the Clean Sky 2 project SORCERER [2], an A4 sized structural battery composite demonstrator is to be developed. Conceptual designs of this demonstrator has been established [3] (shown in figure below) in order to replicate the PSU (Personal Supply Unit) in a commercial aircraft. In the design process, different configurations of the laminate (battery cells) were proposed to show that different performances can be enhanced by varying the material design. In the graphs below the elastic moduli (mechanical performance) for a set of configurations are plotted against the energy density (electrical performance).

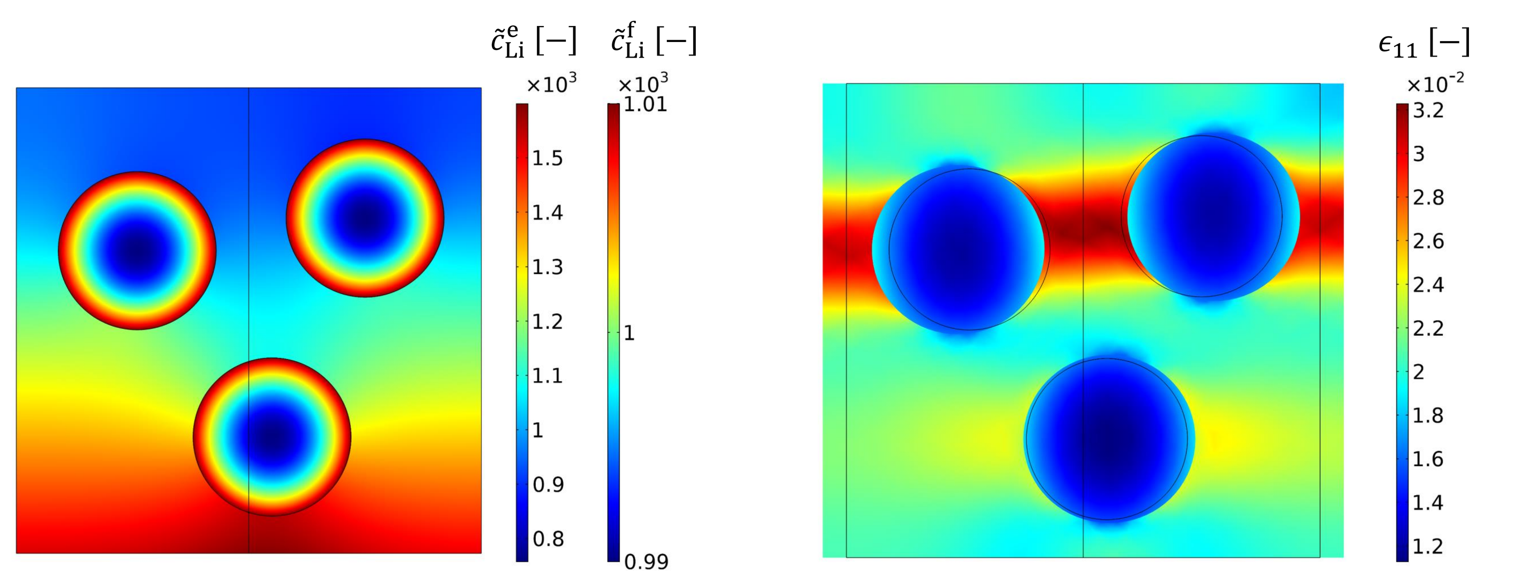


Configuration	Enhanced performance
A	Electrical
B	Intermediate
C	Mechanical



Modelling framework

To study the local effects within this material a computational framework is under development. Because of coupling effects (illustrated as arrows in the Coupled analysis figure) the physical phenomena interact. For example, changes in the electrochemical state will affect the mechanical performance (elastic properties and internal stress state) [4-5]. Moreover, local phenomena will interact. For example, the left figure below shows the Li-concentration distribution (left color bar: concentration in fibre, right color bar: concentration in matrix). The right figure on the other hand, shows the mechanical strain distribution (in x_1-dir.) from mechanical load and expansion of electrode materials. As the fibre expansion is linked to the mass distribution of Li in the fibres (shown in the left figure), the two phenomena are coupled.



Electro-chemical

Mechanical

Conclusions and further work

In this work, the multifunctional performance (i.e. capability of providing multiple functions) of an A4-size demonstrator is presented. Moreover, strategies for predicting the multiphysics behaviour of this material is discussed. Finally, ongoing work on developing a computational framework to study the local effects within this material is described.

In further work the demonstrator will be manufactured and characterized. Moreover, experimental validation of the developed numerical tools will be performed.

References:

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Department of Industrial and Materials Science
Division of Materials and Computational Mechanics

FUNDING:

HORIZON 2020

Clean Sky 2

U.S. AIR FORCE