Potentials of Structure Integrated Flow Batteries in Aviation and Space Applications

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Funded by the Germany Space Agency, we developed an innovative flow reactor design that, thanks to its space-saving construction, aims to bring flow batteries one step closer to integration in aviation and space applications. The project was initiated by winning third place in the Europe-wide idea competition InnoSpace Masters 2021 and has already been showcased at the International Aerospace Exhibition ILA Berlin 2024. This achievement highlights not only the innovation of our design but also the growing interest in sustainable energy solutions in the aerospace sector.

Energy security plays a major role for aircraft and aviation applications due to their isolated and specific operating conditions. In modern aviation, the reliance on chemical energy sources, such as fossil fuels, poses significant challenges. These sources are subject to fluctuations in availability and price, along with environmental concerns related to carbon emissions. As the industry moves toward greener alternatives, the transition from traditional fuels to electrical energy sources becomes paramount.
For this transition to be successful, the necessary energy storage systems must possess a very long service life and high operational safety. This is crucial not only for ensuring the reliability of aircraft but also for minimizing the costs and environmental impact of maintenance operations as well as hazards for humans and equipment.

Flow batteries have emerged as a promising candidate to fulfill these requirements, particularly when utilizing higher energy density electrolytes. For example, zinc-polyiodide flow batteries have potential energy densities of up to 420 Wh/l, making them an attractive option for aviation applications. However, one of the main challenges we face is that current flow battery cells and stacks are too bulky and space-inefficient for direct integration into existing aviation module designs. The same challenge applies for other electrochemical reactors, like non-flow batteries and fuel cells.

To tackle this issue, we focused on developing contour-fitted flow battery cells. These cells are designed to be integrated directly into the support structures of aircrafts (shown in Figure 1). By doing so, we can optimize the use of available space, which is a critical factor in aviation design. This integration not only facilitates energy storage but also allows for the realization of additional functions such as module stiffening, thermal management, and radiation absorption.

The innovative aspect of our flow reactor design lies in its unique configuration, which maximizes energy storage while minimizing the footprint. The contour-fitted cells are engineered to match the structural contours of the aircraft, thereby reducing wasted space. This design philosophy is essential in aviation, where every kilogram and cubic meter counts.

In addition to space efficiency, we have prioritized safety in our design. The flow battery system incorporates advanced safety features that protect against potential failures, ensuring that the energy storage solution meets the rigorous standards required for aviation applications. These safety measures include robust containment systems, smart monitoring technologies, and fail-safe mechanisms that act proactively to mitigate risks.

Moreover, the thermal management capabilities of our flow battery design are noteworthy. Batteries generate heat during operation, which can affect performance and safety. By integrating the flow batteries into the aircraft's structural framework, we can effectively dissipate heat, maintaining optimal operating conditions and enhancing overall system efficiency. This dual functionality not only improves the performance of the energy storage system but also contributes to the overall capability and resilience of the aircraft.

The move toward electrical energy sources in aviation is not just a trend but a necessity driven by environmental concerns. The aviation industry is under increasing pressure to reduce its carbon footprint and comply with stringent regulations aimed at mitigating climate change. By developing flow battery technology that can be seamlessly integrated into aircraft, we are taking significant steps toward achieving sustainability goals.

The potential applications of our flow battery design extend beyond aviation. The principles and technologies being developed can also be applied to space applications, where energy storage solutions are critical for mission success. In space, energy sources are limited and often dependent on solar power, making efficient storage systems even more essential. Our innovative design could support long-duration missions and contribute to the reliability of space exploration initiatives.

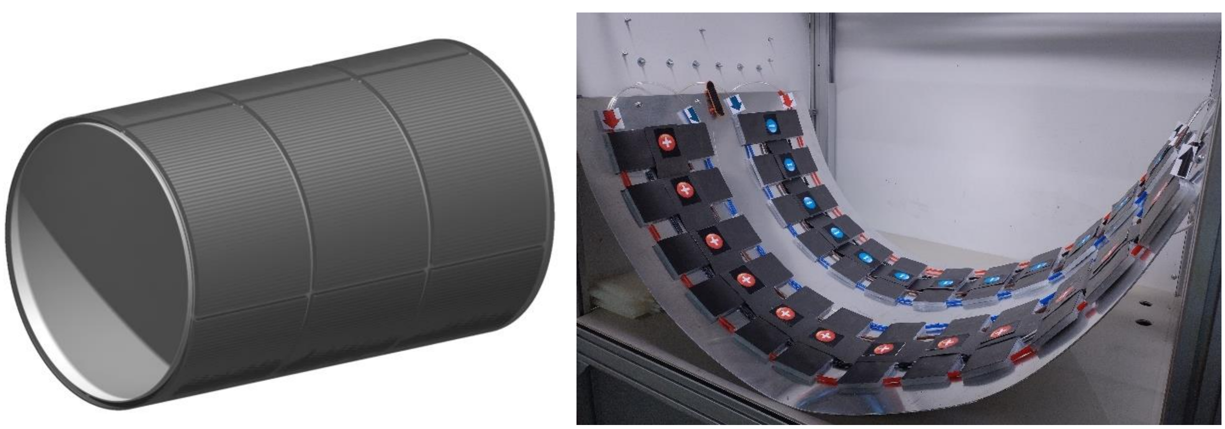

Figure 1: Structure integrated flow reactor cells

Biography

Jan Girschik

Jan Girschik heads the research group battery development at Fraunhofer UMSICHT in Oberhausen and focussed his research on innovative electrochemical reactor designs. After studying mechanical engineering at the University of Chemnitz, he made his PhD at the Ruhr University Bochum and was a research associate at the University of Calgary.