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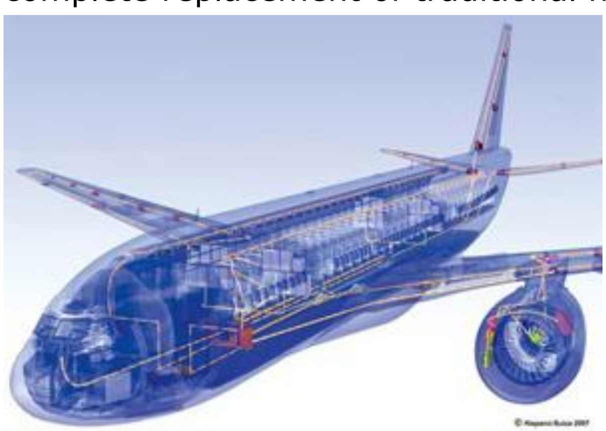
More Electric Aircraft: Better Power Management & Better Batteries on the Horizon

By Maryruth Belsey Priebe, Editor

Modern aircraft use a lot of energy, and that means many types of systems are used to power them: mechanical, hydraulic, pneumatic, and electrical. These work to provide energy for things such as flight control, manage systems such as aircraft configuration for landing gear and brakes, manage the production of energy by engines and generators, services and comfort for passengers, as well as for pressurization and air conditioning of the entire aircraft.

All of these innovations build on the idea of a more electric aircraft (MEA), which essentially a way of designing aircraft to make less use of fuel and more use of electrical power for non-propulsive aircraft systems. Not only does this reduce the fuel consumed by the average aircraft, it also cuts down on operation and maintenance costs through optimized performance. While ultimately the goal is to achieve an all-electric aircraft (AEA) design – a complete replacement of traditional hydraulic fluids and compressed air needed for driving conventional aircraft in preference for electrically-driven systems - for now, the industry is striving for a more-electric design.



Safran Group - MEA Concepts

There have been substantial technological advances in recent years in a variety of areas that impact aircraft design, all of which bring the reality of a more-electric aircraft closer to reality. Innovations in fault-tolerant architecture, mechanical and electrical systems, electro-hydrostatic actuators, power electronics, flight control systems, and power generation and conversion systems are all contributing to the development of MEA. The industry stands to reap many benefits of such a shift. Not only are electrical systems generally more efficient, they can also provide energy only when needed, rather than wasting energy during periods of time when none is needed (such as waiting at the gate as passengers board). The cost savings on fuel and insulation against fluctuating energy prices are definitely strong drivers for more work to continue in this area.

Achieving Optimal Power Management for a More Electric Aircraft Design

A primary problem with aircraft of today is that they are designed to provide peak power with little thought to how they use energy when operating at lower demand. As such, there's a lot of energy wasted in low-duty cycles – in some cases as high as 5% to 10%.[i] By way of example, one of the biggest wastes of energy is the taxiing stage, with the average aircraft spending 2.5 hours daily on taxiways, burning 600 kilograms of fuel during that time for no real purpose.[ii] As such, there is a lot of research today around how to better manage onboard energy to reduce losses and curtail the size and weight of power systems required.

One of the approaches to achieving fewer energy losses in order to move closer to a more electric aircraft is better priority management for power consumption. In current aircraft designs, each controllable load is fixed based on priority, so when overload is a problem, loads are cut according to priority. In an advanced system, by comparison, priorities are variable depending on their importance at different times within the flight.

This requires greater onboard communication among systems, but results in a more fair distribution of power and increased efficiency. Related to the issue of priority management is the need to address the energy performance of an aircraft is to better coordinate different generators and sources of energy in order to reduce overall power losses.

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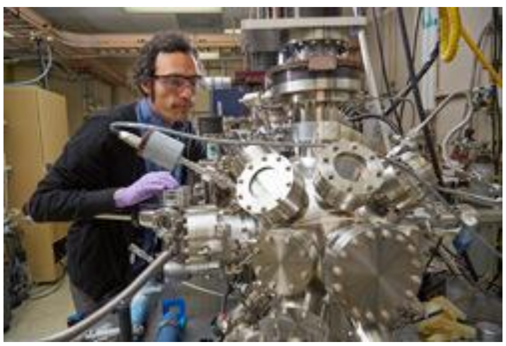
Energy Storage Key to Success of More Electric Aircraft Designs

In many respects, the degree to which a more-electric aircraft design is a success depends on the ability to store energy in things such as batteries or supercaps. Current technologies offer only modest energy storage systems; yet once development, ultra high energy batteries have the power to take the aviation industry to all electric reality it seeks. Not only does energy storage allow for smoother power consumption by various load groups, it allows for lighter-weight generators, converters, and feeders. That said, batteries and supercaps add weight of their own, so it will always be a balancing act to find the optimal battery to weight ratio.



Sandia National Laboratories - Lithium-iron-phosphate battery electrode

One of the most popular batteries in this space is the lithium-ion (Li-ion) battery. There are several advantages to choosing Li-ion batteries compared to conventional flooded nickel-cadmium (NiCd) batteries for aircraft power provisions. Not only are Li-ion batteries twice as dense in terms of battery capacity to weight ratio, they are also lower maintenance. In general, NiCd requires more frequent servicing, including full discharges to remove memory, cleaning corrosion buildup, and adjustment of electrolytes.

Having said all of this, there are still many problems in the use of large capacity batteries for aircraft. Boeing's experience with their new lithium-ion batteries aboard their 787 Dreamliners is the latest example of the kinds of challenges the industry is facing. The batteries – the first Li-ion batteries to be used as the main batteries for an aircraft - were installed to provide energy for additional electrical systems such as electrified hydraulic functions. They were rated to fault only once in 10 million flight hours. However several smoke events and one battery disintegration due to a thermal runaway with fire occurred before the planes had 100,000 flight hours.[iii]

First inspections of the batteries (including the use of CT scans) have suggested that the problem lies with a faulty electrode that caused an electrical short, leading to a thermal runaway with fire. Similar chemistry problems were experienced in 2005 when consumer products such as mobile phones and computers with lithium cobalt oxide ($LiCoO_2$) batteries were recalled due to the one in 200,000 chance of a breakdown.

Though LiCoC2 batteries are less chemically stable than Li-ion, Li-ion batteries face their own problems in larger formats, such as incorrect charging and the need to keep Li-ion batteries cool. They perform best when charged slowly, discharged shallowly and kept cool but not charged below freezing – all conditions that can be hard to maintain on an aircraft that provides flights of various lengths in a variety of climates.

At this point, all of Boeing’s 787 have been grounded worldwide as the company researches why its systems failed to stop the battery damage, though the company remains committed to the Li-ion technology. Since the batteries are necessary only for start-and-backup systems, there is little risk to a catastrophic failure, but having an onboard fire doesn’t inspire confidence and so clearly more work needs to be done before Li-ion becomes mature enough to win back the confidence of the industry and the public.

In fact, much work is being done to improve Li-ion technology. One interesting innovation in battery technology is Sandia National Laboratories’ lithium-iron-phosphate battery electrode, which makes use of LFP, a natural mineral in the olivine family. Cathodes materials like LFP are crucial for creating high capacity batteries, but how these materials work is currently not well understood. Nevertheless, given that LFP is longer lasting and safer than $LiCoO_2$, there is a lot of interest in finding out how it works when applied to Li-ion batteries.

The researchers at Sandia National Laboratories have been observing cross-sections of batteries using X-ray microscopy to better understand discharge and charging rates. What they’ve found is that, “One propagation theory said that when all the particles were exposed to lithium, they would all start discharging slowly together in a concurrent phase transformation,” according to Farid El Gabaly, physicist of Sandia National Laborities. “We’ve now seen that the process is more like popcorn. One particle is completely discharged, then the next, and they go one-by-one like popcorn, absorbing the lithium.”[iv]

This discovery will help the researchers understand how lithium-ion charging works which will hopefully give them insights in how to improve the battery technology.

Organizations such as NASA are also working on battery problems for aircraft, with some research recently conducted on lithium metal anodes combined with advanced cathode materials. Given the chance that these combinations could result in five times more specific energies at the cell level compared to Li-ion batteries, interest in this technology is high. However, lithium metal anodes are plagued by dendrite formation, a poorly-understood process, which results in short circuits. Research therefore continues into this promising technology.[v]

Conclusion

There are so many components that can be improved and systems improved for achieving substantial energy and fuel savings in today’s aircraft. Innovative approaches to handling energy systems and performance within an aircraft are becoming steadily more mature, with the expectation that these electrical systems will make up more and more of aircraft designs in the very near future. And battery technologies are being adjusted to prevent problems like those faced by Boeing while further improving their capacity. It’s only a matter of time before all of these technologies come together to result in a more-electric, or all-electric aircraft. It’s an interesting time in the evolution in how we fly.

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Maryruth can't help but seek out the keys to environmental sustainability - it's the fire that gets her leaping out of bed every day. With green writing interests that range from sustainable business practices to net-zero building designs, environmental health to cleantech, and green lifestyle choices to social entrepreneurism, Maryruth has been exploring and writing about earth-matters and ethics for over a decade. You can learn more about Maryruth's work on JadeCreative.com.

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