Design Challenges of Fully and Hybrid Electric Aircraft

Richard Wilson
RAW Aviation Consulting Ltd
www.RAWAviationConsulting.com
Fully and Hybrid Electric Aircraft

- Currently the Hottest Topic in Aerospace
  - Less emissions during flight
  - Lower operating costs – electrical energy cost < fuel price
  - Numerous architectures, series, parallel, etc
- Focus is often on battery technology, electrical power systems and electrical system architecture
- The overall aircraft design space could also be radically opened up – but there are challenges too
- RAW Aviation Consulting Ltd has developed a Whole Aircraft Capability to model Electric and Hybrid-Electric Aircraft
  - Deployed on customer studies to evaluate system level attributes and sensitivities to design assumptions
Energy Requirements

• Any significant use of electric energy is extremely likely to increase the total energy required to operate a given flight
  • Installed battery specific energy (kWh/kg) is an order of magnitude less than kerosene even with improved energy-thrust conversion efficiency
  • Reduced/no weight burn off through the mission
• Any environmental benefits are conditional on access to plentiful low CO₂ electrical energy generation
  • It must be additional clean electrical capacity on top of any increases for surface transport and general usage
• Low drag or low weight technologies are equally applicable to electric and kerosene powered aircraft
  • Relative benefits on Electric aircraft may be greater lowering barriers to usage

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Variable Benefits – Full Electric

Fixed battery installation assumed

• 2 Prime effects of electrical propulsion
  • Battery energy replaces fuel consumed (positive)
  • Electrical System Mass increases overall energy requirements (negative)

• Greatest benefits achieved with the battery on minimum charge at the end of the mission
  • Respecting Depth of Discharge & reserves
  • Full benefit = full use of additional mass

• Shorter than optimum missions
  • The full battery mass has to carried without delivering it’s full benefit
Peaky Block Fuel Benefits - Hybrid

Fixed battery installation assumed

- 2 Effects of electrical propulsion energy
  - Battery energy replaces some fuel consume (positive)
  - Electrical System Mass increases overall fuel/energy requirements (negative)

- Shorter than optimum missions, battery mass has to carried without providing it’s full benefit
  - Increased Battery C-Rating will reduce this effects but reduce the battery cyclic life/battery capacity

- Longer than ‘Optimum’ mission
  - Once the battery is depleted, the aircraft can continue fight on 100% kerosene, but must still carry the electrical system mass.
Landing

- Approach speed are limiting on almost all aircraft – often balanced with other limits
  - ↑ Approach speed = ↑ Landing Field Length
  - Failure cases and slippery runways add to the issue
- The electrical power system mass increases the landing mass. This will require either:
  - Increased approach speeds (fixed wing area) and hence longer landing runs and bigger brakes
  - Larger wings to retain approach speed – further weight increases, higher energy required
  - More powerful high lift systems, likely to increase weight & complexity and increase approach noise as more energy is imparted to the air
- Full take-off power required for ‘Go-Around’

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In-flight charging in Descent

• In-flight electrical charging sometimes proposed to ‘harvest’ descent energy

• There are few free lunches in flight
  • There is no waste energy unless spoilers used
    • Potential and kinetic energy lost to atmosphere
    • Spoiler are a tactical response to being too high
  • Aerodynamic electrical generation increases drag that causes a steeper descent profile
    • Shorter descent = increased in cruise distance

• More complex systems may get minor benefits
  • Full electric propellers only
  • More thrust for the same energy is best option

Flight Path Gradient = \( \frac{\text{Thrust}}{\text{Weight}} - \frac{\text{Drag}}{\text{Lift}} \)

Descend when \( \frac{T}{W} < \frac{D}{L} \)
Other Issues

Limited time to discuss today

- Clustering of Optimum Cruise altitudes
- Power & Volume Requirements
- Battery Charge vs Replace between flights
- Reduced Engine Sizing
  - Clipping of engine design points
- Operational Requirements
  - Increased empty weights
  - Wind
  - Deterioration – Drag and battery capacity
- Certification
Summary

• Fully/Hybrid Electric Aircraft currently receiving extensive attention with plenty of excellent design work

• There are numerous opportunities and challenges still need to be understood to fully understand the benefits of this exciting technology while achieving certifiable aircraft